Topic No. 5

APPLICATION OF IRON, STEEL AND ALLOY RIVETS, WITH RECOMMENDATIONS AS TO PROPER METHODS OF HEATING AND DRIVING, INCLUDING PREPARATION OF SHEETS, RIVET HOLES AND OTHER INVOLVED PARTS, IRON, STEEL AND ALLOY MATERIALS.

MR. E. H. HEIDEL, Chairman
G. N. WILSON, Vice Chairman
L. C. RUBER C. G. MULLENHOUR W. F. MOORE
O. L. PUGH A. F. STIGLMEIER

With the advent of high pressure boilers much attention has been directed to their design, fabrication and maintenance, as it was quickly apparent that conditions governing successful building and operation of boilers operating at 200 pounds per square inch or less must be changed where boilers are designed for higher pressures and capacities. Not so many years ago 180 or 200 pounds was considered high pressure for a locomotive boiler, whereas today 285, 300, 310 and as high as 350 pounds pressure is being used in boilers with conventional radial stayed firebox construction, the basic design of which has changed but little over boilers of twenty-five years ago. The high capacity of modern locomotives brought about by the use of high steam pressure and high superheat temperature has required the use in many cases of alloy steels, more exact workmanship in laying out and fabrication of the boilers and a better maintenance and operation than was required with older locomotives. Little printed matter is available on these important subjects and it is the desire of the Committee on this topic to present such comments and recommendations as are reflected by practical experience. The Committee desires to recommend to the Association only such methods which we know are attributes to first class workmanship, and we believe the standards set up by the Association should be consistent with the scientific development of boiler design and the demand which is made for keeping the power in operating service continually.

During recent years much study has been given to failures which have developed from the cracking of shell sheets from rivet holes, both in carbon steel and alloy steel sheets, and it is apparent that such fundamentals as design, material, fabrication, water treatment and the washing, firing up and blowing down of boilers must be given consideration in our endeavor to overcome the troubles which have been experienced.

Design

While the design of boilers is not within the province of the boiler maker, the designer can modify and improve the design only through experience gained by the boiler maker in maintaining tight seams and tight boilers, which are essential to successful operation. Care and thought must be given to the location and type of seams, as very often leakage develops on account of riveted seams being improperly placed and designed. The circumferential seams of large high pressure boilers are often a source of trouble particularly near the bottom center line of the boiler as the restricted clearances of modern locomotives makes access to these seams difficult. A number of members of the Association recommend that circumferential seams, particularly between the first and second boiler courses, be triple riveted rather than double riveted on large diameter boilers. Caulking of

these seams both inside and outside is recommended. The importance of tight longitudinal seams has been stressed by Mr. W. C. Schroeder of the Bureau of Mines at the 1939 meeting of the Association. A method of hydrostatically testing longitudinal seams has been outlined to the Committee whereby a hole in the butt strap is drilled and tapped for ¼" pipe after which hydrostatic pressure is applied and the seam made tight before application of the flues to the boiler. The hole for pipe connection is of course, plugged when tests are completed.

Material

A number of members of the Association prefer carbon steel for both shell sheets and rivets to alloy steel, probably on account of troubles experienced with boilers containing alloy steel. Apparently, however, the successful design of large high-pressure boilers demands the use of alloy steel. This subject is receiving a great deal of thought and study by the American Society for Testing Material, the Association of American Railroads and metallurgists generally. Successful use of alloy steel in boiler construction is confidently anticipated by this Committee. While it is not the desire of the Committee to enter a discussion of the relative merits of the various kinds of steels, the following information, abstracted from a letter by Mr. A. L. Roberts of the Development and Research Division of the International Nickel Co. is considered important.

"We wish to advise that the following is our recommended nickel steel for use in locomotive boilers, for rivets:

Carbon %	0.15 max.
Manganese %	0.30 – 0.50
Sulphur %	0.045 max.
Phosphorus %	0.040 max.
Silicon %	0.15 – 0.30
Nickel %	1.90 min.

This steel is recommended for longitudinal seams only, and straight carbon steel is recommended for the girth seams.

The following are the physical properties of this recommended rivet construction:

	Bars up to 1" Diameter	Bars over 1" up to 2"
Tensile strength, psi	65,000#	60,000#
Yield point, psi	45,000#	40,000#
Elongation, % in 2"	28	25
Reduction in area, %	45	40

Heretofore we have recommended SAE 2115 steel, which is a higher carbon, 1½% nickel steel.

The inside edges of the nickel steel plates of girth seams should be caulked the same as the outside edges of the seams.

The hydraulic pressures used on nickel steel rivets should not exceed 100 tons for rivets up to and including 1⅛" diameter, nor 125 tons for rivets up to and including 1$\frac{3}{16}$" diameter.

All hydraulic riveters should be equipped with a recording pressure gauge so that a permanent record may be kept, and it will also provide a check on the men operating the riveter.

In heating the rivets for driving in nickel steel plate, the temperature of the rivets should be limited to 1,500°-1,800° F.

All rivet heaters should be equipped with recording pyrometers which will give a permanent record of the temperatures in case of any trouble."

Fabrication

In fabricating non-pressure vessels the use of sheets sheared or cut by the acetylene torch to size, and rivet holes punched to size are permissible. For pressure vessels, however, sheets should be laid out from blue print or template and rivet holes in shell plates and flanges of heads or flue sheets should be drilled, and reamed to size. Staybolt holes should be drilled ¼" smaller than diameter of the stays required and be reamed and tapped after fitting up. Shell courses after forming should be sandblasted inside and outside, and thoroughly inspected for laminations, pitting and impregnations of mill scale before being assembled. Plates should be sheared or burned ¼" to ⅜" away from shear line and planed back to shear line to take off all hard and burned metal, also planed to form proper bevel. Tool marks along planed edges should be removed by grinding and sharp edges should be removed from holes before rolling. Cylindrical boiler courses should be rolled true to form and all butt straps properly formed with true radii, and be well set up, metal to metal, to the connection sheets before sheets are drawn up tight together. Springing of the sheets, or drawing sheets together other than tightening the connection for riveting should not be permitted.

All connections of boiler courses should be made with connecting sheets parallel for a distance over the width of the lap sufficient to provide a straight surface for the caulking edge of the overlapping course. Sheets should be fitted up as tightly as possible and in proper alignment with each other before any holes are reamed, and when courses lap over or under other courses circumferentially they should be rolled with a ring between the roller and the sheet for a distance equal to the width of the lap in order to provide a true bearing on the adjacent parallel courses. Flanging a tapered course on a bull machine to make it fit adjacent courses should not be permitted.

After rolling and flanging of each shell course has been completed, temporary butt straps or suitable clamps should be applied to the longitudinal seam for the purpose of holding same in position and alignment during the welding at the edge of the sheets.

Assemble shell courses, by heating if necessary, and properly align all courses, making sure that boiler is level both horizontally and vertically, in every respect. Then apply bolts in every other circumferential seam rivet hole. Bolts to be pulled up tight to give metal to metal contact at all points; if not, they should be set up to a metal to metal contact before any reaming and riveting is done.

Weld longitudinal seams at both ends; chip and grind welds flush with surface of plate. Remove temporary butt straps and fit inside and outside butt straps metal to metal with boiler, bolting every other hole. Draw sheets to an actual metal to metal contact and without removing the fitting-up bolts ream and slightly countersink the open holes inside and outside.

Having fitted butt straps and reamed the open holes, ream and slightly countersink all open holes in circumferential seams. Do not remove fitting-up bolts.

Drill rivet holes in dome after flanging and trimming has been completed. Properly fit and bolt dome liner in place. Fit dome to boiler, and with dome in proper position drill shell to dome base rivet holes, using dome as a template. Remove dome and dome liner and eliminate all burrs. Reapply dome liner, and bolt to boiler through every other hole, drawing sheets to a metal

to metal contact, then ream and slightly countersink all open holes, inside and outside. Rivet all open holes through sheet and liner except those in dome base. Reapply dome and bolt to boiler through every other hole, drawing sheets to a metal to metal contact, then ream and countersink all open rivet holes, inside and outside.

Drive all rivets in open holes in longitudinal seams; remove fitting-up bolts, ream and slightly countersink balance of holes, inside and outside, and complete riveting of seams.

Drive four rivets on each quarter of each circumferential seam; then drive rivets in all open holes. Remove fitting-up bolts, ream and slightly countersink the balance of the holes inside and outside and finish riveting of circumferential seams.

Drive all rivets in open holes in dome, remove fitting-up bolts. Ream and slightly countersink balance of rivet holes and complete riveting of dome. Complete riveting of the dome may be done, if desired, before courses are connected.

All butt straps, domes, dome liners, and flanged sheets are to be properly formed, have true radii, and are to be set up metal to metal to the connecting sheets, with the maximum opening at any point not exceeding .005", nor extending over one-half pitch between rivets. All circumferential and longitudinal seam bevels and area around rivet holes between contact surfaces to be cleaned as may be necessary in order to obtain smooth surfaces for a metal to metal contact.

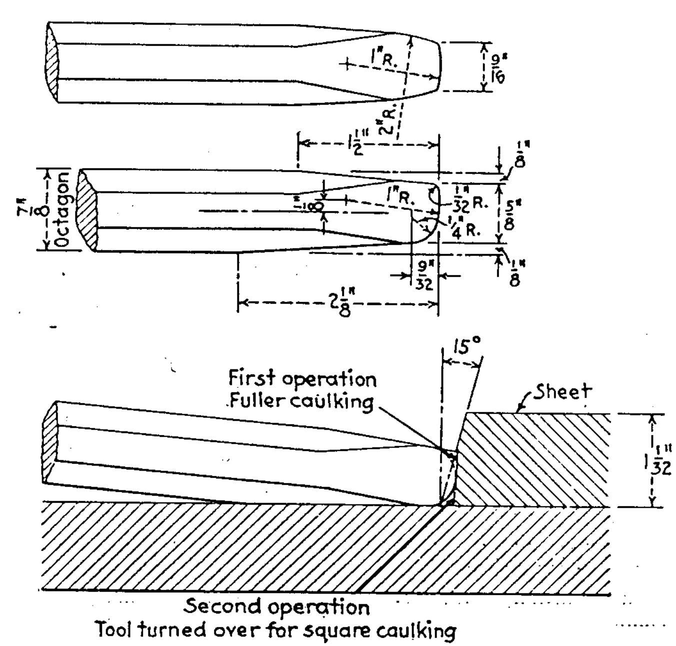


Fig. 1—Caulking Operation.

All boiler course seams and butt straps, inside and outside to be caulked, wherever possible. Caulking tool such as shown on Fig. 1, is recommended. Other caulking tools are shown on Fig. 2. All rivets inside and outside of boiler should be caulked, and the following tools are recommended for rivets:

1. Burring tool to cut off collar
2. Light round nose fuller for caulking.

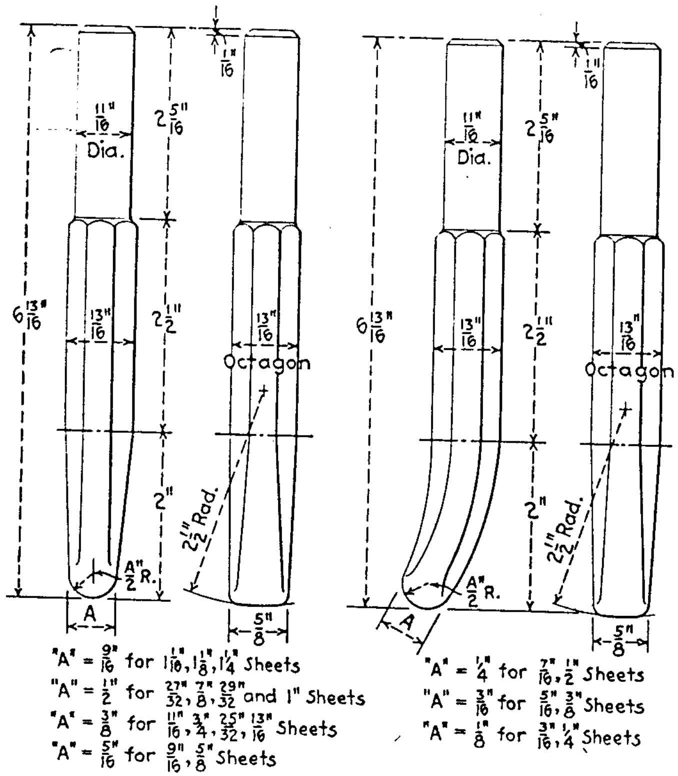


Fig. 2 Caulking Tools.

Rivets and Riveting

The following information, furnished by Mr. C. P. Diemer, Works Manager of the Champion Rivet Co., was considered by the Committee to be of very considerable interest and importance to members of the Association:

"There is little printed matter available on the subject of rivets and riveting, and our comments reflect our experiences on the subject merely as manufacturers.

Rivet making falls into two classes—Hot forming, and Cold forming.

Hot form rivets can be made in all diameters from ½" and upward.

Cold formed rivets are made in all diameters from ⅛" to 1" Standard cold heading equipment has a length limitation of about 4", hence all rivets, regardless of diameter, longer than 4" must be hot formed. However, equipment is available for heading small wires under ¼" diameter into long rivets such as are used in some types of crating, but such rivets or pins are not classed as rivets.

It will be noted from the above that there is a certain range of sizes which can be made either by the hot, or cold process. The determining factor in the choice of process usually lies with the purchaser.

The first rivets used were hot formed in hand dies, and the hot forming machine was an outgrowth of this process. Consequently, many users of rivets adhere to hot formed rivets because of habit. These rivets have inherent deficiencies such as scaled surface, a pinched end due to being hot sheared, fins along the shank due to manufacture in open dies, a wide variation in gauge sizes which is also due to open dies and requires rivet holes 1/16" larger than the rivet.

In large sized rivets which must be produced by the hot process, all of these inherent deficiencies can be corrected by further processing.

Cold formed rivets have the advantage of being formed from bright round wire. They are usually made in solid die machines, and have a smooth surface, a round shank, a square end, and a narrow range of gauge sizes which enable them to be driven into rivet holes 1/32" larger than the rivet. There is a decided trend toward the use of cold made rivets in all sizes up and including ⅞" diameter. This type of rivet is well suited to heating in electric rivet heaters because of its superior workmanship and finish.

Riveting also falls into two classes—hot and cold. Each method of riveting is further divided into hand or gun driving, and bull or power riveting. Hand or gun driving has the advantage of flexibility enabling the operator to drive in close quarters and difficult positions. This method is limited to rivets under 1⅛" diameter although with careful procedure, larger sizes can be handled satisfactorily.

