The following "go" thread gages have plus tolerances on minor diameter: plain plug gage; plain check gages for thread ring gage. One "go" thread gage, the thread ring, has minus tolerance on minor diameter.

The following "not go" thread gages have plus tolerances on major diameter: full-form setting plug; truncated setting plug (full portion); plain snap gage. The following "not go" thread gages have minus tolerances on major diameter: thread plug; truncated setting plug (truncated portion). The following "not go" thread gages have plus tolerances on pitch diameter: thread ring; full-form setting plug; truncated setting plug (both full and truncated portions). One "not go" thread gage, the thread plug, has minus tolerance on pitch diameter. One "not go" thread gage, the thread ring, has plus tolerance on the minor diameter. One "not go" thread gage, the plain check plug gage for thread ring, has minus tolerance on minor diameter.

REFERENCES

For more detailed information concerning American Standard Screw Threads and equipment for threading and gaging, the following publications are recommended:

* H28 (1944). Screw-Thread Standards for Federal Services. Ntl. Bur. Stds.
§ A.S.A. B 1.1 1949. American Standard National Standard Screw Threads,
*CS8-41. Gage Blanks (15). Ntl. Bur. Stds.
*CS24-43. Screw Threads and Tap Drill Sizes (10). Ntl. Bur. Stds.
*R51. Chasers for Self-Opening and Adjustable Die Heads (10). Ntl. Bur. Stds.
§ A.S.A. B 5.4-1939. Taps, Cut and Ground Threads ($1.25).
* May be secured from: Supt. of Documents, U. S. Govt. Printing Office, Washington 25, D. C.
§ May be secured from: ASME, 29 West 39th Street, New York 18, N. Y.

RECENT IMPROVED PRACTICES FOR STAYBOLT APPLICATION AND MAINTENANCE RECOMMENDED FOR HIGH PRESSURE BOILERS

By S. E. CHRISTOPHERSON

To obtain the best possible staybolting job on any modern steam locomotive boiler with steam pressure above 200 lbs., as in regard to a leak tight firebox, the start must be made by the Mechanical Engineer, having in mind the three factors which have proven to be of value to a leak tight job.

Top boiler check with spray nozzle:

Seal weld all staybolts:

A lesser pitch, lighter sheet and small size staybolts:

In our tests of several years we know that top boiler check has improved the condition of leaky staybolts over the side check application and should be made standard for all steam locomotive boilers.

However, top check alone without treating boiler water is a fact that must be adhered to, we have had considerable trouble with leakage of staybolts when for some reason or other the treatment was not available.

Seal welding of staybolts we know is a factor in keeping steam locomotives on their runs, without being dumped for leaks, in fact even with a side check application without any kind of boiler water treatment twice the mileage has been obtained with seal welded staybolts.

As to methods to be used in seal welding of staybolts, there is quite a number of ways to do it, if you can afford the time and expenditure.

However, we have always believed that with a good fitted staybolt, reasonable upset and staybolt material free from ... litting around the head after being driven can be successfully sealwelded.

Iron staybolts have a tendency to split at edg... when driven or upset, less staybolt is chamfered or a cup die being used

Steel staybolts will not split at edges, but req... re more time in being driven.

There is no doubt in our mind that a better electrode will be found, one that will not give us the pin holes in the welded area. This must be overcome, because we have found that wherever this pin hole is found we will eventually have a leaky staybolt.

On the other hand if seal weld is intact, there is no leakage and firebox sheets and staybolts will stay tight for an indefinite period.

The Mechanical Engineer in his calculation to obtain the set figure of 7500 lbs. on a staybolting job should have in mind, that a lighter sheet in thickness a lesser pitch and smaller size staybolt is far better for the firebox than a heavy sheet, large size staybolt with the old standard pitch of 4" x 4"..

We do know that this is also a factor in keeping firebox sheets from leakage owing to the lesser pitch will have more holding power and will not corrugate the sheet in between the staybolts. We do know that once the firebox sheet has started to move the staybolt fit is gone and can never be remedied.

We do know that some railroads have tried this out, without seal welding the staybolts with satisfactory results.

Time and again the question has been raised on the lesser pitch. It is believed that broken staybolts, when removed will lodge in between these staybolts, causing mud to collect and may cause an overheated sheet.

This is not so, practically every staybolt removed either broken or otherwise defective can be cut to almost any size by the acetylene cutting torch; these small pieces will drop down to the mudring and removed the usual way.

As to mud collection we would say it would be impossible if every means as described in our Proceedinges are used, such as, benefit to be derived from properly cooling, modern water treatment, continuous blow downs, manual blow down helps to keep most of the mineral solids in circulation or it is gone out of boiler entirely.

Going into a heavy sheet does not warrant a stronger firebox. Our observation on high pressure boiler with a heavy sheet, that is a firebox sheet heavier than ⅜". The heavy sheet does bring out the corrugation between the staybolts in a shorter period; test has also proven that owing to thickness sheet will develop cracks much earlier.

The boiler shop should always insist on a good layout job on staybolt holes — alignment is important.

Do not drill or punch staybolt holes too small, ...is will wear out your taps and also spoil your threaded sheets. We have ...und that 5⁄32" hole less than the staybolt taps to be used is sufficient ...or a good thread in sheet and will save wear on your tap.

Use an equalizing rigging on your motors wh... tapping; the slower the speed the better for the threaded hole and taps. ...ny shop that does not have the caliberator gages can use the old standby with very good results, namely, tap out a ⅜" plate with taps to be used, trying each tap through the tapped plate for a nearly equal hand tight fit.

Giving the machine operator the plate tapped out to fit his staybolt too.

Staybolts wherever possible should be applied from the outside and set for driving at the firebox side, thus to avoid heating up of sheet and staybolts and spoil a good fitted staybolt.

Double gunning up of the staybolts we believe will do the best possible job, as the two guns will synchronize and a good upset of material will be the results.

All staybolts at least in the affected area in the firebox as to leakage, we do recommend seal welding.

We do know positively that at least double the mileage will be obtained over a none seal welded staybolt.

The serviceable locomotive boiler for a longer period is what we are aiming at and every means to make this possible should be utilized. From the old proceedings and discussion we have had, it has been proven that, giving the locomotive boiler a good tight firebox it can be turned and used for the next dispatchment.

SEAL-WELDING OF STAYBOLTS

By F. A. Longo

It is apparent that a need exists for modernizing the steam locomotive boiler to meet the demands of present operating conditions. One of the contributing factors in making the availability of our steam locomotives comparable with other types of Motive Power is the seal-welding of staybolts.

Without proper chemically treated water over the entire railroad system, it is difficult to keep staybolts from leaking due to the tremendous expansion and contraction stresses in our large modern high pressure steam boilers.

Firebox failures due to leaky staybolts can seriously affect the smooth operation of the railroad by the loss of locomotive time out of service for repairs and the use of man hours of skilled labor that could be applied to better advantage on other work.

Seal-welding of staybolts has made remarkable progress in the past few years. We feel that the progress made to date, not only in regard to the testing of these seal-welded bolts, but progress in regard to the materials themselves is quite encouraging.

We have experienced such good results with seal-welding of staybolts it is now standard practice on all our large power. This has enabled us to extend the life of our firebox sheets from 100,000 miles to 300,000 miles and more.

The bolts are applied in the usual manner with the exception that the bolts are not driven or headed up in the firebox. All rigid staybolts are driven on the outside before bolts are cut to length on firebox sheet. The bolts are then cut off square to a protruding length of three (3) threads. A milling tool is used to remove threads which also mills the end of the staybolts to the proper length.

Before any welding is started, sheets and bolts are thoroughly cleaned of any oil, grease or foreign matter, and sheets must be dry. American

Welding Society classification No. 6010-⅛" diameter electrodes are used in seal welding bolts to sheets.

SEAL WELDING OF STAYBOLTS

By Elmer E. Owens

After making a study of this most important subject, i.e., "Recommended Practices for Staybolt Application and Maintenance" as it has been presented to us by Dr. Greenslade in his excellent papers and the experiences and facts brought to our attention in papers prepared by different members of his committee, I, like Mr. Graulty stated in his paper a year ago, find it difficult in preparing my remarks on this topic, more especially any constructive remarks.

However, additional experience gained by observing performance, seal welded staybolts in fire box sheets has proven conclusively this is proper method to follow and in all cases where proper ca.e is taken in staybolt applications and good workmanship is obtained there has been a great improvement in reducing fire box leakage which in turn has resulted in better locomotive performance, increased locomotive availability and increased fire box life. This is reflected and substantiated by following through the fine performance of some tests I reported on in my paper presented on the subject to committee last year, i.e.:

Engine 834—4-8-4 type passenger locomotive carrying 300 lbs. working pressure, was given a new pair side sheets during Class 3 repairs April 1946; all staybolts were seal welded before releasing for service. This locomotive was again shopped for Class 3 repairs March 1948 after making 330,080 miles. No side sheet or bolt work necessary. To the date locomotive 834 has made approximately 230,000 miles in to 2nd term of flue mileage and estimate side sheets good for an additional 100,000 miles when will possibly be necessary to apply large side sheet patches. Comparing this with previous performance as follows: side sheet patches at 150 to 175,000 miles and renewal of full side sheets at approximately 300,000 miles.

Loco 804, another 4-8-4 type passenger locomotive carrying same working pressure, received Class 2 repairs March 1947 at which time all staybolts and crown stays were seal welded. This locomotive was shopped for Class 3 repairs January 1949, had made 283,000 miles, no side sheet or staybolt work necessary. Has made to date 110,000 miles in to 2nd term flue mileage, fire box sheets and bolts in good condition.

The 3800 class 4-6-6-4 type locomotives referred to in my paper last year are both still in their first term of flue mileage having made approximately 200 to 225,000 miles and will require shopping in the near future. Do not anticipate any fire box sheet renewals, however, staybolt performance has not been as satisfactory as in the passenger type locomotives as has been necessary to renew a few bolts from time to time account welds breaking away from the staybolt heads, one of these locomotives being equipped with iron bolts, the other with steel bolts and the performance has been approximately the same in both locomotives. However, we still consider the performance of staybolts in these two tests satisfactory as in spite of necessity of renewing a few bolts, there has been less leakage and no sheet work necessary and contribute the defects which have developed to the fact these large oil burning freight locomotives are subject to more severe service and terminal abuses which if they could be controlled, more satisfactory performance would be obtained.

We are continuing the practice of seal welding all bolts in new work, all high pressure boilers and continuing our methods of staybolt application and preparing bolts and sheets to be welded which are:

1. Good taps properly threaded bolts.
2. Good fit on a bolt set by hand with 16" wrench.
3. Bolts applied from outside where possible, set at not less than 2 full threads for heading, properly backed up with 60# dolly bar and driven with standard tite staybolt driving snap with a 60# or 80# air hammer.
4. Cleaning ends of bolts and sheets. This is very important and we follow the practice of applying coat of whiting to sheets and bolts to absorb the oil. After whiting dries a steel buffing brush is used to remove the sediment and, where oil is drawn to surface of sheet while welding we have resorted to burning this off with acetylene torches, also sand blast all sheets, fire side, before applying.
5. Seal weld bolt head with ⅛" reverse polarity welding rod starting weld on side bolts at top center, welding down to bottom center, then clean starting and stopping ends of all flux and complete the welding from top downward. On the overhead bolts start the weld at any point and weld continuous full circumference.

While there are several methods and practices being followed in application of staybolts and seal welding, the degree of successful service obtained depends largely on good workmanship.

We are being furnished good material and good machines and can obtain the proper tools. Therefore, if we as supervisors adhere to practices and methods advanced by our committee and insist on first class workmanship, there is no question but what satisfactory results will be obtained.

I thank you.

GENERAL DISCUSSION OF STAYBOLT APPLICATION AND MAINTENANCE AT THE READING COMPANY SHOPS

By B. G. KANTNER

We on the Reading have not gone into seal welding staybolts as yet or have we made any considerable changes in our application or method of maintenance of staybolts in the past several years.

When we converted our Class I-10 locomotives to Class "T" and raised the steam pressure from 220 lbs to 240 lbs., after several months service we had staybolt leakage along the fire line. It was necessary to remove the flexible staybolt caps to hold on the bolts and redrive them. This leaking condition has practically cleared up on the Reading and our Class "T" locomotives have approximately 200,000 miles service, and it has not been necessary to piece out the firebox sheets on any of these locomotives as yet.

We attribute a lot of our success in good water conditions on water treatment. Our staybolt breakage is very low. Class "T" engines are equipped with a top boiler check, front end throttle, three firebox syphons and one combustion chamber syphon, and two arch tubes.

The Class "T" engines, as mentioned above, are 4-8-4 type heavy freight locomotives and the Class I-10 are heavy Consolidated type freight locomotives 2-8-0.

MAINTENANCE OF STAYBOLTS IN LOCOMOTIVE BOILERS

By F. E. Godwin

I fully agreed with Vice-Chairman Christopherson's idea of segregating this topic into sub section —

a) Staybolt manufacture and threading.
b) Application.
c) Seal welding.
d) Maintenance.

By this method, subjects can be discussed in detail, which are sometimes overlooked when one is trying to condense a large amount of information into too small a space to completely cover the whole subject.

I have chosen *"Maintenance"* as my sub topic because I believe maintenance is a "must" that should be considered during the entire life of the boiler and should be carried out just as effectively when it is 10 or 20 years old as it was carried out when it was new and the pride of the railroad.

There is nothing, in my opinion, that will pay greater dividends than a locomotive boiler that receives first class maintenance. This is borne out by the fact that when a boiler or firebox gives trouble we give it better maintenance for a while; invariably we are repaid for our efforts as the trouble disappears. But if we give this some thought, we, in a great many cases could reverse this and do a better maintenance job first, and avoid to some extent the starting of the trouble. This sounds logical, unfortunately we cannot control all the angles because we are at the mercy of production experts in the back shops who are satisfied with the quantity, and seldom consider the quality; in the roundhouses our problem is hostlers, ashpit men, engineers, and firemen. The laying-down of rules for these men to follow, is in most cases, a waste of time.

Maintenance, however, is the challenge we have to meet to make a showing against the influx of the diesel engine.

Maintenance should commence when engines are in the Main Shops for repairs. All heating surfaces should be thoroughly cleaned for scale and oil wherever possible to do so. At present on our road, we sand blast all crown sheets on the water side and around all crown bolt connections at the crown sheet; also down the radius of the crown as far as possible. This is accomplished by wet sand blasting which has, to date, proven a sound investment, especially on engines that have a silica scale deposit on the heating surfaces of the crown sheet.

Staybolts that show signs of leakage or pulling away from the sheet are re-driven by the double hammer process, otherwise these are not touched. Boilers that receive heavy firebox repairs and are contaminated with oil are boiled out before leaving the Main Shops. At present, we are removing the tender tank oil skimmers in favor of a new type oil separator. These are mounted between the cylinder and the feed water heater bundle or cylinder and exhaust steam injector. By removing the oil from the exhaust steam as it leaves the cylinder in an atomized state, proves effective and will eliminate the plugging up of condensate pipe lines; will also keep the copper tubes in the feed water bundle clean, which will increase the efficiency of the heater. Samples of boiler water taken for analysis show 3 P.P.M. to 8 P.P.M. of oil ranging from .3% to 1% of suspended solids according to water conditions.

All large power engines are being equipped with automatic continuous blowdowns (surface). The blowdown discharge is taken from a few inches below the surface of the water adjacent to the dome. Comparative tests of boiler water taken from surface blowdowns and regular blowdown proved that the sample taken from the surface blowdown carried a dissolved solid concentration of 5 to 10% higher than the sample taken at the mud ring. This indicates that we are obtaining greater relative reduction in solids from the surface blowdown for the same volume of boiler water blown out. This surface blowdown working at the dome should help considerably in eliminating carry-over in the steam.

All our boilers are equipped with top checks and wye-type nozzles which divert the water away from the dry pipe and boiler shell plate, eliminating as much as possible feed water coming in contact with the metal. When firebox side sheets are being renewed, staybolt holes in wrapper sheet are gauged and if found to be 1⅛" diameter, these are reduced by countersinking and welding the holes solid, then redrilling for 1" staybolts. We have found that this method is more economical than renewing the outside wrapper side sheets. Care must be taken when tapping welded holes, as these holes invariably are a hardened metal and will destroy the best taps and staybolts will be hard to fit unless proper reaming is done before tapping is commenced.

Very little research work has been done by us on seal welded staybolts on account of initial tests in 1945 proving unsatisfactory. Two boilers had right side sheet staybolts seal welded, both left side sheets were standard application non-welded type. After 36 months' service, seal welded bolts became defective on both boilers; non-welded side sheets are still in good condition after 48 months' service.

Third and Fourth Test in 1946. Two other boilers had staybolts seal welded right and left side sheets; both engines were reported, side sheets in good condition after 44 months' service. On the four above tests staybolts were not hammered up on firebox side, only bucked up on the inside when driving bolts on the outside. The latter two engines showed a considerable improvement over the previous two applications, however as some doubt existed on success of seal welded bolts, no further applications were made in 1947, 1948.