Bull or power riveting has the advantages of—(a) greater power which enables the operator to completely fill the hole; (b) a steady squeezing pressure which upsets the entire mass of metal in the rivet at one time as compared with the repeated light blows of the pneumatic gun; (c) the use of lower driving temperatures which reduce the amount of scale formation; (d) the ability to hold pressure on the rivet until it has cooled below the critical temperature range of the rivet, viz: 1000 deg. F.; (e) reduced physical effort on the part of the operator. The bull riveter, of course, has the limitations of bulkiness and lack of portability and can be used only on straight line riveting within the range of the gap dimension.

Cold riveting ordinarily requires an annealed rivet if it has the conventional Round or Cone head. A special type of flat rivet is now used in large quantities for cold riveting without any annealing. Both cold made and hot made rivets contain internal stresses at the head due to forming, and should be annealed if they are to be cold driven. Cold riveting is done preferably with pneumatic or hydraulic riveters of the squeeze type. This equipment is available in portable designs and often is light and flexible enough to reach difficult spots in the structure. (Hanna Engineering Company, of Chicago, can furnish considerable data on this type of equipment.)

Considerable research has been conducted on cold riveting, and many tests show that such rivets have a greater strength, a closer fit, and a tighter grip than hot driven rivets. This applies, of course, to rivets 1" and under in diameter, because, although rivets have been cold driven successfully in diameters up to and including 1⅝", it is difficult to obtain test plates with these larger sizes.

The advantages of cold riveting are: (a) lower labor cost as no heater is needed; (b) saving of fuel; (c) faster assembly because rivets can be placed in holes by hand instead of with tongs, and also well in advance of the riveter; (d) tighter fit because hole can be reamed smaller without allowance for expansion due to heating; (c) lack of scaling caused by heating.

Design of rivets

Wherever possible all rivets should have fillets under the head. 1/16" R. is satisfactory on sizes from ¾" 1⅜" diameter. Larger fillets are better but plates should be prepared to receive them. On stainless, high manganese, and alloy rivets, it is necessary to use ⅛" R. on all sizes from ½" diameter and upward. This method is seldom used but the experience of those who have tried it gives amazing results.

In cold riveting a thin flat head will give better results than the conventional Round (butt) head. These heads present an unusual appearance which tends t retard their adoption but sufficient experience has already been d eloped to prove the efficiency and economy of their use.

For hot riveting it is recommended that either Cone or Acorn heads be used, and reformed in driving to a Button shape. The shape of these heads permits the flow of metal from the head into the rivet hole, and aids in securing a tight job, and is practically essential on long rivets through four or more thicknesses of plate.

Plates and Rivet Holes

Riveting of pressure vessels requires careful preparation of the plates, and rivet holes. Of course, no holes should be punched. They should be drilled, and after bolting in position should be reamed to 1/32" oversize for rivets up to and including ⅞" diameter; 1/16" oversize for larger rivets unless they have been especially processed. With accurate "True Tolerance" rivets, 1/32" clearance may be used for hot riveting on all sizes up to and including 1¼", and 3/64" for larger sizes.

General

Riveting in general has been conducted in a rough fashion. Precaution as to condition of the holes, the tolerance on the rivets, the heating methods, temperature, shape of rivet heads and sets, riveting power, careful timing, all pay well in the final results obtained. We have seen boilers under 700# hydrostatic tests with no caulking and no leaking. Such a result is due only to meticulous care at every step in the assembly process. We would judge that these extra precautions were worthwhile in the savings made in touching up bad joints, rivets, or replacing poorly driven rivets, and also in the long lived service rendered by the vessel in use afterward."

Rivets may be heated in an electric heater, a gas or an oil furnace. They should be heated slowly, the heat being so applied as to not overheat the outside surface before the center is heated to proper temperature. Do not apply heated rivets in holes more than ten seconds before driving nor apply second rivet in hole before driving first rivet. All rivets after being heated must have scale removed before inserting in rivet holes.

All rivets should be driven with dies that form neat heads with the flash not less than 1/16" in thickness. Avoid die cutting into sheet. In driving riveted seams, to avoid excessive heating of the sheets, alternate the riveting by advancing the riveting in the second row far enough ahead of the first row so as to avoid localizing the heat. This alternate driving of rivets to be followed at all other points where the driving of a number of rivets at one time in a small area is liable to cause excessive heating of the sheet.

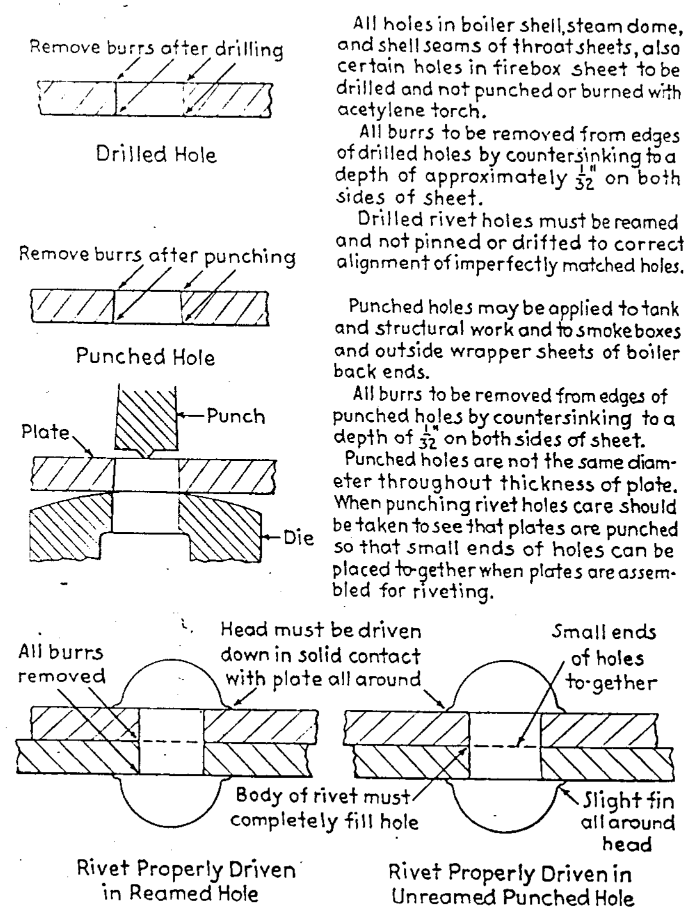


Fig. 3—Riveting Practice.

If driven by a hydraulic riveter, the driving pressures and holding time should be substantially as given in the following table:

Carbon & Nickel Steel Rivets, Diameter	Driving Tonnage on Rivets	Minimum Holding Time
7/8"	60 to 65 Tons	6 Seconds
1"	75 to 80 Tons	8 Seconds
1 1/8"	85 to 90 Tons	10 Seconds
1 1/4"	100 to 105 Tons	12 Seconds
1 5/16"	115 to 125 Tons	12 Seconds

When driving Tee-iron rivets, the tonnage used should be kept as low as possible to prevent spreading of the hole in Tee-iron.

Figures 3 and 4 show recommended practice for punched and drilled rivet holes, and rivet driving.

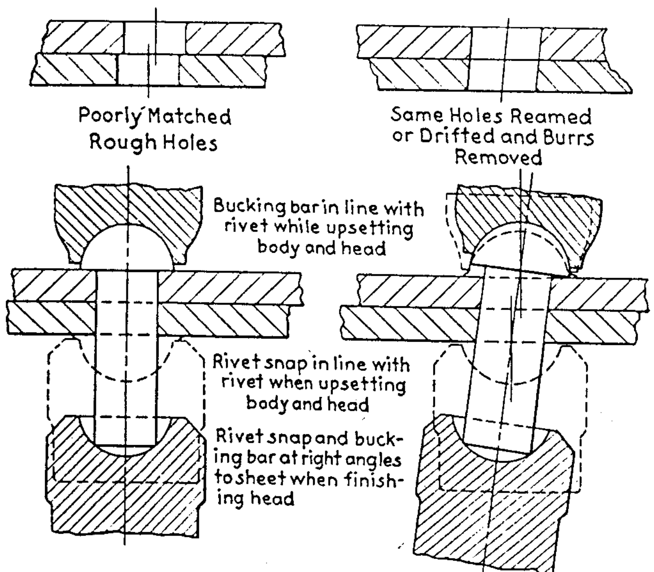


Fig. 4—Riveting Practice.

Tolerances in rivets in general have been allowed in a very rough fashion, and it has become apparent that some consideration must be given to the wide range rivet tolerance in approved A.A.R. tolerance specification, particularly rivets of the 1" to 1 1/4" diameter sizes. These specifications permit variations from basic diameter of .027" undersize to .035" oversize. Recent test conducted with rivet holes in plate 1 3/16" diameter for 1 1/8" basic diameter rivets, but with the rivets machined so that body diameter varied from the basic size to the full extent of this .027" minus to .035" plus range, but accomplished in steps of .005" variations increasing and decreasing from

basic size showed the following: The rivets were driven in their respective holes at a temperature between 1800° and 1900° Fahrenheit and at an actual driving pressure of 91 tons on the rivet. The heads at one end of the rivet were then machined off to study the tightness of rivets in plate. It was found that rivets, with body diameter .014" or more below basic diameter were loose in plates, while rivets driven with body diameters .020" or more above basic diameter caused hole distortion in the plates which was noted in the caulking edge of the seam.

It is recommended that consideration be given to establishing tolerances for 1" to 1 3/8" diameter rivets for locomotive boilers not to exceed .010" minus and .020" plus over basic diameters and that rivets be free of scale.

To further substantiate the importance of closer tolerances for rivets used in locomotive boilers, the following information on Super-True Tolerance Rivets, published by the Champion Rivet Co., is quoted:

"The severe demands on vessels operating at elevated temperatures and pressures have developed a school of design in this type of construction. The joining surfaces of all parts entering these assemblies are machined to close limits. These parts are then pressed together in as tight construction as possible. Rivets used in this work must be equally perfect to insure uniform strength and long life. Super-True Tolerance Rivets have been developed to meet requirements of this class of vessels and are superior to anything of their kind produced up to the present time.

Super-True Tolerance Rivets are accurate and straight within a few thousandths of an inch. Used in reamed holes and driven at a uniform pressure they do not require caulking. The plates will not buckle or creep and in operation boilers will not develop caustic embrittlement in the riveted seams. Since a great deal of expense is involved in producing this type of rivet, extreme care should be used in driving them. A high grade heating forge of a semi-muffle type is

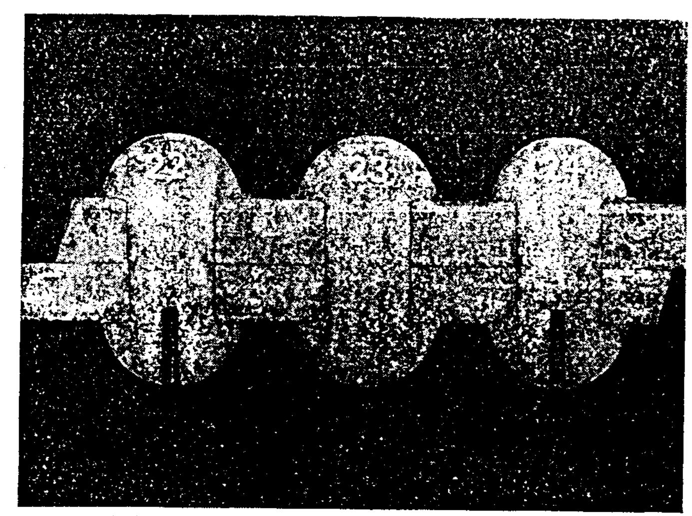


Fig. 5

desirable for this work. An indicating or controlling pyrometer is essential. After heating, scale should be removed by tumbling or with a wire brush, to insure a close metal to metal contact in the hole. These precautions may appear unnecessary, but results warrant their expense many times over in freedom from repairs and in continued long service."

Investigation of results used with regard to tonnage for driving of rivets on hydraulic bull riveter indicates that there is considerable room for improvement, from which we should benefit in our endeavor to overcome cracking of sheets from rivet holes. Today and in the past little attention has been given to the excessive pressures used with the driving of rivets on hydraulic riveters. These pressures are very likely responsible for much of our trouble with cracks out of rivet holes, and such can be noted from a study of the photograph in Figure 5. The rivet marked "22" indicates that the rivet hole has been enlarged toward the caulking edge, and a series of such holes in the same rivet line will cause fractures in service. In the same view, rivets "23" and "24," driven with correct tonnage, show rivet hole in perfect alignment.

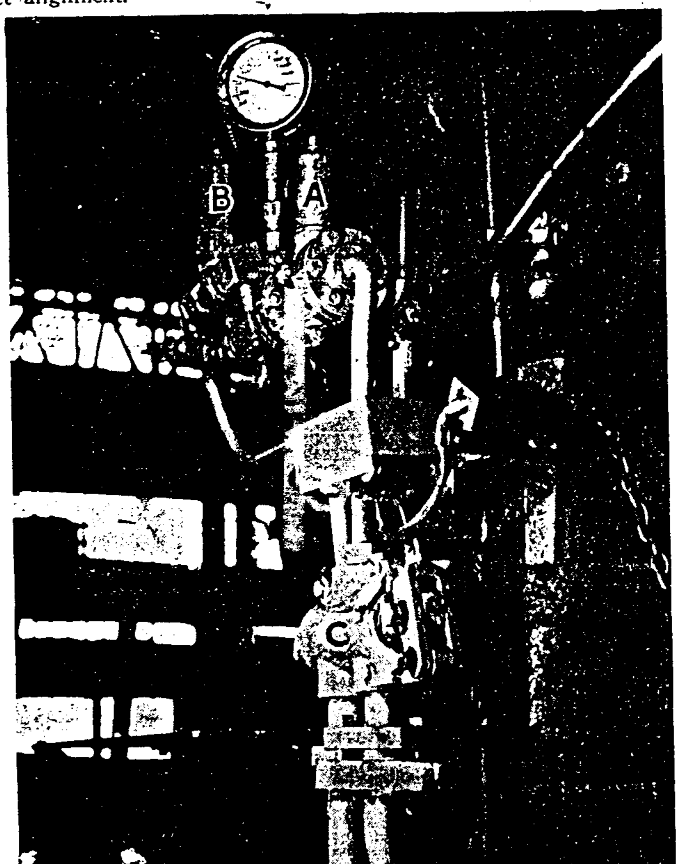


Fig. 6

To better control tonnage on hydraulic riveters to that best suited for the various diameters of rivets, it is recommended that hydraulic bull riveters be equipped with regulating pressure and relief valves, as shown in Figure 6. With such equipment, pressures can be regulated to give any assigned tonnage without requiring any change in accumulator.

Water Treatment

Water treatment has done much to prolong the life of steels used in present boilers. Modern water treatment properly controlled and maintained, by means of testing equipment provided for this purpose, has made it possible to keep the water heating surfaces of our boilers exceptionally clean and free from scale. By keeping these water heating surfaces clean there is nothing to prevent the ready transfer of heat from the fire side of the steel to the water without overheating of the steel which would otherwise occur.