In view of the improved electrodes available on the market this year, in the E-6015 class, low hydrogen electrode with 70,000 P.S.I. tensile with a much higher ductility, we attempted another application of seal welded staybolts to prove the merits of this new electrode. We have welded a right side application with E-6015 and left side sheet with the ordinary E-6010 class rod. On this application, we double-gunned all staybolts, inside and outside, and applied hydro test to boiler to insure tightness before staybolts were seal welded. One-eighth inch electrode was used with the weld commencing at the bottom and up to the top center. It was recommended to peen this type of welding when completed to release any locked-up stresses and bond any porosity that existed in the weld. As this application has only been in service six months, there is nothing to report.

Seal welding is not a positive means of eliminating staybolt leakage, but can only be effective to the extent of the accuracy in mating of the threads in the plate and staybolt. While we know this potential failure exists in all threaded applications, we should endeavor to eliminate this failure by advocating the development of the non-threaded fusion welded staybolt for locomotive fireboxes as the probable answer to this complex problem.

Roundhouse Maintenance is in itself entirely a local supervisors problem, and how best he has organized his staff to cover the various points of Maintenance required by law, and further be able to meet the unexpected problems that periodically arise in everyday roundhouse life.

Boiler foremen should be held in the highest authority in making decisions regarding whether engines should be held for further maintenance to boilers

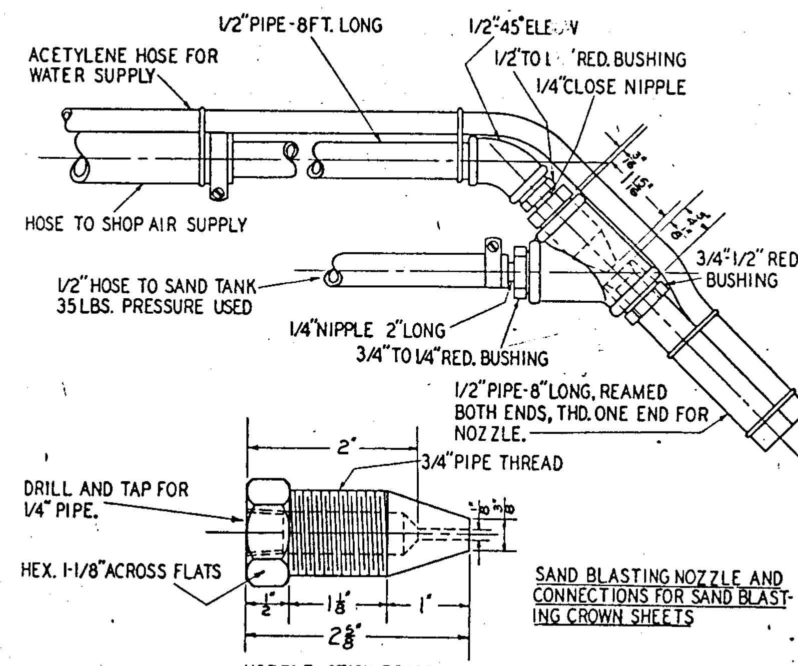


Fig. 1

CROWN SHEET-BEFORE SAND BLASTING   CROWN SHEET AFTER SAND BLASTING

Fig. 2

and their appurtenances, and should not be challenged by locomotive foremen who are dissatisfied when told that the engine is unfit for service.

The boiler man's best-known rule is: "Defects" when found or reported, large or small, should be repaired immediately. Boiler staffs that are trained along these lines pay big dividends. Time study proves that jobs properly done, need not be done again. This also applies to back-shop maintenance.

Cooling down boilers with the cold water method is gaining in popularity and will soon be standard procedure in all railroads. Hot wells should be of proper capacity to take care of the heavy wash-out programs that sometimes arise. One of the most important jobs in any roundhouse is keeping boiler flues clean at all times; an engine dispatched with dirty flues is false economy and should not be tolerated. The same applies to leaky or defective superheater units.

One of the surest ways to reduce engine failures is to tighten up on Maintenance by increasing the standard of workmanship.

DEVELOPMENTS IN THE SEAL-WELDING OF STAYBOLTS ON THE CANADIAN PACIFIC RAILWAY

By F. R. Milligan

When we had boiler pressures ranging from 190 lbs. to 225 lbs. P.S.I. we experienced practically no trouble with leaking staybolts or cracks developing in the side sheets and crown sheet between two or more bolt holes in the so-called good water districts. However, when boilers with pressure ranging from 250 lbs. to 300 lbs. P.S.I. were put in service, leaking staybolts and cracked side sheets became quite a problem, and not only reduced the side sheet mileage considerably, which was as low as approximately 80,000 miles between renewals on a number of locomotives in certain territories, whereas in other parts mileage as high as 500,000 was not uncommon, but also the availability of the locomotive use was greatly reduced, due to the fact that it was continually being held out of service to make necessary repairs to side sheets and staybolts. These defects would generally start after about 30,000 miles service.

Several different reasons as to why these defects developed were advanced from time to time, along with ways and means of overcoming them. All were tried out but none proved successful.

In April, 1944, we decided to try seal welding of staybolts. Two "Mikado" locomotives, wheel arrangement 2-8-2, boiler pressure 275 lbs. P.S.I., were put in the shop for right and left side sheet renewals and the solid staybolts were seal welded in the following manner — Sketch No. 1 of Fig. 1 shows our method of applying these bolts: Starting at the first row above the grates and extending upwards ⅔ of the height of the sheets, no flexible bolts were seal welded. One engine had staybolts seal welded on the right side, and staybolts on the left side were batted up in the usual manner; and the other engine had seal welded bolts on left side, and staybolts on the right side batted up in the usual manner. The locomotive with the seal welded bolts in the left side was shopped in April, 1949, and had accumulated 455,530 miles since the application; no defects were found, and no bolts have leaked and no cracks have developed in either side sheet during this mileage. The locomotive with seal welded bolts in the right side was shopped in April, 1949, with an accumulated mileage of 449,324 since the application. While we experienced no trouble with bolts leaking or cracks developing in the right or left side sheets during this mileage, inspection of the sheets at the shop disclosed that cracks were developing from the bolt holes on side sheet with the seal welded bolts and it was necessary to apply a fairly large patch to remove the defective area, while the side sheet with the bolts

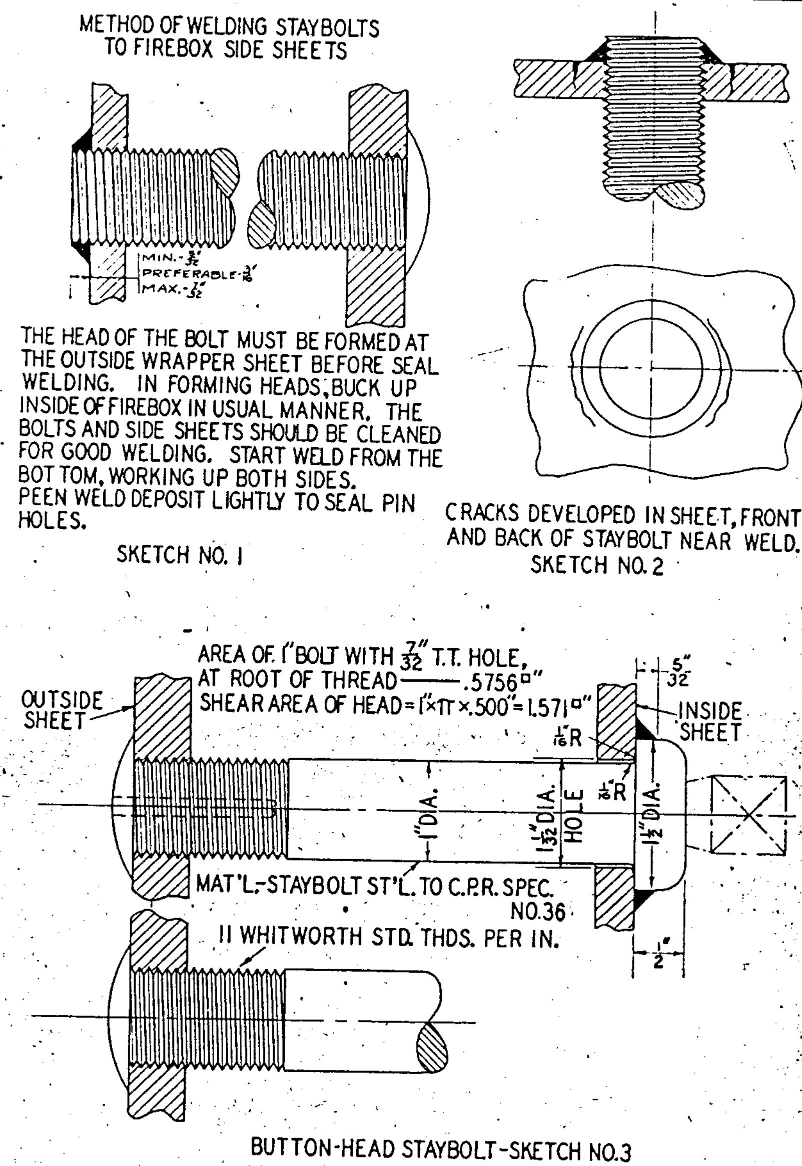


FIGURE 1

batted up in the usual manner was still in good condition and no repairs were required.