Those of us who have had experience with modern high capacity locomotives know how important it is to keep the firebox heating surfaces of these boilers free from scale. A very thin scale on these surfaces may cause severe cracking and other maintenance difficulties due to overheating of the steel. Firebox temperatures on these new locomotives must be very much higher than we have had to contend with in older locomotives as difficulty is experienced where only light deposits occur on the side sheets of these new engines. The same amount of deposit in older boilers would be ignored and the boilers pronounced "clean."

These experiences have made us more conscious than ever of boiler water treatment and made us realize the value of maintaining the proper boiler water conditions at all times.

With boilers constructed in the best possible manner to prevent concentrated solutions from lodging between the plates at riveted seams, and with the research work being done by interested parties, we can feel confident that improvement will be made in the prevention of caustic embrittlement.

Boiler Maintenance

A locomotive boiler may be constructed in the best possible manner and of the finest material, but if not properly maintained in service may give no better results than a poorly constructed boiler, and be a source of trouble not only from cracks from rivet holes, but boiler troubles in general. This is particularly true today with high pressure and high capacity boilers. It is essential that the closest attention be given to the preparation and issuing of instructions for blowing down, washing, and firing up locomotive boilers so as to reduce as far as possible the stresses due to expansion and contraction during these operations. Attention should also be given to proper lubrication and maintenance of sliding pads or shoes.

Conclusion

It is the opinion of the Committee that due to the importance of this topic particularly as regards the fabrication of alloy steel sheets and the use of alloy rivets, this topic should be continued, and that a Committee be appointed representing the Locomotive Builders and the Railroads with a Mechanical Engineer or Metallurgist to be selected by the Association to act as Chairman, this with the approval of the Mechanical Division, Association of American Railroads. This proposed Committee to report further on this subject at the 1941 meeting of the Association with a view toward recommending a standard practice for the locomotive builders and railroads.

President Harper: Thank you, Mr. Heidel. You and your Committee Members are to be congratulated for your splendid report.

Topic No. 5 is a new and important subject, a subject that the railroads are very much interested in. After hearing the Committee's Report it would seem that we have made a good start in the development of facts on this topic.

You have heard the reading of the Committee's Report, what is your desire?

Mr. H. A. Bell (C. B. & Q. R. R., Lincoln, Nebr.) : I move that the report be received as read and opened for discussion.

. . . The motion was seconded by Mr. Moore, voted upon and carried. . .

President Harper: Before Topic No. 5 is opened for discussion we have a treat in store for you. We have with us this morning one of the leading engineers of this Country who will read a paper, with illustrations, on "The Effects of Service on Carbon and Alloy Steels in Boiler and Firebox and the Aging of Material." I now take pleasure in introducing to you Mr. Ray McBrian.

SERVICE AGING OF FIRE BOX MATERIALS

RAY MCBRIAN

Engineer of Tests, D. & R. G. W. Ry. Co.

Mr. Chairman, Members of the Master Boiler Makers' Association and guests:

We who are interested in the steam locomotive have been challenged to seek improvements, or to face the possibility of seeing it being replaced by other types of motive power. I hope, by this paper, to point out some difficulties encountered and outline possible improvements which may be made in our present type of firebox materials.

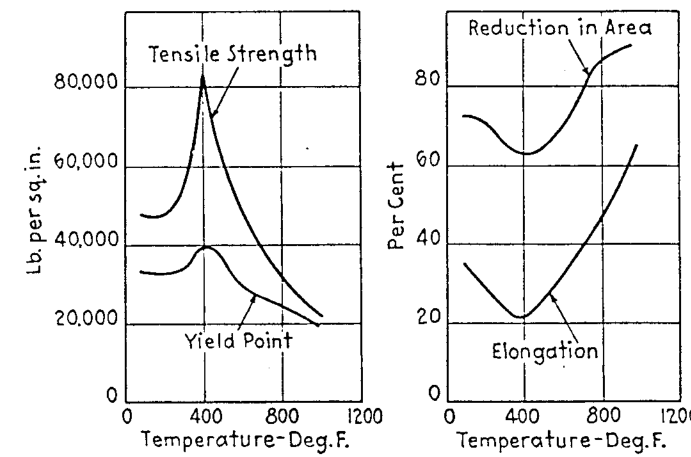
The important factors which have not been fully understood, or readily recognized, as affecting the service life of firebox materials may be classed as follows:

1. Effect of Temperature
2. Surface Strength
3. Aging Properties.

These will be discussed in detail, but may I first suggest a comparison of the effects of service upon firebox materials as to the effects of time upon ourselves. Similarly, as we age with the passing years and develop such weaknesses as stiffening of the joints, hardening of the arteries, etc., so do our firebox materials react to the effects of service environment. A good many of you men who are beginning to work with higher boiler pressures are possibly having troubles which you did not experience before and are aware that these problems do arise from service.

Since you are all so familiar with constructional and design problems, and I so little, this paper will be confined to a discussion of the problems relating to the materials used in the firebox which is subjected to the severest operating conditions. We will first discuss the effect of temperature.

All of us recall that our specifications for firebox, boiler, and staybolt materials are based upon the properties of the material, determined by a room temperature test. We also know that the severest service imposed on these materials occur at elevated temperatures. Many of you realize, I am sure, that the properties of these materials at room temperature differ greatly from those properties we determined on room temperature tests, and that we should have based our specifications upon actual operating temperatures. To demonstrate, let us now consider Slide No. 1, which shows the physical



CHEMICAL COMPOSITION

Carbon per cent	0.11
Manganese, per cent	0.41
Phosphorus, per cent	0.010
Sulphur, per cent	0.028
Silica, per cent	0.008

Fig. 1—Change of physical properties of a typical rimmed steel with an increase in temperature.

properties of plain carbon AAR rimmed steel. It will be noted that the physical properties change with an increase in temperature. At 400°F., for instance, the tensile or ultimate strength is almost double the room temperature value, and, at 1,000°F., it is practically half the room temperature value. Similarly, there are changes in the value for the yield point, elongation, and reduction of area.

Let us examine, for a moment, the temperature range 300°-600°F. These temperatures are commonly associated with the "blue brittle" range. This brittling phenomenon is also observed in the case of firebox steel, which, at 400°F., has a marked elevation of tensile strength and yield point, coincident with a lowering of the elongation and reduction of area. Compared with the room temperature values, these properties at 400° F. indicate brittleness. Because of its importance, I call attention to the peaks shown on this dia-

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Mr. Chairman, Members of the Master Boiler Makers' Association and guests:

We who are interested in the steam locomotive have been challenged to seek improvements, or to face the possibility of seeing it being replaced by other types of motive power. I hope, by this paper, to point out some difficulties encountered and outline possible improvements which may be made in our present type of firebox materials.

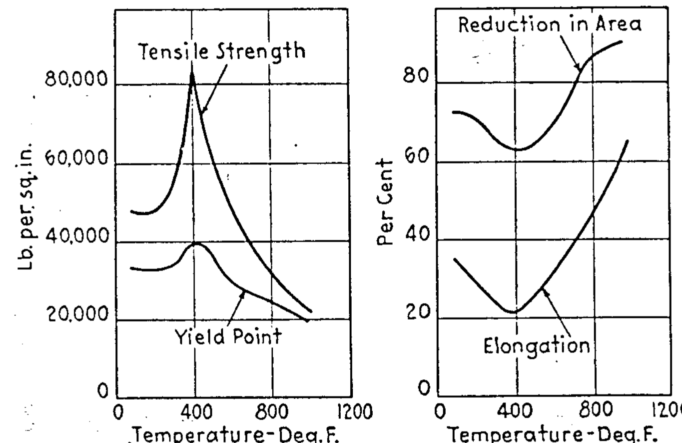
The important factors which have not been fully understood, or readily recognized, as affecting the service life of firebox materials may be classed as follows:

1. Effect of Temperature
2. Surface Strength
3. Aging Properties.

These will be discussed in detail, but may I first suggest a comparison of the effects of service upon firebox materials as to the effects of time upon ourselves. Similarly, as we age with the passing years and develop such weaknesses as stiffening of the joints, hardening of the arteries, etc., so do our firebox materials react to the effects of service environment. A good many of you men who are beginning to work with higher boiler pressures are possibly having troubles which you did not experience before and are aware that these problems do arise from service.

Since you are all so familiar with constructional and design problems, and I so little, this paper will be confined to a discussion of the problems relating to the materials used in the firebox which is subjected to the severest operating conditions. We will first discuss the effect of temperature.

All of us recall that our specifications for firebox, boiler, and staybolt materials are based upon the properties of the material, determined by a room temperature test. We also know that the severest service imposed on these materials occur at elevated temperatures. Many of you realize, I am sure, that the properties of these materials at room temperature differ greatly from those properties we determined on room temperature tests, and that we should have based our specifications upon actual operating temperatures. To demonstrate, let us now consider Slide No. 1, which shows the physical



CHEMICAL COMPOSITION

Carbon per cent	0.11
Manganese, per cent	0.41
Phosphorus, per cent	0.010
Sulphur, per cent	0.028
Silica, per cent	0.008

Fig. 1—Change of physical properties of a typical rimmed steel with an increase in temperature.

properties of plain carbon AAR rimmed steel. It will be noted that the physical properties change with an increase in temperature. At 400°F., for instance, the tensile or ultimate strength is almost double the room temperature value, and, at 1,000°F., it is practically half the room temperature value. Similarly, there are changes in the value for the yield point, elongation, and reduction of area.

Let us examine, for a moment, the temperature range 300°-600°F. These temperatures are commonly associated with the "blue brittle" range. This brittling phenomenon is also observed in the case of firebox steel, which, at 400°F., has a marked elevation of tensile strength and yield point, coincident with a lowering of the elongation and reduction of area. Compared with the room temperature values, these properties at 400° F. indicate brittleness. Because of its importance, I call attention to the peaks shown on this diagram; these peaks which show a sharp rise in tensile strength do not necessarily mean that because the tensile strength is higher the steel is better, but, on the contrary, they indicate a very pronounced aging tendency.

This discussion may seem somewhat technical, but let us examine its effect from the practical standpoint. In other words, let us translate this diagram into practical terms. The next slide (Slide 2) shows a piece of

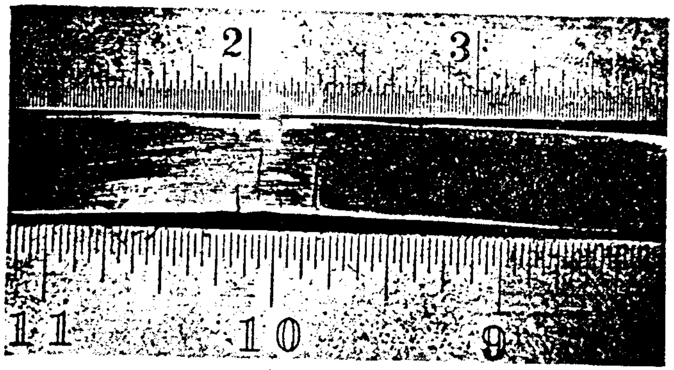


Fig. 2—This piece of firebox steel met room temperature specifications when applied. In service it has been deformed permanently.

firebox steel which passed the room temperature specifications, yet in service we see that the plate has been permanently deformed. This deformation can occur in only one way. The elastic limit must have been exceeded; not the elastic limit at room temperature, but the elastic limit the steel possessed when it was deformed. Recalling the previous slide, at 1,000°F. for example, the stress necessary to produce such a deformation may be only half the value necessary at room temperature.

The question naturally arises as to the effect of some insulating medium such as scale in raising the temperature, but I would like to stress the need of recognizing the actual operating temperatures, as we have had the opportunity to examine permanent deformations or corrugations which occurred very soon after the locomotive was built and put into service. Examination of these corrugated sheets failed to reveal any cause for deformation other than stress-temperature conditions prevaling in service. Elevated temperature tests also revealed that the material had too low an elastic limit at the operating temperature.

Many times the question has arisen as to whether or not a given piece of firebox steel has been burned. The next slide (Slide 3) may be of interest to you in that it shows how this condition may be detected and recognized. The lower micrograph shows the structure of normal low carbon steel (AAR firebox grade) while the upper one shows the tremendous grain growth and incipient fusion at the grain boundaries associated with burning of the same type of material, as shown in the upper micrograph. Under temperature effects, we have observed the effect of temperatures as high as 1,000°F. in the head of an iron staybolt. To illustrate, the next slide (Slide 4) shows the typical wrought iron structure of an iron staybolt. Then, the next slide (Slide 5) shows the microstructure of an iron staybolt that had

been in service for some years. The coarse grains of this structure were reproduced by recrystallization after cold work. Since the lowest temperature of recrystallization is around 1,000° F., we know that the head of this staybolt had been subjected to this temperature; otherwise, the iron would not have recrystallized. This is of importance because it shows that some of our materials of construction have high surface temperatures. These temperatures vary throughout the material and result in temperature stress gradients.

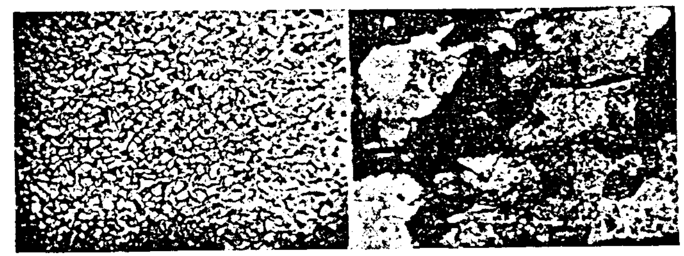


Fig. 3—Left: Normal structure of A. A. R. firebox-grade steel. Right: Grain growth and incipient fusion at grain boundaries of burned firebox steel. (Magnification: Left, 100; Right, 250.)

Fig. 4—Typical structure of a wrought iron staybolt. (Magnification of Micrograph, 250.)

Fig. 5—Microstructure of an iron staybolt after some years of service. (Magnification, 1,000.)

Since we have mentioned iron staybolts, the question probably arises, do the changes in physical properties at elevated temperatures apply to iron as well as to low carbon steel. The next slide (Slide 6) shows the effect of temperature on the physical properties of double refined staybolt iron.

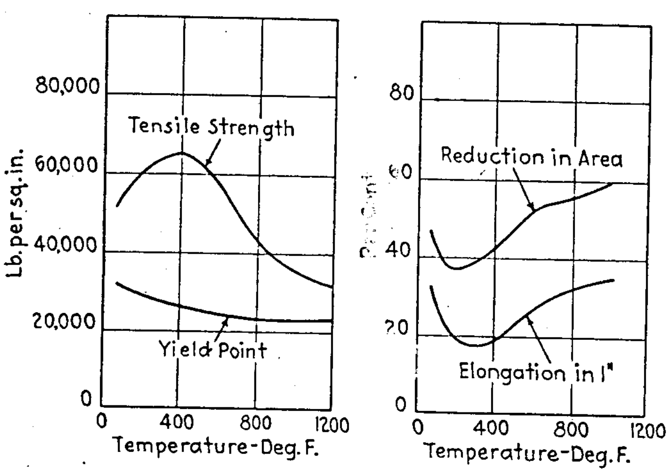


Fig. 6—Effect of temperature on the physical properties of double refined staybolt iron.