After these two locomotives had accumulated approximately 100,000 miles we were satisfied with results obtained and decided to seal weld staybolts and a number of engines of different classes now have this application.

In the year 1944 we were building a number of Pacific type locomotives, wheel arrangement 2-6-2, boiler pressure 250 lbs. P.S.I. The second one turned out had ⅞ Monel staybolts in the left side and 1 inch steel staybolts in the right side, both sides were seal welded. This engine was shopped in July, 1946, with an accumulated mileage of 151,006. No defects were found and no leaks or cracks had occurred during this mileage. This locomotive was again shopped in February, 1948, with an accumulated mileage since the application of welded bolts, of 272,015. While no leaks or cracks between bolts developed during this mileage, the inspection of the fire box at the shopping disclosed cracks developing in the sheets right and left side following the edge of the weld front and back of the bolts and in a number of cases the crack had developed all around the bolt — Sketch No. 2 of Fig. 1 shows the location of this cracking. There was a definite indication that the crack started at the front and back of the bolt. This cracking covered a large area of both sheets, but more severe in the centre of the sheets. Both sheets had to be renewed, and one inch steel bolts were applied and batted up in the usual manner. The finding of this condition caused us to discontinue seal welding of staybolts for the time being, until we see what develops in the other fire boxes that have seal welded bolts.

We have not come to any decision as to what causes this condition. The boilers on this class have a 4½" mudring. This narrow water space between the sheets may have been a contributing factor.

We are now experimenting with a 1" button head staybolt in the side sheet on a Pacific type locomotive, 4-6-2 wheel arrangement, boiler pressure 275 lbs. P.S.I. This bolt has no threads for the fire box sheet, thread only for outside or wrapper sheet and the button head is seal welded to the side sheet. Sketch No. 3 of Fig. 1 shows the design of the bolt and the method of application. Forty-two of these bolts were applied in the centre of the right side in the location where all our severe cracking and bolt leakage develops.

Some time ago we had reason to make tests to determine the pull-through load value on parallel thread stays and tapered stays and button head stays in an overheated sheet, and the following was the result of two tests we made of each type of bolt, sheet brought up to a temperature of 1700 degrees:

Parallel thread stay	1st, 2420	2nd, 2550
Tapered stay	1st, 2420	2nd, 2350
Button head stay	1st, 8450	2nd, 8390

There was such a vast difference in the load of the button head bolt over the parallel threaded or tapered thread bolts that we decided to make a test of 1" button head bolts. Tests were made in the following manner: no thread at the button head end, threads only in the outside end; seal weld some button heads and not seal weld the button head on others. Photos, at the end of this paper, show the results of the test — you will note the seal welded head failed at a maximum load of 7350# and the not seal welded head failed at a maximum load of 6710#.

The result of this test and the general belief that the sharp edge of the thread in the sheet is where the cracks start from and that thread is a large contributor to the cracking of side sheets, caused us to experiment with 1" button head staybolts with no thread in the side sheet and seal weld the head.

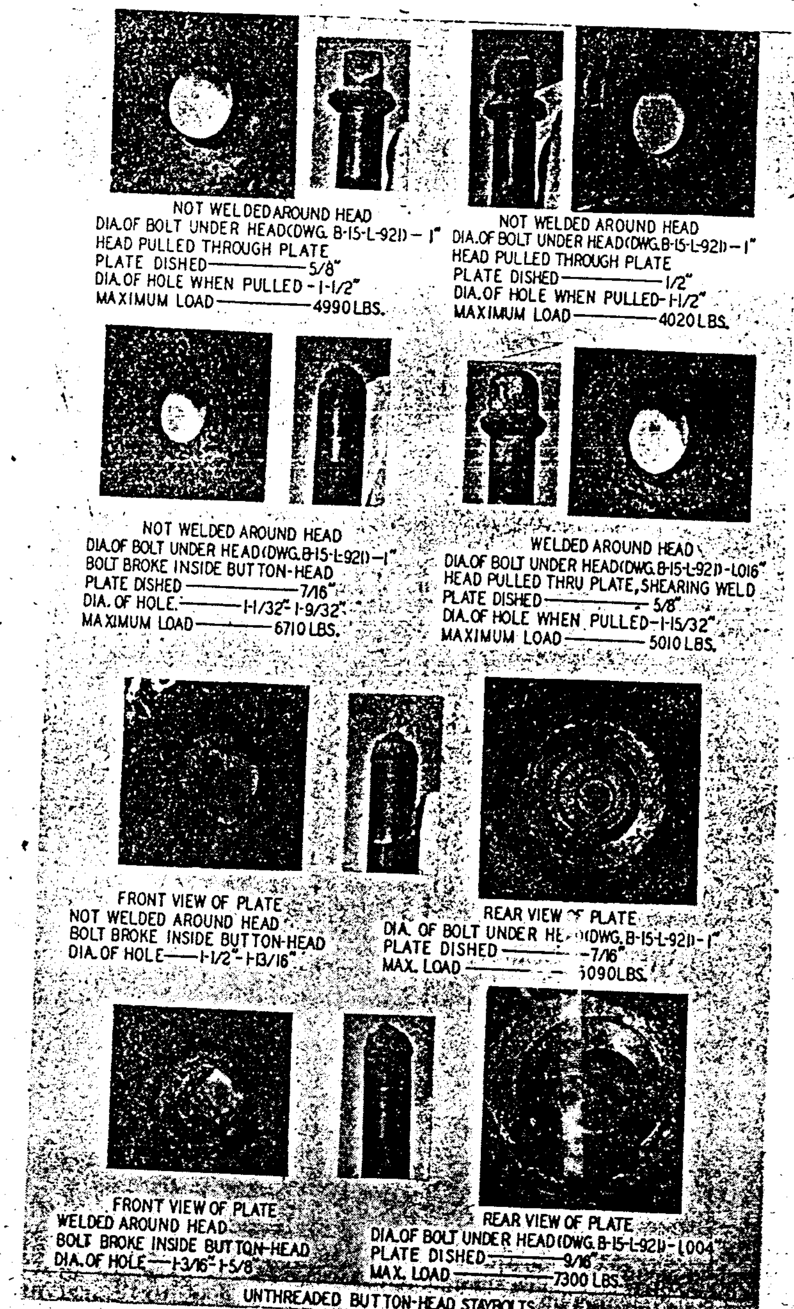


Fig. 2

These bolts have now accumulated 98,000 miles and show no indication of leaks or cracks developing in the sheet and the button heads show no indication of being overheated.

We have been experimenting along the lines of the late Mr. Huston's idea, International Nickel Company, of reducing the size of staybolts to increase their flexibility. In 1946, when we were building new Pacific type locomotives, wheel arrangement 2-6-2, boiler pressure 250 lbs. P.S.I., we applied 13/16" dia. Molybdenum steel staybolts to ten of these boilers in the following manner: Five boilers have 13/16" Molybdenum steel staybolts applied to the right side sheet and our one inch ordinary steel staybolts to the left side; five boilers with 13/16" Molybdenum steel staybolts applied to the left side sheet and our one inch ordinary steel staybolts to the right side, for comparison purposes. So far we have not found any broken bolts, 13/16" Molybdenum or ordinary steel, in these boilers.

RECOMMENDED PRACTICES FOR STAYBOLT APPLICATION AND MAINTENANCE

By Harold W. Chandler

The subject of staybolt application and maintenance is one which has long occupied the attention of the Master Boiler Makers' Association, and has been discussed from so many angles by recognized authorities that an attempt to add to what has been said seems presumptuous. Without any claim to originality, the following remarks are offered on the subject of staybolts.

A recent publication of the Interstate Commerce Commission, in commenting on the work of the Locomotive Inspection Bureau soon after the inception of the Boiler Inspection Act, lists some of the particularly hazardous conditions that were frequently found by Inspectors in the early days, in the order of their importance:

1. Cracks and grooves in boiler shells, roof sheets and back heads.
2. Cracks in firebox sheets.
3. Bagged crown sheets.
4. Bagged or blistered arch tubes.
5. Broken braces, crown stays and staybolts.
6. Leaks from defective boiler joints, loose staybolts, studs and rivets.
7. Flues plugged because of cracks or pit holes, etc.