It is of importance to note the changes in the physical properties at 400°F., where there is an increase in tensile strength and a decrease in ductility. Also note the low tensile properties at 1,000°F. We have made tests on a large number of the standard staybolt irons and have one instance on record where, at 1,000°F., the staybolt had practically no tensile strength. The effect of the use of such materials, with their very low physical properties at operating temperatures, is the occurrence of such service failures as pulled bolts and possibly leaks.

Thus far, we have considered the effects of temperature on our materials. Let us now consider the second factor—surface strength. And I am reminded now of an old axiom, a chain is as strong as its weakest link. The center of a steel plate is the link which connects the two surfaces, and, if the surface of the plate were as strong as the center, we would have a strong chain from edge to edge. But, unfortunately for us, this is not the case. All constructional steels fabricated in the hot rolled condition have decar-

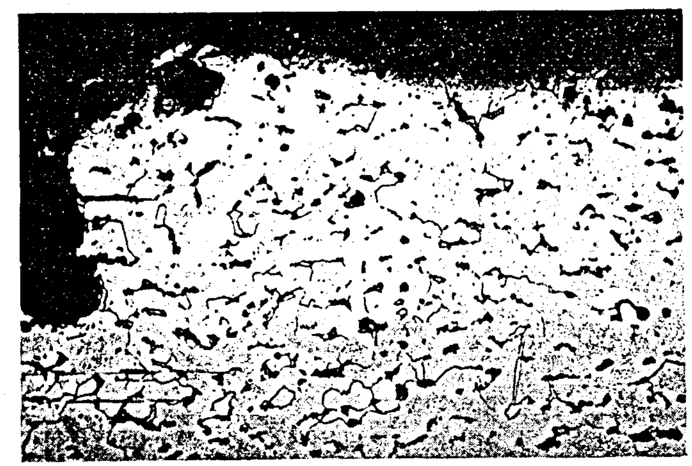


Fig. 7—Photomicrograph at the surface of a section of A. A. R. firebox steel. A deplation of the carbon at the surface is indicated by the decrease in the dark areas at the top. (Magnification, 100.)

burized surfaces. This decarburized surface, as you may know, is produced by the oxidation and diffusion of carbon out of the steel at its surface and may vary from a few thousand to somewhat over one-hundredth of an inch. Obviously, the strength of the plate is less at the surface than at the center. Yet we have failed to recognize and take into consideration this condition. The next slide (Slide 7) is a photomicrograph at the surface of a section of standard AAR firebox steel, showing a depletion of carbon at the surface, as shown by the decrease in the number of the dark areas which contain the carbon, and an increase in the light, or ferritic, areas. Although the average physical properties of the cross section may be within the specification requirements, as measured by the tensile test, it is to be noted that the decarburized layer at the surface may have only one-half the strength of the interior. Remember, also, that the physical properties for both the interior and surface change with temperature, and it is at the surface where highest temperature is obtained that maximum stresses can

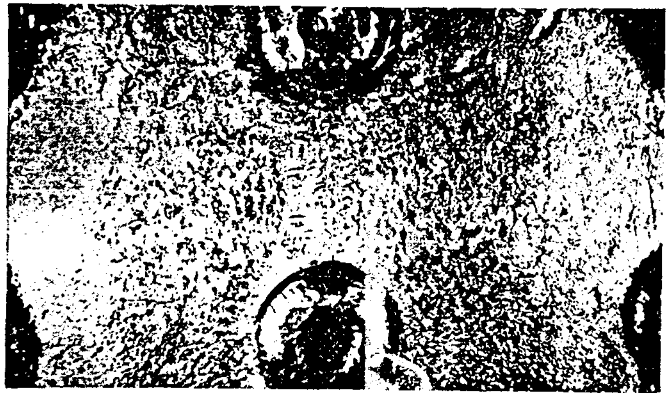


Fig. 8—Fire-side surface of a piece of firebox plate that developed fatigue cracks because of insufficient surface strength.

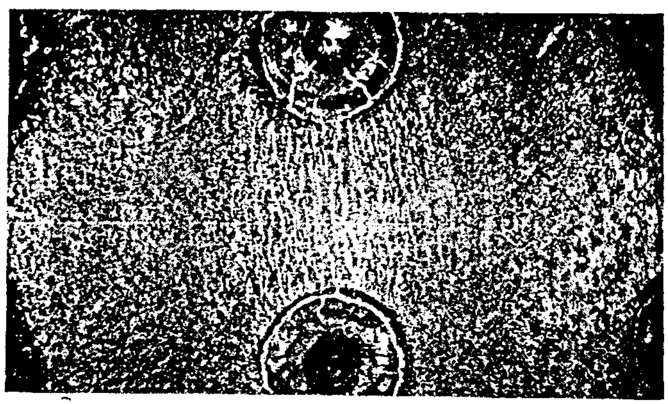


Fig. 9—The same surface shown in Fig. 8 after having been Magnafluxed. This plate failed only eight months in service.

occur. It is also at the surface, where fatigue cracks originate, and, as an example of what may occur in service, the next three slides will show surface fatigue cracks which occurred because of insufficient surface strength. This material, as purchased, met the AAR specifications, yet failed after only 8 (eight) months of service. Slide 8 shows the fire-side surface of the plate, as received for examination. The second slide (Slide 9) shows this same surface, after having been Magnafluxed. You will note the outline by

the Magnaflux powder of the fatigue cracks. Slide 10 shows this same surface after a portion of it had been ground. It is noted that, even after grinding, the cracks prevail, showing that they had progressed to considerable depth.

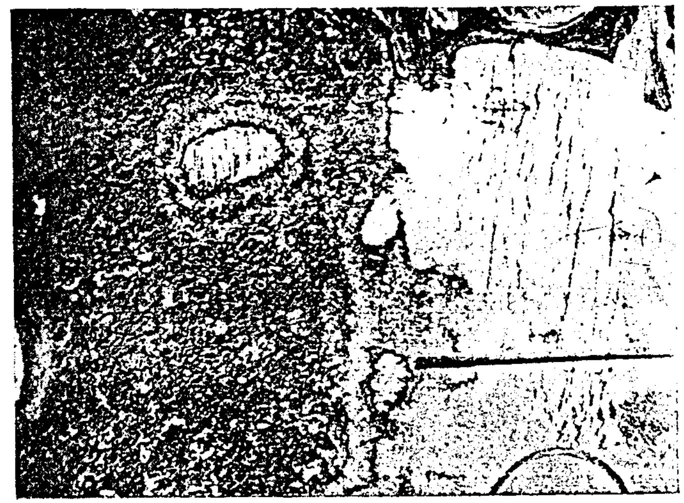


Fig. 10—The surface shown in Figs. 8 and 9 after a portion of it had been ground showing the cracks had progressed to a considerable depth.

Steel staybolts are subject to surface weakness, due to surface decarburization, which may be the cause of failure, as shown in the next two slides. First (Slide 11), is a photomicrograph, showing decarburization at the surface, with a small crack. The second (Slide 12), shows a section of the failed bolt. It is important to call attention to the fact that steel staybolts may be subjected to aging.

This last factor to be discussed, and one which we believe to be the most important, is aging. Aging, in brief, is a spontaneous change of physical properties with the passage of time. This change is accelerated by the application of stress and an increase in temperature, and manifests itself in boiler and firebox steels by a raising of the yield and ultimate strength, accompanied by a corresponding loss in ductility. In the case of firebox and boiler steel, this aging is accelerated by cyclic stresses.

A stress cycle occurs each time the locomotive is fired up. Washing, and repeated heatings and coolings occasioned by feed water intermittently passing over the hot metal, introduces stresses, as does the opening and closing of the throttle while the engine is working. The next slide (Slide 13) shows the effect of boiler washing on the aging of firebox steel, which is shown by an increase in the yield point. It will be noted that the least aging occurred on sheets which had been operating on a 30 day washout schedule.

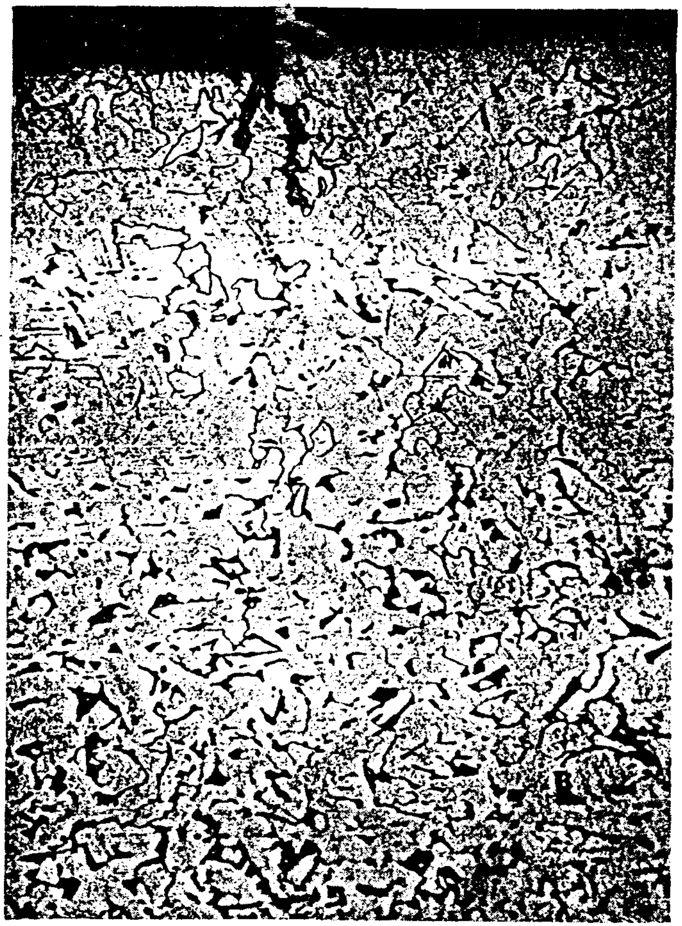


Fig. 11—Photomicrograph showing surface decarburization and a small crack in the surface of a steel staybolt that failed. (Magnification, 100.)

Fig. 12—A section of the steel staybolt, the surface of which is shown in Fig. 11.

GROUPING PHYSICAL CHARACTERISTIC'S FIREBOX SHEETS AFTER SERVICE USAGE

Kind of material	*Years Service*	*Yield Point*	*Ultimate Strength*
BOILER WASHOUTS 30 DAY AVERAGE			
Side Sheet	15	34,100	61,700
Side Sheet	7	35,100	61,900
Crown Sheet	20	44,100	59,620
Back Head	17	42,970	66,800
Door Sheet	16	38,920	55,620
Crown Sheet	16	48,870	64,120
Side Sheet	16	43,280	59,200
Side Sheet	16	43,400	60,980
BOILER WASHOUTS 15 to 20 DAY AVERAGE			
Door Sheet	6	41,300	60,250
Side Sheet	7	35,100	61,900
Side Sheet	12	46,600	61,000
Crown Sheet	21	41,200	55,750
Side Sheet	19	48,400	65,200
Side Sheet	16	45,450	66,900
BOILER WASHOUTS 2 to 5 DAY AVERAGE			
Door Sheet	11	51,400	57,620
Side Sheet	10	47,100	61,000
Crown Sheet	9	48,200	58,840
Crown Sheet	9	55,900	68,340
Side Sheet	10	51,390	57,180
Side Sheet	10	51,250	60,000

Fig. 13—Effect of boiler washing on the aging of firebox steel.

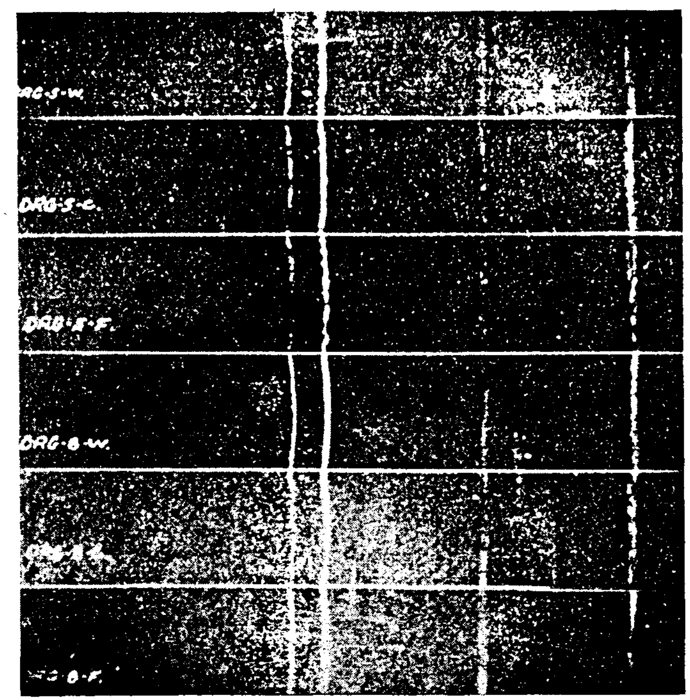


Fig. 14—Diffraction patterns made on the fire-side surface, center and water-side surface of a piece of firebox steel. The top three patterns are of a specimen that has not been aged, the bottom three are of one severely aged.

The effect of aging has also been investigated by the application of X-Ray diffraction. In this method, the amount of strain is determined from the atomic displacement in the lattice. An example of this method of checking aging is shown in the next slide (Slide 14), which shows the diffraction of a piece of firebox steel, which has not been aged. The diffraction patterns were made on the surface of the fire-side, the center of the material, and the surface of the water side. This material, when removed from service, had a yield point of 35,000 pounds per square inch. The three bottom photographs are patterns of a severely aged specimen, whose physical properties were 49,360 pounds per square inch yield point, and ultimate strength 59,150 pounds per square inch. Without going into details, I have shown this as a new method of analysis. It also will be noted that the material is not strained or aged uniformly from surface to center.

The next slide (Slide 15) gives the results of physical tests of some firebox plate, removed from the service of an eastern locomotive. This was rimmed steel, and you will recall from the first slide shown that rimmed steel had elevated temperature characteristics of very pronounced peaks in the blue brittle range. The peaks indicate that this type of material would age, and, from this service test, it can be seen that aging had been severe.

PHYSICAL TESTS—FIREBOX PLATE

	As rolled	*As removed from service*
Yield Point	36,000 psi	60,200 psi
Ultimate	57,400 psi	66,200 psi
Elongation	33.0%	25.0%
Reduction of area	61.0%	56.5%

Fig. 15—Physical tests—firebox steel.