It is gratifying to note further on in this article that "defects such as enumerated in the foregoing are now rarely found." This statement can, I think, be taken as reflecting in part the aggressive action of the Master Boiler Makers' Association in improving the construction and maintenance of locomotive boilers.

The Federal Law limits the maximum stress per square inch of net cross sectional area on firebox and combustion chamber staybolts to 7500 pounds per square inch, which is the same stress permitted by the Locomotive Boiler Code of the American Society of Mechanical Engineers for unwelded or flexible staybolts less than 20 diameters long, screwed through plates with ends riveted over.

Probably the first item in the proper application of staybolts is their correct spacing, an item in which the boilermaker does not have much to say, other than to see that the bolts are spaced in accordance with the boiler design. The problem of a continuous flat plate such as a side sheet, supported at a series of points, usually pitched on rectangles or squares, is an extremely important one, and a theoretical discussion of this case usually assumes that any strip connecting two adjacent rows of staybolts is in condition of a

beam fixed at both ends. A formula often used, which expresses the relationship between working pressure, thickness of plate and pitch of staybolts is

$$P = C\frac{T^2}{p^2}$$

where P = maximum allowable working pressure in pounds per square inch
T = thickness of plate in sixteenths of an inch
p = maximum pitch of staybolts
C = 125 for stays screwed through plates not over 7/16" in thickness with ends riveted over

For 1" staybolts spaced 4" x 4" and 3/8" firebox sheets, the allowed working pressure would be 281 lb. per square inch by this formula. Assuming 12 U. S. F. threads per inch, the maximum permissible working pressure would be about the same. This combination of staybolt size, pitch and thickness of sheets is about what is usually encountered in the conventional 200# to 225# locomotive boiler, and in combination with reasonably wide water spaces gives a satisfactory arrangement for circulation, etc., while still staying the sheet well below the pressure at which the first permanent set takes place in plate of 55000 lbs. tensile strength. In locomotive boilers carrying in the neighborhood of 300 lbs. boiler pressure it is customary to use 13/32" side sheets in order that the staybolt spacing be not reduced materially below the 4" x 4" pitch which is based somewhat on practical consideration and good common sense, due to the complication in the stress distribution under varying operating conditions. The rate of heat transfer through the thicker firebox sheet is, of course, slower than in the low pressure boiler, and the higher boiler pressures are invariably associated with the larger boilers applied to modern high speed locomotives. A factor not always given sufficient consideration is the amount of distortion or change in shape of the back end which takes place during changes in pressure and which can have serious effect on the staybolts, particularly the short radials, and staybolts and crown stays in about the middle third of the firebox, measured longitudinally between the connection seam and the back head of radial stayed fireboxes. The design and thickness of wrapper sheet has considerable bearing on the amount of distortion in large high-pressure boilers.

The question of staybolt material has been discussed by this Association for a number of years and each kind of staybolt material has its advocates. Apparently staybolts made of any of these recognized materials, when properly threaded and applied to a firebox, will give satisfactory results. In applying the staybolt, it is very important that the plates be laid out carefully so that the holes, when drilled, will line up as intended when the boiler was designed. Careful attention must be given to drilling of the holes for staybolts, and the drilled holes must be sufficiently small to allow proper reaming and tapping to insure the proper fit of the bolts in the holes. When bolts are applied it should be possible to turn the bolt without the use of excessive force, but the bolt must not be loose in the hole.

The use of as wide a mudring as possible is desirable to give ample water space in the water legs and throat sheet. Top boiler checks equipped with spray nozzles are most effective in preventing cold water from reaching the firebox sheets than side checks, and where both injectors and feed water heaters are used, the feed water pump should be used only when the locomotive is in operation except for necessary terminal testing. Proper cooling down preparatory to washing the boiler is of great importance, as is the use of sufficient time in firing up the boiler after washing. It is not necessary in this day and age to comment on the necessity for properly treated boiler feed water, and the use of manual or continuous blow-down systems. A number of railroads now wash out superheater flues at the time the locomotive is held for monthly inspection. This practice has a bearing on staybolt condition for the reason that if it is not necessary to take the engine out of service to blow flues the firebox sheets and staybolts will not be harmed by cooling off and firing up too often. Proper terminal handling of the locomotive while cleaning fires at the cinder pit will pay handsome dividends.

As far back as 1937 this Association has debated seal welding of staybolts. It is the writer's belief that staybolts properly applied and seal welded will remain tight, and the absence of leakage will increase materially the life of the firebox sheets.

SUGGESTED PRACTICES IN STAYBOLT APPLICATION

By I. H. GRANCELL

No standard specifications covering joint sealing compounds have been set up by the Mechanical Division of the Association of American Railroads. The question is therefore left to the judgment of each locomotive equipment manufacturer and operating company.

Joint sealing problems are of interest to the manufacturers of locomotive equipment as well as shop foremen, superintendents and other men responsible for maintenance. A little extra thought to these problems will increase the efficiency of equipment, save many hours of repair time and reduce the costs of replacement parts.

In spite of improvements in thread cutting tools and machinery, no two pipe joints, studs, or bolts are cut exactly alike. Male and female threads are cut with separate tools. An allowance or tolerance is established to secure a "perfect fit." When the pipe joint, stud or bolt is assembled, a jamming action results. The friction generates heat. If the temperature created is high enough, the metal parts tend to fuse. Galling and seizing may also take place.

Many types of joint sealing compounds have been developed for the purpose of sealing joints tight against leakage. Among these are combinations of oils, grease, soaps, gums, clays, molasses, graphite, powdered zinc or powdered lead. If a compound eliminates leakage then it is a good joint sealing compound.

To be an anti-seize compound also, the joint sealing compound must have additional properties. A compound which reduces the torque required to break out a pipe joint, stud or a staybolt is called an anti-seize compound. The torque required to disassemble should not be more than the torque required to assemble.

When a locomotive is built it is known ahead of time that many pipe joints, studs, etc., must be disassembled periodically for cleaning or other service work. Some joints are considered "permanent" but even these may be the subject of action by a man with a wrench at some future date. A proper joint sealing and anti-seize compound which will keep the joint sealed or the stud or staybolt tight while in service and which will allow the joint, stud or staybolt to be disassembled easily when desired is therefore of definite value.

In reading a very interesting booklet by the Flannery Bolt Company, "The Various Problems of Staybolts," it is very evident that they have gone into the question of staybolts very thoroughly. This booklet was compiled by Dr. G. R. Greenslade of the research laboratories of the Flannery Bolt Company, October 15, 1940. This is in line with many discussions, and shows and stresses the expansions and contractions caused by different temperatures.

First is the movement of the sheets at different temperatures, and it is noted that there are three distinct movements — the inner sheet, the outer sheet, and the staybolt, which, when in working use, proves conclusively that there are three different temperature movements. This appears where the difficulty lies, and some method should be devised so that the staybolt would be flexible enough to allow for these changes. With every thread, regardless of where it is applied, no matter where it is inserted, male and female, the great question is to eliminate fractures. In noting the inserting of staybolts, the bolt is assembled in the sheets and due to the method that is being used I do not find any place where torque wrenches are used in the assembly. This is a very important item, since it will enable every bolt to be inserted at the same torque, thereby getting the same expansion and contraction.

In putting in staybolts there is a tendency for the sheets to either expand or contract. Riveting is hard on a staybolt, also has a tendency to fracture and dish the sheets since they are loosely assembled by either wrenches or hammers. Not knowing the amount of power that is being used, has a tendency to do two things — one is to dish the sheet and the other is to stretch the bolt. If it does not do it at that time, after the boiler is being used the entire assembly is expanded and the contraction taking place during the cooling-off period causes them to leak. There are so many factors entering into this discussion that it would take volumes for every little detail and after that we would have nothing because the main question is the human element in this assembly. You have men who have spent their lives in assembling threaded connections. One man is stronger than the other so he applies more power, not knowing what he is actually exerting. This work is always done under difficulties, especially in the fire box. While I have been in the thread fitting business for many, many years, I have always found that men in general have a tendency to go beyond the limits that are necessary to make a proper assembly, where it applies to nuts and bolts.

I believe when we actually get into a discussion on this subject, many things will be brought to the front. In summing up this matter my suggestion would be that all staybolts or other threaded assemblies should be assembled with a torque wrench. Then if a suitable anti-seize joint compound has been used, all chances of stripping and fracturing would be eliminated as this type of lubricant would cause the metals to flow without fracture. In using any other type of lubricant it would have a tendency to pile up and gall. Another advantage would be that due to the pressure exterted by the wrench, it would have a tendency to flatten the sheet against th nut. On hollow staybolts my recommendation would be that the staybo be inserted the same with a lead compound. Then the hole be expanded w a tapered pin so that it would seal itself in the hole from the inside rather than to peen it from the outside, and there are tools on the market by which e portion on the outside of the sheet could be rolled by the same tool which would have a tendency to make a nice, clean job and look a whole lot like a utton.

In inserting a flexible staybolt I feel sure the plication of a leaded compound in the ball and socket, including the copper asket, would not only make a more flexible seal and allow freer movement of the bolt, but would help to eliminate fracture of the sheet. The use of the leaded compound will eliminate corrosion and keep it free so it could be knocked out at any time easily.

Summing up this matter we must begin with the tapping of the hole in a sheet. This hole should be tapped with a clean tap and a wire brush used to clean out the feather edges, then a leaded compound applied, both on the staybolt and tapped hole. The bolt should be inserted with a leaded compound and screwed in with a torque wrench, each bolt being inserted, with the proper amount of pressure. On hollow staybolts the same method should be used. On flexible staybolts the ball should be inserted into the socket with a leaded compound, including copper gasket. This will allow free movement of the flexible staybolt.

Dr. Greenslade (continuing): I am going to ask Mr. Christopherson to come up here. Mr. Christopherson is Vice Chairman of this topic and I am one of those who feels that the Vice Chairman ought to do most of the work. So I am asking Mr. Christopherson to take the program from this point to say whatever he has in mind in regard to the adoption of the proposed thread standards, and then to proceed, from that point, with the presentation of his own paper and the various other papers which you have before you in the printed program.—Mr. Christopherson.

Vice-Chairman Christopherson: Before we go along with the part pertaining to our own end of the program, I wish to ask the Chair for permission to make a motion. My reason for wanting to make this motion is that I feel that Dr. Greenslade has done something that the Master Boiler Makers never did have. I don't care what you have in the shop or what you buy from the makers of your staybolt iron, if this standard threaded form was adopted in the United States and Canada, it would mean this, when you ordered the material for your various sizes of staybolts the same tolerance would be alike for every one of us, the threaded part of that bolt, if you called for an inch or $1\frac{1}{16}$", whatever it would be, would always be the same. In other words, whether you threaded the bolt yourself or you purchased the bolt threaded, you could stock it and it would be a Class 3 Fit.

So if it is all right with the Chair I would like to make a motion that we adopt that part in your program starting with page 33 and ending at the top of page 45 where it says, "Tables 3 and 4, which follow, give the limiting dimensions and tolerances . . . for Class 3 fit." That would be the only thing that we would need to adopt; in other words, we would not hold any railroad company that they would have to buy all the gages which go along with it. I believe that the setup of the tolerance on the staybolts and the taps would be sufficient for the Master Boiler Makers. So I am making this motion, that the Master Boiler Makers' Association go on record that we will adopt this part of the paper as a standard for the United States and Canada for steam locomotive boilers.

I would like somebody to second that motion.

. . . The motion was seconded by Mr. B. G. Kantner, Gen. Boiler Inspector, Reading Company . . .

President Heidel: You have all heard the motion that the Master Boiler Makers' Association go on record as adopting that part of Topic 2 starting on Page 33 and ending on Page 45 of the Official Program, as a standard. Is there any discussion? I would like to say that the subject of threading standards for staybolt application was discussed at the September 19th meeting of the Executive Board of the Master Boiler Makers' Association and it was decided that upon completion of the work by Dr. Greenslade the Executive Board will submit the standards to the membership for adoption as recommended practice. Then, if favorable action is received, the Specification will be submitted to the Association of American Railroads with the recommendation that it be adopted as a tentative standard.

Mr. R. W. Barrett (Chief Boiler Inspector, Canadian National Rys.): Mr. Chairman, can't we recommend this as a standard to the A.A.R.?

Mr. Christopherson: We could recommend that the Master Boiler Makers' Association has recommended adopting the practice, but after having this gentleman work for four or five years there must be something in this for us all to let him keep on working as hard as he has done to make something we never did have. That is the reason why I would like to have the Master Boiler Makers’ Association go on record as adopting this as a standard, and of course it would have to go to the A.A.R.

President Heidel: The motion is now up for adoption. All in favor will give the usual sign of raising your right hand; contrary, same sign. The motion is carried.

Vice-Chairman Christopherson: We will now come to our own part of the program, and during all the years that we have spent on it there is only one conclusion that I have come to: regardless of what you do to a staybolt, if you have a leakage, that crack will be in that sheet.

We have listened to quite a number of metallurgists, they tell us that the stress crack is in that sheet only you can't see it, the only time that a Boiler Maker can see it is when you have a leaky bolt. We have found during our tests that wherever there is a leaky bolt we have the stress cracks shown up. Wherever we don't have a leaky bolt you cannot find the stress cracks although they are there. So the only way that I can see to hold the firebox leak tight would be the seal welding. Top boiler check alone, which is also one of the things that does make a leak-tight firebox, is not a cure-all. You can leave the water treatment out of a top boiler check steam locomotive boiler and within a week you will have leaky bolts. You can put that treatment right back again and do no work on the bolts, and it will dry up. That has been proven. So with a combination of the three things, the top boiler check, 100% treated water, and seal welding of staybolts, I believe you will have what I call a leak-tight bolt.

On the electrode and how to weld these bolts, I think there are quite a number of you here who were at the meeting when Dan Stark of the Lehigh Valley brought up the first two seal-welded bolts. Instead of welding the head of the bolt on the outside so he could see it, Dan Stark countersunk the staybolt hole about $\frac{3}{16}$", shoved the bolt through the sheet, and before he drove the head on that bolt the bolt was seal-welded in the countersunk hole and then the head was driven over the welding.

I have written to the Lehigh Valley but did not get any answer and I presume that these boilers that Dan Stark seal welded in that way are probably out of service. I am wondering if there is any Lehigh Valley man here that we could call on a little later who could give us any information on how long these bolts lasted, owing to the fact that I don't think a certain method would have to be adopted in order to seal-weld a bolt. I believe if you take precaution to have a clean job and that you have no cracks in the head after it is driven and you do seal-weld the bolts with the best electrode that you can get hold of, you will have a perfect job.

I believe that we ought to have a few words from all of the committee members. Mr. Longo is not here so I am going to read his short paper.

(Mr. Christopherson read the paper prepared by Mr. F. A. Longo entitled “Seal-Welding of Staybolts,” page 58 and top of page 59 of the Official Program.)

Mr. Christopherson (at conclusion of Mr. Longo's paper): As far as I know in all my tests that would not have to be done. I presume the cleaner and the better that bolt is, the better job you probably would have; but if you are using iron, I believe that a cupped die would answer the purpose just as well. Of course, as I say, this is immaterial. You can do a good job either way on steel. You can drive any staybolt with a cupped die and round it off if you want to, or you can go ahead and seal-weld it

Mr. Longo also speaks about the electrodes used. I haven't had any experience with the 70 wire — that is a low hydrogen, high tensile electrode. I believe that when Mr. Godwin gets up with his paper he probably will have something to say on that. The 6015-1/8" electrode is what we have been using right through our experiences on the tests.

I am going to call upon our good friend Elmer Owens.

Mr. E. E. Owens: I haven't prepared anything further than what is printed in the proceedings.

We have gone far enough in our seal welding of bolts to prove the practice can be successful if we follow religiously the last paragraph of my paper:

Quote. We are being furnished good materials and good machines and can obtain the proper tools. Therefore, if we as supervisors adhere to practices and methods advanced by our Committees and insist on first class workmanship, there is no question but that satisfactory results can be obtained. End Quote.

The further I go with the seal welding, the more I am impressed that we should continue the practice.

Mr. Longo's method advocated in his paper of seal-welding the bolts without driving them, is good. I have tested this method, and after observing performance of 53 bolts in a side sheet against all other bolts in that side sheet being welded after I had driven them, found both methods giving satisfactory performance after two years service.

However, I do believe we get better results seal-welding steel bolts when they are driven than we do with iron bolts, as the steel bolts do not crack or feather edge the heads. We have adopted the steel bolts as our standard

As I see it, to obtain satisfactory performance, the first thing is a good fit and the proper application of your bolts, then thoroughly clean your sheets, and then a competent welder to do the job.

Use reverse polarity wire which has better penetration.

Thank you.

Mr. Christopherson: As I said before, there has been quite a discussion over why iron staybolts won't weld as good as steel. We tried both ways of driving these bolts and we found that by using a cupped die the same size and about a 1/16" depth, which was in the PROCEEDINGS for 1944 I believe, you could obtain good results with an iron bolt. But you can not take a buttonhead and drive it flat, it will split, and the welding will not take those splits out of the iron bolts.

I am going to call upon Mr. Kantner of the Reading.

Mr. Kantner: Gentlemen, I cannot give you too much on staybolts. We have not made any appreciable changes, so I will let somebody come up here that has learned something new.