The next slide (Slide 16) will be of interest in that it shows a specimen cut from a crown sheet which had aged in service. It will be seen that the specimen exhibits a double necking phenomenon. These necks occurred adjacent to staybolts. In connection with the aging problem, there are, of course, other influences which should be briefly mentioned. One is the effect of the design which permits stresses to be localized, and another is the effect of the placing of low carbon and high carbon sheets in the same box. By low and high carbon, I mean carbon in the lower range and higher range of our present specification. An actual example is one where we found that, where a 20 carbon material was used in the crown sheet, and a 14

carbon in the side sheet, the crown sheet aged in service. This, of course, suggests a question for consideration, and that is, "Do we permit too wide a carbon range in our specifications?"

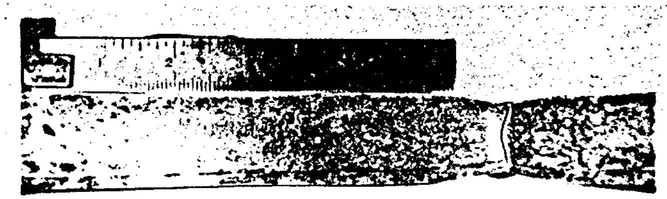


Fig. 16—This specimen cut from a crown sheet, aged in service, exhibits a double-necking phenomenon.

We have discussed three important factors which affect the service life of our firebox material; now let us consider the possible approaches toward a solution of the problem. Of course, the obvious solution would be to provide a non-aging, uniform material, whose strength under all operating conditions would be greater than the maximum stress that would be imposed upon it. This is rather a simplified expression, but probably the reason such a material has not yet been provided is because of the failure to recognize the full importance of these factors which have been under discussion.

Considering, now, the elevated temperature effect, it will be necessary to select a material which has not only sufficient strength at elevated temperature, but also one whose physical properties are as uniform as possible over the range of temperature ocurring in service. Some satisfactory indications have been obtained from research studies by using alloy steels, and from the making of an alloy wrought iron.

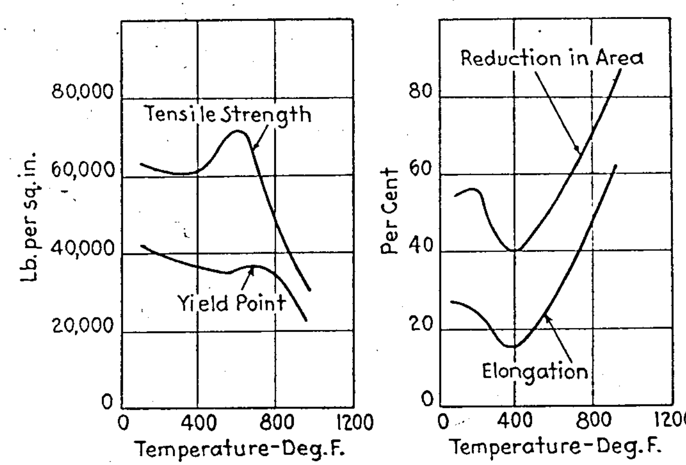


Fig. 17—Physical properties of standard firebox steel.

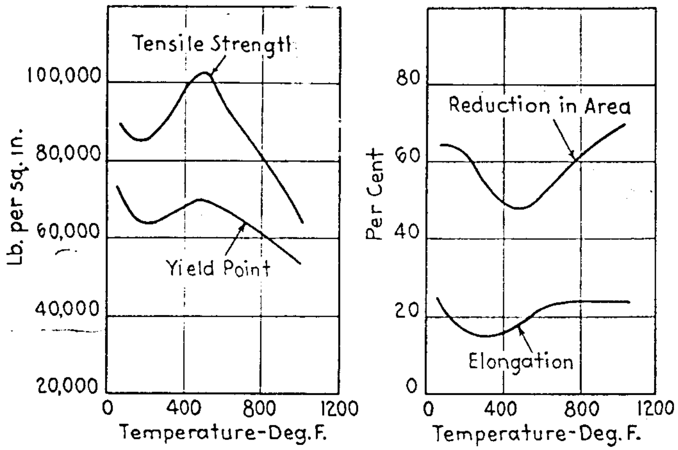


Fig. 18—Physical properties of a carbon-molybdenum steel.

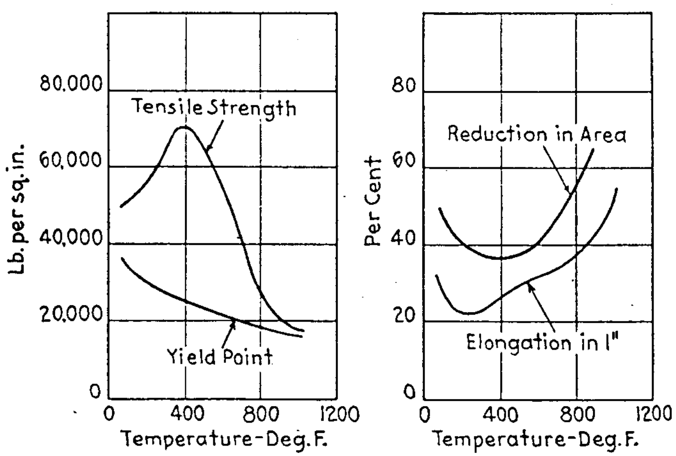


Fig. 19—Physical properties of staybolt iron to which molybdenum has been added. Compare with physical properties shown in Fig. 6.

Considering, now, the elevated temperature effect, it will be necessary to select a material which not only has sufficient strength at elevated temperatures, but also one whose physical properties are as uniform as possible over the range of temperature occurring in service. For example, a comparison of the next two slides (Slide 17) will show the effect of the addition of molybdenum. This slide gives the physical property of standard firebox quality steel. The next slide (Slide 18), however, gives the properties of a carbon-molybdenum analysis. The molybdenum addition has increased the yield strength, as well as the ultimate strength, very materially, and at the same time the ductility is greater for the molybdenum steel. This is one example of the benefits that may be obtained by the addition of alloying elements.

Molybdenum has also been added to staybolt iron to make an alloy, and the next slide (Slide 19) gives the physical properties of this material at elevated temperatures. Comparing this with the properties of the standard staybolt iron which was shown in a previous slide (Slide 6), it will be noted that the properties at elevated temperatures have been improved. Of special importance is the maintaining of higher yield strengths at the higher temperatures in this alloy iron.

Our designers and writers of specifications should take into consideration the physical properties at elevated temperatures of the materials to be used. Probably alloy steels and alloy irons will be a necessary requirement. The use of an alloying element such as molybdenum in both iron and steel will thus aid in preventing deformations occurring from lack of physical strength under operating conditions. It will aid in preventing leaks at the higher pressures and temperatures, by allowing a material to be used which has greater yield strengths and which is capable of maintaining loads at larger elastic strains.

Considering now the factor of surface strength, it has been shown that the rolled surface may be seriously weakened by the presence of a decarburized layer. Present manufacturing methods, however, seem to offer little promise for the elimination of this decarburization, but, until we are able to purchase decarb-free steel, we must look for some other means to eliminate surface weakness. If it is not practical to remove it, what can be done to strengthen it? Again we find the use of alloys suggested, and molybdenum again is beneficial. This element enters into a solution with the iron or ferritic surface, and gives it added strength, and, although the carbon may be depleted from the surface of a molybdenum steel plate, the molybdenum remains in the ferrite, and the surface retains a greater strength than the steel plate which has not used this material. Surface strength then may be improved by the selection of an alloy which enters into solution with and strengthens the decarburized layer, remembering, of course, that the alloying material used must be capable of giving the surface increased strength at elevated and operating temperatures.

The study of the third factor, aging, has not, as yet, been as fruitful as the first two factors. As you can see, this is a very complex problem, and its cause even now is not well understood. Its effects are easily measured and observed. We are now attempting to develop a means of measuring the capacity of a steel to age, and I may say that to date the results are very promising. When we are able to accurately evaluate steels according to their aging properties, we may more certainly determine the cause for this unusual phenomenon. Present knowledge seems to indicate that steels showing a marked susceptibility to peaks in the blue brittle range, as shown in the slides, are more susceptible to aging than those which are less affected in the blue brittle range. We believe a satisfactory steel will be developed which will resist aging tendencies, as our research shows promise for such a material.

I hope that this paper has brought out some of the factors which influence the service life of firebox materials. There has been no discussion of the factors affecting the stresses. These stress factors are numerous; they are important, and no study of the problem should overlook them, but it was not the intent of this paper to discuss them.

Summarizing, we have seen that our firebox material problem is a complicated one. It has an inherent weakness, due to surface decarburization. It has aging tendencies, and is affected by its service conditions. Because of variations in temperature, a material should be selected with the proper physical properties at operating temperatures, and the specifications should be so written. Consideration should be given to the placing of sheets with the same analysis in service. Lastly, continued research will aid in securing better materials, and this will result in economies by improving service life. The data collected and presented in this paper has been the result of a cooperative research program between the National Aluminate Corp. and the Denver and Rio Grande Western R. R.

Thank you.

President Harper: Mr. McBrian, I thank you for your splendid paper, with illustrations.

In behalf of the Master Boiler Makers' Association, will Mr. Leonard C. Ruber please respond to Mr. McBrian's paper?

Mr. Leonard C. Ruber (Baldwin Locomotive Works, Darby, Penna.): Mr. McBrian, Mr. Chairman, members of the Master Boiler Makers' Association: Mr. McBrian, I want to express to you, on behalf of the members of this Association, their appreciation for the time, the thought and the study which you must have given to this paper in order that you might be able to present it to this Association. I feel sure when this paper and its illustrations become a part of the proceedings it will be given great study by not only the members of this Association but also by the Mechanical Officers of the various railroads for it is certainly a very important subject.

Mr. McBrian, I want to again thank you on behalf of this Association for your paper.

President Harper: We will now open the discussion on Topic No. 5, and I hope the discussion will be continued into the afternoon session.

Mr. Heidel, will you please open the discussion?

DISCUSSION

Mr. Heidel: Mr. Chairman, Master Boiler Makers. This meeting is wide open for the discussion of Topic No. 5, not only for the boiler makers, but also for the mechanical engineers and the metallurgists. Many of you have large boilers of high capacity and high pressure. Maybe you don't have any trouble. If so, we would like to have you tell us why. Some of us have boilers with which we are having trouble, and we would like to know what your trouble is, and what you are doing to overcome it.

We have attempted in this topic to scratch your back, maybe the wrong way. We hope it brings out discussion. We know that when we have a good discussion we will all go back with a clearer idea of some of the things which are confronting us today in boiler making.

President Harper: Gentlemen, the discussion is open.

Secretary Stiglmeier: Mr. President, this Topic No. 5 in my opinion is the salvation of the steam locomotive boiler. No doubt you have all heard from time to time of the troubles that many are having. I wonder how many men here have given this study.

We are going into high pressure and alloy steel boilers and there is only one way that the steam locomotive boiler of today can compete with something that is stepping forward very rapidly—that is the Diesel Locomotive—and unless each and every member here gives this a very thorough study I am afraid it will not be long until we will have all Diesel Locomotives and no more steam locomotive boilers.

This topic is of importance to everyone: not only to Master Boiler Makers, but to the water treating people, the steel people, the rivet people —everybody.

You will hear from time to time different gentlemen speaking—such noted authorities as Dr. Schroeder who addressed you at your last meeting. Since that time he has addressed the Mechanical Division of the A. A. R. and at every one of these meetings he brings out something on that so-called caustic embrittlement.

I have been quite fortunate since December 25, 1939 to serve on a committee covering research work on fabrication of boilers. Gentlemen, I tell you there is a vast improvement in the fabrication of locomotive boilers and unless you enter this discussion we are not going to get much from this committee report.

You have heard about tolerances on rivets. Who would be more surprised than you gentlemen to know that the A. A. R. have a tolerance of 35,000 plus; 27,000 minus. I tell you gentlemen if you ever see a test conducted with rivets of those tolerances it will really surprise you.

In your meeting today it was read to you that there was a test conducted. Yes, that test was conducted by one of our locomotive works in conjunction with our committee. We had taken these rivets, as your report states, and brought them down to step sizes—from basic down to 27,000 in 5,000 steps. We also had taken them in 5,000 step sizes up to 35,000.

Of course, all of these holes that were drilled in these sheets were all calibrated to get perfect size: 1³⁄₁₆". We took these rivets and when over 20,000 plus I tell you gentlemen you had a condition that no wonder the holes in boilers had been cracking. When you got below 12,000, after these heads were machined off you could take the peon of a hammer and just touch them and the rivets would fall out of the holes. For full report see your committee report.

If we are going to get boilers of that kind, no wonder we have trouble; no wonder the railroads are buying Diesel Locomotives; no wonder there is a possibility that it won't be long until we won't be building locomotive boilers.

Another subject that came up was nickel steel. Up to five months ago we were told that nickel steel could not be manufactured unless it was in a pitted condition. Today you can get nickel steel that hasn't got a pit. Why? Simply because somebody had nerve enough to tell the steel manufacturer that his steel was not good enough; that he had to make it without pit.

That is what you are here for today: to tell your troubles. If you will tell your troubles, we will be glad to answer any one as far as our ability is concerned. As I stated a short while ago, we have done lots of research work. Up to date we will say, nine months ago if you would have told anybody that they could fit up shell courses that would be within 5,000 before there were any bolts in the sheet, any reaming done, they would have told you that you were crazy. Not today any more. You can step into any locomotive shop in the United States or Canada and they are building boilers that are less than 5,000 tolerances in the fit of the shell sheets. The locomotive boiler builders have cooperated in every way.

It wasn't so long ago that when you went into a place and asked anybody what the tonnage was on hydraulic riveters, they would say, "I don't know." Today you have information that will give you tonnage that in places where you drove rivets at 145-ton you are only using 95-ton, and so on.

This afternoon I am going to read to you a report that I don't have with me now, but I am going to give you some information that one railroad has prepared; this will astonish you, and they are not afraid to give the facts.

So gentlemen, if you have anything at all to contribute to this topic let's hear from you so that we can discuss it thoroughly this afternoon, because I tell you it means the life of a locomotive boiler. If we can get boilers that are going to stay when they leave the locomotive builder and not fall apart so that a year or a year and a half after you've got to renew the shell sheets—which has been done, no question about it—you will hold your steam locomotive boilers, but if you get boilers where the railroad must renew the shells after one or two years. I am afraid the locomotive boiler's life is short.

You wonder perhaps why the Committee recommended that this topic be discussed further. Today there is research work going on in getting carbon content on rivets. Perhaps we have had rivets, I am taking .25 carbon contents. I believe by the time the research work is completed you will have rivets with about .09 carbon contents. You haven't given this much study, you haven't given the rivet much study. You thought it had to be in sheer all the while, but today we've got to get rivets that stand tension.