Mr. Christopherson: Mr. Kantner, I have something that I would like to mention here owing to the fact that this top boiler check is one of the things that is going to come into seal-welding of bolts.

Mr. Kantner mentions in his paper that his Class "T" locomotives have cleared up after approximately 200,000 miles with a top check. If that top check was on there before or after he had the trouble, I don't know.

Mr. Kantner: They had that before we had the leakage. They had that when they were built.

Mr. Christopherson: Then it shows that the water treatment was the contributing factor in stopping the staybolt leakage.

I am going to call upon Mr. Godwin.

. . . Mr. F. E. Godwin read his paper entitled, "Maintenance of Staybolts in Locomotive Boilers," pages 61 to 64 in Official Program . . .

Mr. Christopherson: Thank you, Mr. Godwin.

Next on the program is Mr. Milligan.

Mr. Milligan: I have very little to add to my paper on this topic, which will be found on Pages 64-65. On Page 65, you will note we had cracks develop in side sheets where we had seal welded bolts, also that I stated we were discontinuing seal welding. This does not mean we have given up the idea of adopting seal welding as standard practice, but rather we are waiting to see what develops on the other fireboxes which have this application, and we have quite a few of them. So far they have given satisfactory service.

We have come to no decision as to why this particular application cracked in this manner. The narrower water space may have been a contributing factor. Both sides cracked to such an extent that it was necessary to renew both sheets.

Our original seal welded bolt application was made on two locomotives operating on a District where we had considerable trouble with leaking bolts and cracked sheets. As I have stated in my paper, this application was made by seal welding one side and hammering the bolts up in the usual manner on the other side. To date, these two engines have accumulated over 500,000 miles and we have had no trouble with the seal welded bolts or the bolts hammered up in the usual manner. These two locomotives with this application were put in service after we had improved our water treatment considerably and changed our method of cooling down boilers.

I think it is a mistake to lead any one to believe that seal welding of staybolts in itself is a cure-all. It is absolutely necessary that the bolts be applied properly, and that all oil cutting compound that has accumulated on the water side of the sheet during the process of tapping and applying staybolts be removed entirely, and that your water treatment is properly maintained for the District in which you are operating, also that you cool boilers down properly. If this is done, I believe it is possible to get good life out of firebox sheets whether you seal weld or not.

As you know, I was very enthusiastic about seal welding of staybolts, but I am beginning to wonder whether it is necessary to do it or not. It may be that under certain water conditions, better results can be obtained by seal welding. If the applications we have now made prove that longer life can be obtained from seal welding, no doubt we will continue to seal weld staybolts.

We made an application of 42 button head staybolts in the side sheet of a Pacific type locomotive, 250# working pressure. These bolts have no threads on the firebox end; they are hammered up in the usual manner on the outside and the button head is seal welded. This locomotive has made approximately 250,000 miles since the application, and we have experienced no trouble whatsoever.

We are experimenting with this type of bolt because it is the opinion of some people that the cracks that develop in side sheets start in the sharp edge of the thread in the sheet. We are also experimenting with the same type of bolt in the crown sheet, that is, the button head crown bolts are applied without threads in the crown sheet end, and the button heads seal welded. The locomotive with this application has just been placed in service.

President Heidel: These bolts that Mr. Godwin and Mr. Milligan just talked about, are put in in Canada. I am afraid that our Federal Inspectors would not agree with putting bolts here in the U. S. if we did not put some threads on them.

Mr. Christopherson: I have always stated that the seal-welding was meant for in the beginning. Owing to the fact that when any Railroad gets a new locomotive of the latest type it will try to get all the mileage off of it that it can get, within 26,000 miles we had leaky staybolts. There was no way that we know how we could cure it.

When we first received ten brand new Hudson-type passenger locomotives, five of these were treated and five were not treated. On the untreated boiler, within 26,000 miles we had to put a patch about 26 x 46 on the right side The funny part of it is that all the same type of locomotive started leaking exactly in the one place. I could go in there blind-folded and put my hand on the 11th, 13th, 15th and 17th staybolts from the inside flue sheet of the third row. The most peculiar part of it was that every one of them developed the leakage and crack in that zone. On the treated boilers we got practically 385,000 miles, but after 385,000 miles they were just dumped on one end of the railroad. But we have obtained double life out of the jobs that we did seal-weld and that is all that we were after. We know eventually, regardless of what we do, that the sidesheet will crack and we will have to put in a new sidesheet.

I am going to call on Mr. Chandler of the Bureau of Locomotive Inspection.

. . . Mr. Harold W. Chandler read his paper entitled, "Recommended Practices for Staybolt Application and Maintenance," . . .

Mr. Christopherson: The next member of the committee has been in the hospital and he asked me if I would not read his paper: Mr. Elmer R. Hemberger, Assistant Superintendent of the Boiler Shop, Baldwin Locomotive Works. He must have come over on the Mayflower because he talks about the "bean pot." You know Boston is a regular bean town anyway.

. . . Mr. Christopherson read the highlights of Mr. Hemberger's paper . . .

RECOMMENDED PRACTICES FOR STAYBOLT APPLICATION IN LOCOMOTIVE BOILERS

By Elmer R. Hemberger
Baldwin Locomotive Works

In the application of staybolts in a locomotive boiler we always think of the man who had a dent in his coffee pot. He filled it with dried beans, tied the lid on securely and placed the whole thing in a pail of water. The dent came out all right, but everything else bulged out to as nearly a spherical shape as it was possible to make it.

Perhaps in this homely anecdote we can see what would happen to a

boiler if the portions thereof not truly cylindrical or spherical already were not stayed properly.

To stay properly? This means so much more than scientifically spacing the bolts to suit the given pressures. It means making sure the bolts and threaded holes are so made and so fitted that they actually represent the 100% picture drawn on the blueprint.

So many things, sometimes so imperceptibly visible can mar the picture and reduce immeasurably the tightness and efficiency of the threaded joints. To point out a few of these hazards then, we append the following notes.

Accurate alignment;—To support its load properly the staybolt must be applied as nearly 90 degrees to the firebox plate as it is possible to set it, under operating conditions. Otherwise eccentric strain will tend to loosen the bolt sooner or later. The importance then, of accurate development and triangulation in the layout of the firebox and outer wrapper sheet becomes clear, so that all bolt holes will match each other accurately and give us this accurate alignment without which we can never be sure all bolts are bearing a measurably equal load. In the cases of fireboxes expanding more than the outside shell, as they do, means the forward rows of bolts when cold must be aligned with less than 90 degrees in order to take up expansion and pull properly when expanded and under load.

At the Baldwin Locomotive Works the realization of the importance of accurate laying out is stressed to the point that all developments are made directly on the plates themselves *Full Scale* rather than in the Engineering Department where plans naturally are made ⅛ or at most ¼ scale. In this way minor errors are picked up, and with the layouts rechecked by layout men other than the ones who originally did the work, mistakes are reduced to a minimum.

In drilling, the vital consideration is always to keep holes small enough to allow full thread, and the staybolter runs his reamers through outside and inside plates simultaneously to insure true alignment. The firebox crown holes being perpendicular means many of the holes will have to be reamed out at a considerable angle. Since the original holes are drilled in the flat the only way to insure proper threads here is to lay down the hole and find what diameter of hole may be safely drilled in the flat before starting.

For tapping holes the carbon steel taps formerly used have become more or less obsolete and taps of high speed steel in which the threads are ground after the taps are hardened, are the only economical ones to use. Not only do they last longer, but they do not wear down on the threads quickly, and with proper care the 500th hole tapped is as good as the first. With the carbon steel tap the threads get progressively worse and with the harder steels in use for boilers today, anything but high speed ground taps have become impracticable.

For lubricants in staybolt tapping we have found a refrigerant base oil mixed with paraffin is most satisfactory. It doesn't burn out or clog and adheres to tap while tap is in motion more so than ordinary cutting oils.

Of course the most important factor in getting good staybolt application is to have good threads on the bolts, and threads that will match those in the holes. These must match in Outside Diameter, Root Diameter, Pitch, and fullness and shape of thread. We can have all kinds of gauges, Go and No Go, Ring, Plug, Micrometer and the like which check only one or more of the four main factors that we ask to be accurate in our threads.

The best way to check threads is to use the Optical Comparator which magnifies the thread 50 times and on which all of these four factors can be determined quickly and accurately for specimen bolts, and the thread cutters dressed accordingly. Once having the cutters set right, successive bolts can be checked with micrometer gauges set for Go and No Go pitch diameter. Such gauges are taking the place of the old snap gauges.

In getting good staybolt application many factors enter into the picture, but we append some of the more common.

1. Pitch:—Bolts that are wrong in pitch will not screw in a tapped hole unless they are undersize. Then they will go in shaking loosely for a few threads and with a turn or two more, suddenly tighten. Only they are not tight, just jammed, with regular channels for leaks.