You gentlemen all must remember that some years ago Mr. FitzSimmons made quite an extensive test on the working of shell sheets. You all know that it is just about impossible to roll a shell sheet perfectly round. Mr. FitzSimmons at that time showed that a shell sheet that is not perfectly round when it got under its full steam pressure, would set itself perfectly round when under pressure. When it cooled off, it would come back to its original position.

That is research work, regardless of the fact that Buffington shakes his head, no. Research work proves itself. You can't take everything for

granted. You can't stop progress regardless of what you think. If we have a shell sheet that is ¼" out of round one way, and the other sheet ¼" the other way, we then have rivets in tension in the girth seam following Mr. FitzSimmons' study.

It was only a year ago that they recommended nickel steel rivets for girth seams. Today they don't recommend nickel steel rivets for girth seams. Why? Because they are in tension.

Those are the things to which we have got to give study. Let's not hold on to these old ideas that somebody has got in his head that isn't a fact. Let's give the subject some study. Let's hold the steam locomotive boiler where it belongs. In the end it is the cheapest power. If we get Diesel Locomotives we will have them perhaps as an advertising feature, not because they are cheaper in initial cost or in maintenance.

Gentlemen, in conclusion may I state: You may have the best of materials, tools and instructions for methods to be used with the fabrication of the boilers, they are of no better use than the poorest kind if not properly used, and we the Master Boiler Makers must insist that the proper procedures are followed in doing the work and inspection, may the same be at the locomotive builders or at our own shop, for many a time when a new method is suggested, the proper spirit of cooperation is not given in doing the work; this only leads to results very unsatisfactory when the locomotive boiler is placed in service and will in time be the downfall of the locomotive boiler and your positions as Master Boiler Makers.

This, gentlemen, is my message to you this morning, and do hope it is taken in the same spirit as given. (Applause)

President Harper: Gentlemen, we are about thirty minutes past schedule, and our discussion will be deferred until this afternoon meeting. We will appreciate having you return here so we can resume the discussion of Topic No. 5 promptly at 1:30 o'clock.

The Executive Board desires to have all suggested topics for 1941 in their hands this afternoon. Will the members who are preparing topics for the Executive Board turn them in to the Secretary just as soon as possible?

We will now entertain a motion to recess until one-thirty this afternoon.

Mr. Kearn E. Fogerty (C. B. & Q. R. R., Chicago): I move that we recess until one-thirty o'clock this afternoon.

. . . The motion was seconded by Mr. Yochem, voted upon and carried, the meeting recessing at eleven-thirty o'clock . . .

WEDNESDAY AFTERNOON SESSION

October 23, 1940

The meeting was called to order at one-forty o'clock by President Harper.

President Harper: Members and Guests: The afternoon meeting of the second day of our convention is now in session.

Mr. Stiglmeier, will you please continue with the discussion on Topic No. 5?

Secretary Stiglmeier: Gentlemen, this morning I made mention that I anticipated to read to you a paper that in a way would substantiate the recommendations of the committee as presented in their paper; this points out to you the importance of good work. It also gives to you information other than the committee paper as to the use of nickel steel successfully for locomotive boilers. Also to make you familiar with the fact that I am not selling nickel steel, only trying to bring before you methods that must be used with the fabrication of nickel steel, these methods should also be followed with the use of carbon steels. The paper that I am about to read to you is a report of the Canadian Pacific R. R. that they had prepared on request as to the status of their nickel steel boilers, and methods used with the fabrication of same, and there can be no question but that the Canadian Pacific R. R. surely are familiar with nickel steel boilers as you will note in the first part of the paper as to the many in service as well as the long period.

PREPARED REPORT

Our railroad has a total of 286 locomotives that are equipped with nickel steel boilers to date, the first locomotive boiler so built was in 1926, so that we have approximately 15 years experience with boilers of this material.

Our experiments with riveting pressures started in 1932, and the first locomotives built after that date, that is, in 1936, were constructed to limited rivet pressures. This does not mean that excessive pressures were used prior to that date as our riveting pressures have always been conservative. They were not, however, graded according to the size of the rivet or for the material used, and our specification limitations were introduced purely as a protective measure and to crystallize our ideas to this very important feature which I will comment on further.

Up to the present we have had absolutely no trouble of any kind with any nickel steel boiler or firebox plates. All original sheets are still in the boilers as constructed with the exception of some firebox side sheets which have been renewed, but which we have demonstrated have given at least 50% greater service than is the case with carbon sheets.

The only difficulty we have had with any nickel material is nickel rivets which we first started to use in 1930. The reason that we introduced the use of nickel steel rivets was that with increasing boiler pressure, we

found the sheering strength of a longitudinal joint was becoming the critical factor in design. To increase the diameter of carbon rivets would make the diameter of the rivet out of proportion in relation to joint thickness and length, and it is for this reason that the stronger material was adopted. The only difficulty that we have had with nickel rivet steel is that one source of supply furnished us with rivets for one lot of locomotives in which the billets were defective in that they contained seams, or else that shrinkage seams had not been thoroughly chipped out with the result that there were minute cracks in the bars as furnished for the manufacture of rivets and these minute cracks opened up when the heads were formed. By changing our source of supply, and also by revising our specification, this trouble has not again been experienced although a considerable number of locomotives have been constructed since the trouble was experienced. I have still retained some of these rivets as exhibits and the defects are quite apparent, and the nickel content is in no way responsible for the defect. We have had no trouble whatsoever in regard to rivet heads coming off, either during constuction or in service.

Comments: When nickel steel boiler plates were first adopted, it was to make use of higher boiler pressures possible, and it was anticipated that higher pressures would mean higher maintenance. To reduce the anticipated greater maintenance to a minimum, every safeguard was taken to produce boilers constructed to the best possible practices. Already, our boiler construction had improved very materially, the punching of holes had been eliminated, better shop equipment had been introduced, and taken all around, our boiler practice was of a high standard.

It soon developed with the use of nickel steel that the material had considerable increased inherent toughness. It was more difficult to fabricate, but once it was formed it was equally resistant to distortion. Although the investigation of riveting pressure had been primarily made on account of evidence of excessive pressures in old carbon steel boilers, it was also recognized of very great importance for other reasons.

Many, in order to build tight boilers with the minimum trouble, always liked fairly high pressures as it ensured that any inaccuracies in joint assembly would be corrected to some extent by the bull riveting pressures. In other words, if the main course and the inner and outer welds were not absolutely in contact, the bull riveter would exert sufficient pressure to bring the seam sheets together and hold them there with rivets. It will be appreciated that particularly with nickel steel with its greater strength, that if preparatory seam assembly is not accurate, there can be excessive stresses introduced in the rivets which are tensile, and if too high will result in rivet heads snapping off, particularly if such rivets are medium high in carbon or if there are any other improper practices such as working the rivets at too low a temperature.

Our investigation of rivet behavior shows the following:

Rivets must be driven with sufficient pressure to fill the hole, properly form the head, and to produce sufficient rivet tension to maintain a tight joint. In driving a rivet, the shank end which is formed into a button head is worked to a greater extent than the end with the pre-formed head. This results in a greater hydraulic pressure being set up in the shank end and rivets when driven have their larger diameter under the head that is formed. In the same way, the hole in the boiler plate is enlarged more at the shank end. The hot rivet expands more than the surrounding plate and when the rivet is in position and cooled, the rivet diameter is slightly less than the size of the hole, all of which means that the holding power of the rivet between the heads is responsible for maintaining to joint tightness.

In order to arrive at some ready means of determining whether there has been any abuse in the practices used for driving rivets, we have come to the conclusion that a rivet hole in the plate may have a maximum enlargement up to twelve to fourteen thousandths inch in diameter without hurting the plate material surrounding the hole.

We have recently endeavored to determine the residual tension in rivets driven at different pressures, and following our own practices, we found that for 1¼" diameter rivets with 95 ton pressure, the residual tensile strength in the rivet shank was 17,350 lbs., and that if this was increased to 115 tons the stress went to 21,000 lbs. These are quite high enough and, in fact, do not always give the minimum factor of safety of 4 that is required. These pressures were obtained for perfect joints and if there was any spring in the plates between the main sheets and the welts, these stresses would be increased considerably and readily account for snapped heads. In order to control this feature, we require that in rolling course sheets that the ends be pre-formed to template to the correct radius of the course. The entire course is then rolled gradually and when complete is required to be truly circular at any point within ¼" when resting on the floor. There is, of course, some deflection of the course while unsupported in this way but our experience is that if accurate within ¼" when resting freely, that it is accurate within a maximum of ⅛" when in position.

All plates that are in contact including circumferential seams and longitudinal seams are pre-ground by buffing the surface to remove all free scale or high spots and when these surfaces are buffed in this way they are not bright all over, but are mottled and a good even bearing is secured. Weld plates must be pre-formed to template and must agree in contour with the course sheets. This is tried out by visual examination by looking through the holes or looking at the edge of the weld sheets, and when put in position and lightly tightened with match bolts, the sheets should be in contact within an accuracy of six thousandths inch. If they exceed this or are up to approximately twelve thousandths inch the welds must be re-formed. In fitting up a seam there must not be more than one empty hole between two match bolts and when bolted up there must be no evidence on the seam at any point either in the holes after reaming or along the edges of the weld sheets, that the plates are out of contact by more than six thousandth inch. This is easy to check and is comparatively easy to line up to once the standards are set. The sharp edges of all rivet holes are carefully removed usually by compacting, and once the course if fitted up with not more than one hole between matched bolts, rivets are driven, course removed from the bull, bolts removed, holes reamed, and the final rivets driven.

This, in general, has been our policy for a considerable number of years, but the initial boilers built of nickel steel in 1926, while well built, are not, in my opinion, as well or carefully constructed as those built during the last 10 years. Nevertheless, they represent good commercial practice and have given absolute satisfaction.

It used to be that boilers were quickly built and in many cases, very roughly built, holes were not machined properly, not thoroughly reamed out, plates not properly fitted together, and, in general, it is the abuse that material have been put to that has resulted in trouble. My opinion is that boiler plate does not have to be of absolutely the highest quality, as I have tested material removed from boilers 25 to 40 years of age and although the material has been considerably dirtier than we use at the present time, the material so tested would pass modern requirements as far as tensile strength and ductility factors are concerned.

This is a brief summary of the points you wished to be covered with the fabrication of nickel steel boilers.

NOTE: Permission to publish this report was given our association by the Canadian Pacific Rys.

Secretary Stiglmeier (Continuing): In the committee report this morning you were given certain pressures. We will take, for instance, 95 to 100 tons per rivet. Most of the shops today have only one hydraulic bull riveter in a shop. We all know that the tonnage on a hydraulic bull riveter is figured by your accumulator pressure and the riveter cylinders.

To give to you an idea of a hydraulic bull riveter that we have in my railroad shop at West Albany, N. Y., we at the present time at 1600 pounds hydraulic accumulator pressure can get 55 tons, 95 tons and 150 tons. Say we have 1⅛" and 1¼" rivets that require from 95 to 115 tons pressure, what pressure would be used? There is no question but the next pressure you had on your riveter or 150 tons, this you understand would then be excessive pressure.

There has been recommended by your committee that reducing valve be placed on the hydraulic bull riveter, which in my opinion is correct, and should and must be done in order to overcome the developing of checks out of rivet holes, both in the longitudinal and girth seams of the high pressure boilers of today, may the same be carbon or alloy steels.

We have worked up pressures on the hydraulic bull riveter on my railroad using reducing valve as is shown in figure six of the committee report in step pressures of 100 tons as follows.

TABLE NO. 1

Accumulater Hydraulic Pressure	Hydraulic Pressures out of Reducing Valve	Tonnage Using Large Cylinder Only	Tonnage Using Small Cylinder Only	Tonnage Using Large and Small Cylinders	Pull Back Cylinder Tonnage
1600 lbs.	1600 lbs.	95 tons	48 tons	159 tons	16 tons
1600 lbs.	1500 lbs.	89 tons	45 tons	149 tons	15 tons
1600 lbs.	1400 lbs.	83 tons	42 tons	139 tons	14 tons
1600 lbs.	1300 lbs.	77 tons	39 tons	129 tons	13 tons
1600 lbs.	1200 lbs.	71 tons	36 tons	119 tons	12 tons
1600 lbs.	1100 lbs.	65 tons	33 tons	109 tons	11 tons
1600 lbs.	1000 lbs.	59 tons	30 tons	99 tons	10 tons
1600 lbs.	900 lbs.	53 tons	27 tons	89 tons	9 tons
1600 lbs.	800 lbs.	47 tons	24 tons	79 tons	8 tons
1600 lbs.	700 lbs.	41 tons	21 tons	69 tons	7 tons
1600 lbs.	600 lbs.	35 tons	18 tons	59 tons	6 tons
1600 lbs.	500 lbs.	29 tons	15 tons	49 tons	5 tons

Gentlemen, you can see what a reducing valve will do on a hydraulic bull riveter to regulate tonnage. The locomotive builders are cooperating in every way possible. One of the builders has already made application of this reducing valve, while others have regulated pressures at the accumulator. **But bear in mind, gentlemen, regardless of whether you have alloy or carbon steels, in order to keep out this so-called caustic embrittlement you have got to build boilers that are as tight on the inside as on the outside. The water and chemical** engineer can furnish the best of compounds and set up the best of instructions, but unless you have a tight boiler on the inside and hold stresses to the minimum, there are chances of this so-called caustic embrittlement. This Dr. Schroeder has made mention about in all of his papers.

Gentlemen, that is about all I have to say on this subject. (Applause)

President Harper: Is there any further information or discussion on this subject?

Mr. A. S. Vaughan (A. T. & S. F. R. R., San Bernardino, Calif.): I just want to bring out the fact that where we have been listening to the maintenance and building of boilers the back shop work mostly has been brought out, but nothing has been mentioned as to the maintenance in roundhouses. Whether we have alloy steel or nickel steel or carbon steel, we have not gotten down to the foundation of that trouble which we can correct in the firebox.

When we remove a set of flues in my shop we caulk all rivets and seams inside the shell of the boiler and it is very seldom that we have any cracks in the shells of our boilers, but I do know this: that 30 or 35 years ago we had engines come in the shop and we would knock the fire out of those engines and they were allowed to lay there and they would contract gradually. They were fired up in the same manner. They were expanded in the same manner that they were contracted.

Let's take an engine coming into the shop: she has a throttle disconnected and if we are not on our jobs today they blow that boiler out, and they blow it out just as quickly as they can possibly blow it out; they make their repairs and they fire it up just as quick. She has contracted quick and expanded quick. If there is any embrittlement in there it can't help but crack.

Take an engine coming over the fire track—that is where a lot of damage is done to our fireboxes. We have a lot of inexperienced men who don't know anything at all about boilers on the fire track. We have a hostler come down there and pull the fire out on one side and a darky on the other side washing that pan out. That is the punishment that fireboxes get.

That same thing refers to a flue sheet, which I think is the heart of a locomotive boiler. Mr. McQuinn says the locomotive boiler is the heart of a locomotive; I say the flues are the heart of a locomotive boiler. If we get together and get to the foundation of this thing we can correct it.

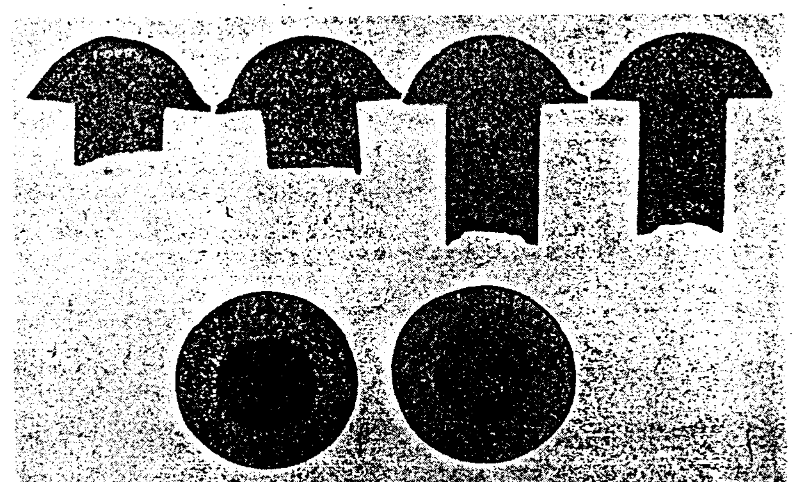
Years ago we had the ashpan coming up tight to the mud rings; today we have it coming up to your frames and your side sheets and you stick these holes through the side of your pan and mud ring. Some fireboxes are covered outside and some are not. They take that ice cold water and just shoot it all over the place. They don't care where it is hitting; they don't care what damage they are doing—and it is doing a damage.

We have more trouble in the firebox than I believe we have in the shell of the boiler, though there is enough trouble in the shell of the boiler which I believe Mr. Stiglmeier has brought out in a very intelligent way. But I believe if we can correct the conditions I have mentioned we will have a better firebox. We won't have the leaky staybolts and we won't have fire cracks in the firebox.

Mr Service: Mr. Chairman, members of the Master Boiler Makers' Association: I think this is one of the most lively subjects that has been considered by this Association for several reasons. Those that have their troubles are in the midst of them at the present time, and those that are not in their troubles don't have them. I am referring to nickel steel boilers. We have quite a number of them, twenty-eight in all at the present time.

I must say that we have received a pretty good job from the manufacturer and we haven't had any trouble whatever. I say that for the circumferential seams as well as the longitudinal seams. However, we have had some trouble in the outside casing in longitudinal seams, but before we get to the cracking of the seam let's get down to the point of what may be our trouble.

The outside edge of this seam is welded; the inside edge is caulked. I have here some photographs of some rivets that were removed. If you look closely you will see that black lines running crossways in the shank. That is not seams in the material as it is rolled for seams don't develop that way. They go longitudinally. You will also note that where the rivet points are driven there are also seams. That is the inside head. See there are longitudinal cracks. Every one of these, gentlemen, are the fractures of that rivet, and there are several other fractures in that same rivet.



Now, what caused those fractures? They opened up, certainly. When they opened up you reduced your bearing area holding power of the rivet head of its power to hold those sheets together. Then you have a place for steam to get in and cause this embrittlement. If we can stop some of that we may overcome some of the embrittlement of the sheet.

My thought in the matter in this particular case is that we have locomotives bought in duplicate fashion. How were the rivets made? We have got to say that the manufacturer made them all alike. We have no way of disproving it. But were they overheated alike? That is the same time element that would bring that nickel alloy steel up to the proper temperature before it is riveted.

I think it is a study, gentlemen. I believe that the Committee have made such an elegant report that if we will go further into this we will develop something along these lines.

I will say that I have made some experiments heating electrically, with the old coal fire and with the oil furnace. If we wanted to heat the rivet quickly with electricity we could blow a hole in the side of the rivet. However, if we would heat the rivet slower electrically, we could get a nice uniform heat, but we would get a heavy layer of oxide on the outer side of the rivet due to the atmospheric conditions surrounding the rivet. We did not get away from that in any heating process. However, there was more oxide on the rivet ele 'rically heated than on any of the other two. We found that we could fil the hole up better with the rivet heated in the oil furnace.

I was glad to learn also this report of the difference in rivet diameter tolerances.

Gentlemen, there are a lot o' you young fellows here. I would like to see some of you get up and express your trouble. I am here to learn.

I don't want to take any more of your time, but that is my trouble, and I think we are going to have to make a table for heating temperatures of these rivets and find out what we are getting in our rivets to begin with.

President Harper: Is Mr. H. G. Miller, Engineer of Tests, of Milwaukee, in the room?

Mr. H. G. Miller: (C. M. St. P. & P. R. R., Milwaukee, Wis.): Mr. Chairman and Gentlemen: As I have listened to this discussion this morning the thing that has struck me most forcibly is the scope of the topic that is under discussion. I think it covers entirely too much ground. The most important remark I can make about the whole subject is that the Committee has made a brave attempt but they have taken in too much territory and it should be divided into a number of sub-committees so that definite work can be done on each subject.

In the discussion of riveting, the question of filling the holes seems to be very important. In a recent study of this subject we found that the University of Illinois cooperated with the San Francisco Bridge Commission and made hundreds of specimens to determine whether or not they could fill holes by various methods of riveting. As far as I can tell from my reading of this report, they can not fill a hole over two inches in length.

As to heating rivets: rivets are getting bigger all the time; in fact, they are nothing but small forgings and all of the precautions that are taken to heat forgings should be applied to rivets. It isn't a matter of the surface heat; it is the kind of atmosphere in which the rivets are heated. If you are going to heat them electrically with all the air in the world circulating around them, you are going to have heavy scaling. So you will have to copy from your friends the blacksmiths and get muffle furnaces of some sort and keep down the scaling.

Further, as to dividing this subject: I simply recommend that the Committee differentiate very carefully between the requirements for firebox steel and for shell steel. Mr. McBrian gave you an idea this morning of what can be done with alloys in firebox steel selection. The same thing can be done in boiler shells, and you should make a study of the damage done in fabrication to the various types of carbon and alloy steels. Some of them will stand a lot of abuse and others will not.

In reporting your experiences about whether or not you have so-called caustic embrittlement the water conditions and the methods of fabrication should be recorded so that you know all of the factors entering into the case.

When you are scrapping old boilers it would be very instructive, and valuable information could be obtained if each one of you would select some specimens of the old material and see what the damage has been during the service life of the material.

Thank you. (Applause)

Mr. L. R. Hasse (B. & O. R. R., Baltimore, Md.): Mr. Chairman and Gentlemen: What I am going to have to say is in connection with the fabrication of new boilers. I noticed on the top of page 62 it says: "The importance of tight longitudinal seams has been stressed by Mr. W. C. Schroeder of the Bureau of Mines at the 1939 meeting of the Association."

At that particular meeting I had the privilege of being here and we had quite an illustration in regard to the seams where the water had seeped through and which they term is caustic embrittlement.

Also on the bottom of page 63 it says: "Weld longitudinal seams at both ends; chip and grind welds flush with surface of plate."

I know that for the last 15 or 20 years it has been the practice to electric-weld the longitudinal seams for a distance of about 24" at the front and the back end. What difference does it make if we electric-weld the whole length? In other words, we are not depending on the electric-weld at all for the seam efficiency so why not weld it the whole length and have a good job to start with? We've got a good tool; the electric-weld, so let's use it. By welding the entire length makes a good tight job.

Mr. Yochem: Gentlemen, you have been called upon to rebuild some boilers. Now do we have the tools to do the job with like we have in the machine shop? Boiler shops don't get new tools like the machine shops. (Applause) Still in all, they have asked us to build boilers and we are building them with air hammers and sledges.

In the past year we rebuilt seven passenger locomotives in our Sedalia Shop, renewing the shell courses.

These shells were of three course construction, two straight courses and one tapered course, the sheets for one boiler were laid out and then stacked drilled with a radial drill press removed from foundation and placed on stack of sheets, drill press moved as required with crane, all rivet holes were drilled, ⅛" to 3/16" smaller than required, this stock for reaming after fitting up, after sheets were drilled they were trimmed and beveled with portable oxweld machine, then ground with portable emery grinder, these sheets were beveled for caulking inside and outside, after rolling sheets were fit up, using eight machined fit up bolts on each ¼ center line, these bolts had a slight taper and a driving fit in hole, what heating was necessary was done with oil torch, rough or regular bolts were used in every other rivet hole in circumferential seam, also butt straps rivet hole, in fitting up boiler and after open holes were reamed and bolts applied same size as rivets used the previous bolts were removed and these holes reamed to rivet size, we have in our Sedalia Shop a 125 ton hydraulic bull riveter which was used on all rivets but at throat sheet connections and circumferential seam of first and second course, these rivets were driven with an air hammer and 100 pounds air pressure doubled gun, after several rivets were driven we learned that double gunning rivets would not do the job for the reason the rivets did not fill the holes, the air hammer on the original head of rivets was pulling the rivets and the air hammer on the point end of rivet after head was formed was also pulling the rivet, which resulted in the body of rivet being stretched in place of filling hole, this was proven by the use of a pry bar to buck the original head or rivet on inside of boiler, driving point on outside with long stroke air hammer, we removed several rivets and found that body of rivets filled the hole perfect and all rivets that were not applied by bull pressure were bucked with pry bar and points driven with long stroke air hammer, riding rivet with air hammer until practically black, we found that a long stroke air hammer was never heavy enough to buck or double gun rivets on the shell of a boiler, these boilers had 1⅛" rivets and operate at 225 pounds pressure. I feel sure there are some members here that are rebuilding boilers, or renewing shell courses and they should get up here and tell us what their experience has been if they are using a hydraulic bull where possible also air hammers, are they double gunning their rivets, what pressure they use and what success they have had, it would be all good information, fellows.

I might add at the present time at our Sedalia Shop we are rebuilding seven of our 1900 class heavy freight locomotives, these engines came from the builders in 1930 and had straight flue sheets, no combustion chamber, we are renewing the second and third shell courses and making them longer account applying a 56" combustion chamber and using the same length flues and units, also applying new fireboxes, the second shell course is 1 1/32" thick and the third course is 1 1/16" thick and 1 5/16" rivets used throughout, we use 125 ton bull pressure on these rivets, three of these engines are out and in service, and we have experienced no trouble whatever on account of leaks, the method used for fabricating was the same relative to preparing the sheets for drilling, fitting up and riveting as I stated on the seven passenger engines that we had rebuilt, these engines operate at 250 pounds working pressure.

President Harper: Mr. Longo, how about the nickel steel boilers the Southern Pacific built.

Mr. Longo: Mr. President and Gentlemen: I surely have been enjoying this meeting very much. There is a lot in this Topic No. 5 and all these discussions that take place this afternoon are worth much to us all, especially what Brother Stiglmeier and Mr. Miller said.

There are so many variables that enter into the construction of a nickel steel boiler that we could not cover it if we talked a week about it. I can tell you of the experience we had in the construction of our twenty (20) Daylight engines.

The first six (6) were carbon steel throughout, 250 pounds pressure and fourteen (14) were nickel steel shell courses, 280 pounds pressure, all twenty (20) were built in 1936 and 1937.

We experienced no trouble with the fabrication of those carbon steel boilers, because when you rolled your shell plates and fabricated your carbon steel boilers and laid up your shells or welt and butt straps they stayed where you put them, whereas: with the nickel steel boilers, in the rolling of shell courses you have to roll them back and forth thru the rolls from 12 to 15 percent more times, due to the toughness and spring in the sheets.

When we planed the edges of our sheets, the carbon sheets planed smooth, whereas on our nickel steel it was necessary to get the best possible tool steel on the market, then the edges of the plate had to be ground smooth with a grinder as it was impossible to secure a smooth job of planing edges of nickel steel in any other manner.

Mr. Stiglmeier spoke of the rough surface of nickel steel shell plates that was turned out of the mills prior to May 1940. There is a very big improvement in the nickel steel shell plate we are getting for our twenty (20) all nickel steel boilers now under construction over the steel we got in 1937.

With these nickel steel boilers we built in 1937 we caulked everything on the inside and outside. We have not had the trouble with the shell courses that these other fellows speak about and we don't expect any trouble with the boilers under construction now.

I heartily agree with the conclusion of this report that the committee report further on this subject at the 1941 meeting of the association with a view toward recommending a standard practice for the locomotive builders and railroads.

I thank you.

Mr. W. H. S. Bateman (W. H. S. Bateman & Co., Philadelphia, Pa.) Mr. President and Gentlemen: I have been very much interested in this discussion of Rivets and Riveting. I have been knocking around boiler shops for nearly a half century and I have had some experiences in connection with the matter of riveting and the heating of rivets.

They used to say of that dear old character, Mr. S. M. Vauclain, President of the Baldwin Locomotive Works, that he used to "eat and sleep locomotives" and I have been labeled by friends of mine among the Boiler Makers as having eaten and slept rivets.

There has been a lot said about the heating and the driving but there is one subject that I think you have overlooked, and that is the condition of the dies that you use to drive your rivets. How about it, Brother Service?

Mr. Service: You bet!

Mr. Bateman: Whoever designed the shape of the first rivet knew their business. I am going to illustrate to you what I have in mind. I want to illustrate a cone head rivet, which in my opinion, is the best shaped head of any kind of rivet to drive. They get their dies ready, whether it is on a bull machine or whether you are driving up with a pneumatic hammer or whatever it may be, but particularly on bull-riveting I have noticed it. I have seen dies that came up against a head and pressed against the plate without doing a darn thing in displacing any metal in the head or the shank, particularly on what we call a button head rivet.

The idea of developing a rivet of this character (indicated by blackboard sketch) is this: when you put a die on there, drive that down; that metal has to go somewhere. That metal has got to go down in the shank and that helps fill up the hole. On the other hand, I have seen dies where they have a button head or where they drive up on the end of the rivet and there is no displacement of metal whatsoever.

What can you expect? You can't expect a rivet to perform the function of a bolt, and I have seen that happen in my time too. You've got to have enough inset on your die to drive that head down.

If you have scale on the rivet, what is going to happen? You are going to have right in along both sides of the shank pulverized oxide of iron. That is due, in the majority of cases, to overheating.

Of course, you are talking about pressures. Sometimes I think that there is not enough pressure exerted back of the driving of rivets in some of the boiler shops I have been in. For that reason, I think you should be careful to see how you heat your rivets; even if it takes a little longer to do it, and see also that you have the scale off the rivets. I have seen fellows have a little rotary machine that they stick the rivet in and whirl—understand, *whirl* that scale off the rivet. When you are driving a rivet with scale on it you are impeding the effect of what that rivet is being used for.

In regard to heating of rivets, I can't go into detail. I went into a boiler shop one time (this did not happen to be, in this particular case, a railroad shop) and they complained about rivet heads coming off. I went up on the rivetting deck. They had two bull riveters and they had electric rivet heaters working there. I stood there for quite some time. Those rivets were ¾" in diameter and I should say 4½" long—some of them probably a little longer, that they were driving up with a bull.

When I came down, the foreman of the shop thought my eyes would pop out. He said to me: "What did you find?" I said; "I found this, my friend—that I have never found any body that was able to successfully drive a rivet with a patriotic heat on it."

He said: "What's a patriotic heat?"

I said: "Red, white and blue." (Laughter)

That rivet was put in between the electrodes; the lower end of the shank of that rivet was almost white hot, the middle part of the rivet was red and the top part of the rivet—the most important part of it—was that fatal blue or critical heat which I assumed had probably dropped to about 600 degrees.

So I want to say to you gentlemen that we rivet manufacturers have delved into the scientific manufacture of rivets and you can't always blame your troubles on the rivet, whether it is a carbon steel rivet or whether it is an alloy steel rivet. These are things that have to be taken into consideration in riveting; the heat that is used and the manner in which a rivet is driven, and, most important of all, the tolerance and clearance of the rivet before it is driven.

Mr. D. J. Champion, that dear old gentleman who was dean of the rivet manufacturers in this country, used to say: "There are as many rivets abused as there are used." I saw that factor during the World War when I went into some ship yards and saw rivets piled high alongside of the heating furnaces like you would pile potatoes on a floor. You have to be careful, gentlemen, not only in heating but in seeing that the dies are set properly to perform the function that is expected of them.

There is one more thing I want to say to you, and that 's the question of a cold made rivet versus a hot made rivet. I would sooner see a rivet driven cold, absolutely, rather than heated improperly. In a cold made rivet you should use greater care than you do in heating a hot formed rivet. A hot formed rivet, as you know, is heated to be formed and a cold formed rivet is made without any heating and there is a stress in that rivet, particularly around the head portion, that has to be relieved by being uniformly heated before being driven. The result is, if it is not uniformly heated, you are going to have trouble with heads coming off; more particularly on cold made rivets than on hot made rivets.

From my own experience in going around, as well as the experience of others, I would not recommend a cold made rivet being used in a locomotive boiler larger than ⅞" in diameter at the outside, and I have reasons for making that recommendation. I have been through the mill with people that have had trouble, and came to the conclusion long ago that cold made rivets are not suitable for all classes of locomotive boiler construction.

There are a lot of other things about this rivet business that I would like to take up, but I have intruded on your time. As an honorary member of the Association and having been associated with you all these years, I thought I would like particularly to bring this matter to your attention; the dies you use in driving the rivets.

President Harper: I think that Mr. Bateman has brought us another angle of this topic. This is the place to bring out the angles so that finally we can smooth the subject up.

Mr. Fogerty: Mr. Chairman and Gentlemen of the Master Boiler Makers' Association: I am interested in this question to a certain extent, in listening to the different discussions that have been brought out here on the subject, although it drifted away from the question quite a little

In the first place, it reads: "Application of iron, steel and alloy rivets, with recommendations as to proper methods of heating and driving, including preparation of sheets, rivet holes and other involved parts of the locomotive boiler." Now then, 90% of you gentlemen here do not build locomotive boilers and I do not believe there is 50% of you that know anything about the riveting of these boilers. With all due respect to you, they are built by the Lima, Baldwin and American Locomotive Works and they, to the best of their ability, are doing what up to the present time they know to be 100% efficiency.

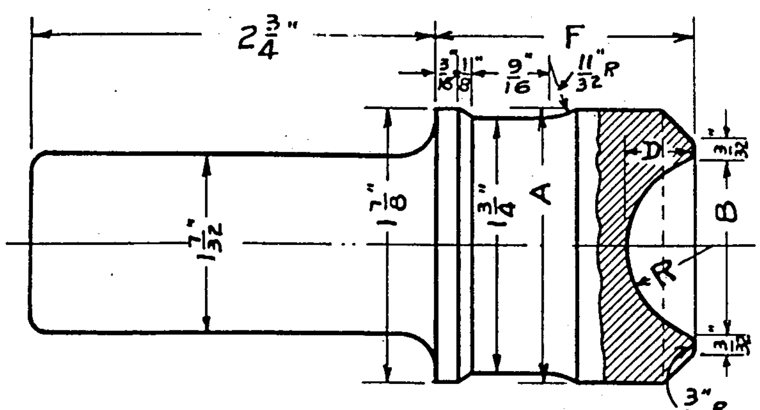
You go on here to state about heating the rivet. To my way of thinking, you've got to upset the rivet in the center, that's all there is to it. You can talk about cold or hot, but it's got to be upset in the center or you can't make the sheet tight. In the first place, you've got to have the sheet iron to iron or you don't have a tight fit.

That is all I have to say.

Mr. Service: Gentlemen, I want to call your particular attention to what the Committee had to say on page 68, figure 3, as illustrated in your program.

I am now going to go outside of my own railroad to talk about bum jobs. We are the ones that endeavor to secure good jobs! It shows a rivet head more or less in that shape with full head in contact with plate (draws diagram).

It does not show a rivet head coming down like that and not having a full head (again illustrating). It shows the rivet head snap coming to about there (indicating). So you are driving the head of that rivet to its proper place, and the rivet snap that you use, on the point of the rivet is supposed to be finished likewise with 3/32" radius inside at edge so that you have this (see sketch).



BUTTON HEAD RIVET SET

In other words, you are driving the hot metal in place to fill the hole. When you use an oversize rivet snap that will ride the sheet here "A" (indicating on diagram), then you are driving the sheet and pulling on the rivet head, and you are not doing a good job. That method will never fill up the hole. The area of a button head of rivet is designed for a certain size snap and when you use an oversize snap you get a bum job no matter what kind of rivets you are using.

In these pictures that I showed you gentlemen, every one of those heads were upset in the proper manner. It is the shanks that are cracking. I am not worrying about the filling up of holes. I had a pretty hard time getting these rivets out. I know they filled the holes. I say, watch your dies.

Secretary Stiglmeier: Mr. Chairman, I have just been taking a few notes here and I would like to answer some of these questions as to what the Committee had in mind.

I believe we have covered about every subject that was brought up here. The gentleman spoke about maintenance. I believe if you will look at the committee report in your meeting program you will find the following, the best boiler built is no better than a poor boiler if it is not properly maintained.

In heating rivets, Mr. Service brought out a point in regard to oil and electricity. Let's take a rivet here in that shape (draws diagram), drill three holes about 3/16" deep into the side of the rivet body, put it into an electric rivet heater and look into those holes while it is heating. You will find out that you will have perhaps 2,000 degrees F. in the center of that rivet and perhaps you will only have 700 or 800 on the outside. Take that same rivet and you bring it up to about 1700 on the outside; take it into your laboratory and let them cut out half of the body, and as Doc Bateman says, you have a patriotic rivet. I am afraid you have more than a patriotic rivet; you have about five different ranges. You will find your rivet burned here in the center (indicating on diagram) and the dammendest looking thing you ever saw.

Mr. Yochem spoke about laying out. I think we stress pretty much that we want good work, that includes laying out.

In regard to tools, I believe the object of bringing this subject before the meeting is to give the Master Boiler Maker an opportunity to go back to his railroad official and tell his superior that he has got to have tools similar to what you get when you get roller bearings. You will spend thousands and thousands of dollars in getting tools for roller bearings; you will spend a fortune on getting equipment for Diesel engines. Should we not go back and tell our officials that we need tools to do work properly or we are going to continue as in the past.

Mr. Longo spoke in regard to the builders. In the past year the builder has been mighty active. You can go in any of our boiler shops of our locomotive builders in the United States and Canada today and you will find some of the finest boiler work.

Mr. Service spoke in regard to rivet dies. Doc Bateman, I believe, spoke on that subject. I believe if you will read in your proceedings you will find that the Committee recommends not less than a 1/16" flash. The

If this rivet is caliphered directly under the head after it is driven, it will be found heavier there (indicating on sketch) than this part of the rivet (again indicating on sketch).

You wonder sometimes why it is that you can knock a bulled rivet out of the hole with just a few blows. That rivet when put into the hole hot is expanded. We know that when a rivet is heated it has got the full expansion that the heat will give it. However, the rivet does not stay hot —it cools off immediately. It has got to shrink. It shrinks away from the sides of the rivet hole. There isn't any other way for it to go.

We recently tried an experiment in which two one-inch plates bolted together were drilled for a hole 1/16" larger than the diameter of the rivet, or the conventional way of drilling a hole for a rivet. Then we drilled another hole in the same sheets, 1/16" smaller. You know what happened: When the rivet is heated it can't be put into the small hole. The hole was then reamed 1/32" larger. The rivet was heated, the scale knocked off and placed in the hole, and we had a true rivet in the hole 1/32" larger than the cold rivet diameter.

These sheets, riveted together, did not have the conditions you have in a boiler, where expansion and contraction takes place. We took these sheets from the drill press to the bull machine, back to the drill press again, and to the floor to knock out the rivets. The rivets came out of the holes very easily, and the rivets showed a small amount of scale.

Those are the best of conditions in riveting. In a boiler other conditions will be found, but it was shown that a rivet does shrink in the hole after it is driven.

Mr. France: I would like to move that we accept the report of the Committee and concur in their recommendation that we carry it over as a topic for next year.

The motion was seconded by Mr. Service, voted upon and carried.

President Harper: I see sitting in the audience two gentlemen that addressed us last year. Both men are honorary members of this Association. Mr. F. K. Mitchell, Assistant to the General Superintendent of Motive Power, New York Central, will you favor us with a few remarks? (Applause)

Mr. F. K. Mitchell: Mr. President and Officers, Members and Guests of the Association: I am very glad to be here today for a number of reasons, primarily because I am deeply interested in the problems that you have before you. I am sorry that I am not going to have time to attend all of your sessions because your problems are of great interest to anybody who has the interest of the American railroads at heart.

I have listened with a great deal of interest to your discussion on this very important subject you have just finished, and the thing that comes to my mind is this: that, after all, this problem, and all of your problems I think, reminds me of one of the most popular games that is played in this country, bowling. I would like to liken this subject to that game because there are a lot of lessons to be learned by it.

In the bowling game, as I recall it, you have ten frames and in very one of these frames the result that you get is reflected in the total score that you have at the end, so every frame is a problem and the good bowler attacks each frame as though it were the most important thing that he is going to do. If he expects to reach that 300 total score (which very few can reach but which every bowler would like to reach) he can't slight any one of those frames.

On this particular problem that you have just discussed, the primary frames that I see in it are these: the design; selection of materials; the layout; drilling and reaming of the sheets; rolling; fitting and laying up; rivet heating; rivet driving; the tools that you have to use; the workmanship, or how you use the tools that you do have. The final score is the satisfactory service from the boiler after you have finished.

In any one of those frames if something slips and you don't get the results you should get—in other words, if you make 8 on the selection of your material, or if you get a complete miss on the tools that you use—you can't expect to get that 300 at the end.

It is just the same with all of these problems that we face every day. Primarily, I think that the fundamental basis for a good job is common sense. More and more we must have the auxiliaries of common sense, water treatment, metallurgy, and the various scientific things that enter into it; but without the common sense you don't get the job that you want when you finish.

So it seems to me that in the consideration of these problems we should take them like the bowler takes his job—frame one first, and do the best job we can do on that. Nail it fast; get it in its proper position with the right kind of a job done, and then pass on to frame two.

So in the consideration here of your problems, as I said to you last year, I think it is fundamentally important that you go to the bottom of each of your individual factors that enter into the problems, decide definitely what your recommendations are, and then follow them through.

I see that you are very busy, too, and with that one suggestion I want to leave you and thank you for your consideration. (Applause)

President Harper: Thank you, Mr. Mitchell, for your encouraging remarks.

President Harper: The other gentleman is Mr. John Hall, Chief of the Locomotive Inspection Bureau, Interstate Commerce Commission. Will you favor us with a few remarks, Mr. Hall?

Mr. John N. Hall (Bur. Loco. Insp., I. C. C., Washington, D. C.): Mr. President and Brother Members: I don't pay dues but I am a member anyhow.

I want to congratulate you on your meeting and on the attendance. You fellows are surely interested in your jobs. You don't have to believe everything that everyone says, but you can get something out of every speaker on this floor. I think your meeting is certainly well worth while. (Applause)

President Harper: Thank you very much, Mr. Hall. In all sincerity, you gentlemen encourage us with your remarks. We appreciate your presence, for it is men like you who help us to succeed, and we need your continued support.

The meeting is open for the report of Committee on Topic No. 3.

Mr. E. H. Gilley, Chairman, will you please come forward and read the Committee's report?

MASTER BOILER MAKERS' ASSOCIATION
Topic and Committee Personnel
Topic No. 3

What means have or can be suggested to further improve circulation and other conditions in the locomotive boiler to improve steaming qualities and eliminate leaking staybolts and cracking of firebox sheets?

Sub-topic A. What means can be used to increase temperature of feed water entering the boiler and reduce the shock of impingement due to the entering feed water?

Sub-topic B. What means can be used to reduce detrimental effects on circulation due to improper firing practices?

Sub-topic B-1. Proper firing up and cooling down of large high pressure locomotive boilers to reduce excessive strain and damage therefrom.

Sub-topic C. Proper design of new boilers to improve their water carrying properties.

Chairman: E. H. Gilley, General Boiler Foreman, Grand Trunk Western Lines.

Vice-Chairman: M. V. Milton, Chief Boiler Inspector, Canadian National Railways.
H. E. May, Shop Engineer, Illinois Central Railroad.
F. C. Reinhart, General Boiler Foreman, Atchison, Topeka & Santa Fe Railroad.
E. Crapper, Chief Boiler Inspector, Buenos Aires Southern-Western Railways.
H. L. Harrell, General Locomotive Inspector, Illinois Central Railroad.
C. A. Brandt, Chief Engineer, The Superheater Company.

Topic number three, in its present form, is a continuation of the subject from our 1939 meeting, and, in carrying this topic over to this year the recommendation of the preceding committee is quoted:

"It can readily be seen from the foregoing report that the subject in its present form is a very broad one, involving many and varied parts and conditions in the boiler which for one committee to cover in one report is a considerably larger job than it is convenient to handle. To gloss over the matters briefly without coming to any more or less definite conclusion is, in our opinion, doing very little towards advancing the solution of our problems. It is therefore our recommendation that certain particular angles of this subject be studied to a conclusion, enabling us to make some definite recommendations, and that topic number three in its present form be continued, but sub-divided for definite study during the next year."

In compliance with the recommendation of the 1939 committee, our Executive Board has divided this topic into four sub-topics, each of which will be discussed in the order of its relationship to the general topic.

SUB-TOPIC A. "What means can be used to increase the temperature of feed water entering the boiler and also reduce the shock of impingement due to the entering feed water?"