2. Thread Fullness:—Bar stock to be in size to insure clean all around thread. This thread can be crossed and destroyed which occurs when taps are thrust into holes carelessly. Workman must start taps by hand before applying machine power. Crossed and damaged threads are many causes of leaks.

3. Straightness of Bolts:—Bolts with upset heads are not always perfectly straight, hence square may not fit properly in socket of lathe and if turned 90 degrees and reinserted in socket, bolt will roll untrue, not at the point but about 4" back.

4. Roundness of Bolts.

5. Correctness of taper.

6. Clean tapped holes of turnings and foreign matters.

7. Number of taps to use:—It is best if possible to use a single tap as two taps may cause the second to dig into the first thread irregularly, due to small differences in the thread contours of the taps themselves or to not entering the hole truly. On the other hand trying to crowd too much thread cutting on a single tap may tear threads if the process is too rapid.

8. All squares for driving staybolts are burned off. Do not use the shearing nippers.

Further details of application might be given indefinitely and can vary with the design and specifications of locomotive boilers, and I honestly believe more has been said and written on this subject than any other in the craft of boilermaking, and rightfully so, as I feel it is one of the most important.

A good tool in the hands of an experienced workman with conscientious supervision will give us a better job than all the words we can write.

Mr. Christopherson: There is one more member on this committee. Is Mr. Grancell in the room?

. . . Mr. I. H. Grancell read his paper appearing in the Official Program . . .

Mr. Christopherson: Mr. Service of the Santa Fe, I understand you have made quite a number of tests and I would like you to come up here and tell the audience just what you have done and what has been the outcome of it.

COMPARATIVE INFORMATION REGARDING DIFFERENT JOINTS RECOMMENDED FOR STAYBOLT FIRE ENDS

By H. H. SERVICE

In order to secure some comparative average information regarding the various design joints recommended for fire ends of staybolts, the Director of Research, Mr. J. M. Nicholson, arranged for four designs of staybolt joints to be tested: standard threaded staybolts vs. seal welded threaded design, Miller-Grant design and 60 degree included angle design. Ten samples of each design, per Sketches 1 to 4, inclusive, were made up for test purposes.

All materials were duplicated in each of test samples, using nickel firebox plate, L-210 1" diameter mild steel for staybolts and machined for Miller-Grant staybolts per Sketch No. 3, and E-6013 electrodes used for all fusion welding operations, all operations performed in horizontal position to represent application to side of firebox plate. Each sample was made on plate 6" square.

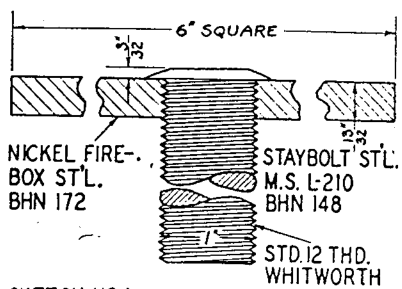
It was also decided that each sample be tested so as to not place the joints directly in shear but to permit each design to have equal stresses applied, simulating what would be in service, except for higher temperatures that would exist in service. Therefore, anchor base clamps and blocks were designed to represent a staybolt joint supporting a 16 sq. in. area, however the 4 11/32" diameter was used to produce uniform stresses around the various design joints as shown in Sketch No. 5.

The results of tension and compression tests are as shown on Sketches 1 to 4, inclusive, and as follows for comparison:

	Tension	*Compression*
Standard Staybolt: Aver. load	29,795 lbs.	26,920 lbs.
Standard Staybolt seal welded: Aver. load	34,295 lbs.	35,825 lbs.
Miller-Grant design, 1 weld pass: Aver. load	35,555 lbs.	28,665 lbs.
2 weld passes: Aver. load	38,240 lbs.	42,180 lbs.
60° included angle (solid bar not threaded) all welded: Aver. load	34,950 lbs.	52,272 lbs.

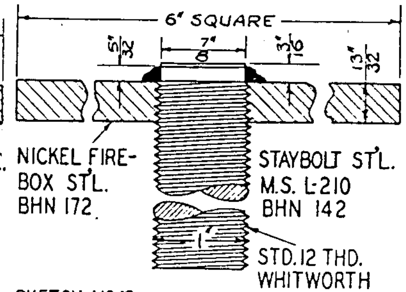
For fatigue test similar designed anchor clamp blocks were used to hold plates 6" square tight and still permit plates at joints to flex within the area of 16 sq. in. with movements of staybolts 1/8" up and 1/8" down and spaced 7" from plate at the rate of 200 r.p.m. with spring tension load on plate. Photographs Nos. 1, 2 and 3 show machine and setup used for this testing and the results were as follows:

	Average Cycles
Standard Staybolt: Final bolt fracture	55,718
Std. staybolt seal welded 1 weld pass: Initial weld crack	36,653
Final bolt fracture	116,646
Miller-Grant design 1 weld pass: Initial weld crack	10,808
Final bolt fracture	42,737



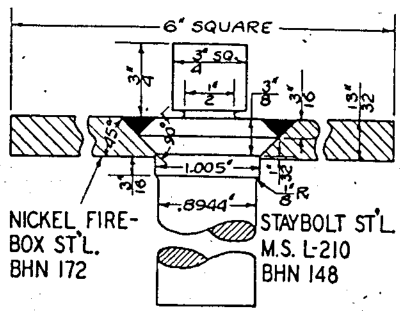
SKETCH NO. 1.
ALL STAYBOLTS TIGHTLY FIT, UPSET AND SNAPPED AS PER STD. PRACTICE.

A-STD. DRIVEN STAYBOLT.
TENSION ——— 29,795 LBS. AVE. LOAD
COMPRESSION —— 26,920 LBS. AVE. LOAD
FINAL FATIGUE FRACTURE ——
55,718 AVE. CYCLES



SKETCH NO. 2
ALL STAYBOLTS FIT TIGHT IN HOLES AND OUTSIDE END SLIGHTLY UPSET. FIRE END MACHINED WITH STD. HOLLOW MILL AND SEAL WELDED IN VERTICAL POSITION USING E-6013 ELECTRODES.

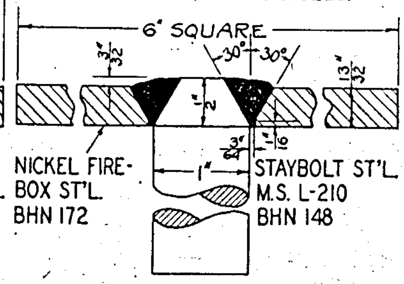
B-STD. THREADED AND SEAL WELDED STAYBOLT.
TENSION ——— 34,295 LBS. AVE. LOAD
COMPRESSION —— 35,825 LBS. AVE. LOAD
INITIAL FATIGUE CRACK (WELD) ———
36,653 AVE. CYCLES.
FINAL FATIGUE FRACTURE (BOLT) ———
116,646 AVE. CYCLES.



SKETCH NO. 3
STAYBOLTS MACHINED SMOOTH BEFORE APPLICATION. ALL WELDS MADE IN VERTICAL POSITION WITH E-6013 ELECTRODES.

C-MILLER-GRANT DESIGN WELDED STAYBOLT.

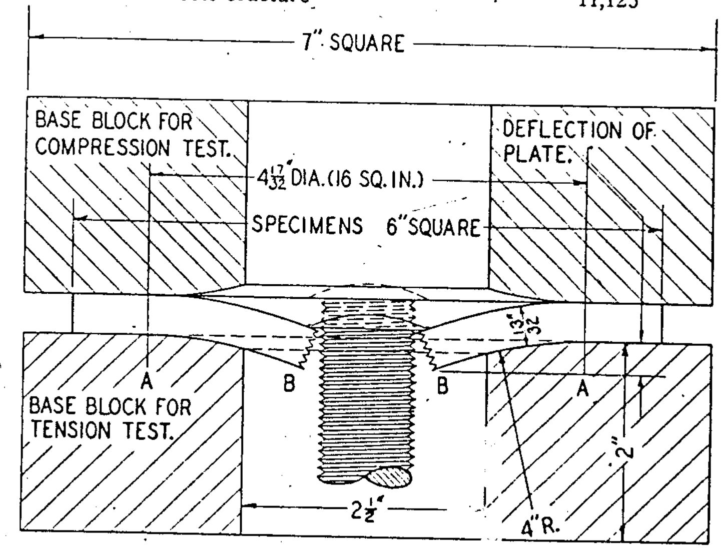
	ONE PASS	TWO PASSES
TENSION	35,555	38,240 LBS. AVE.
COMP.	28,665	42,180 LBS. AVE.
INITIAL FATIGUE CRACK (WELD)	10,808	20,794 AVE. CYCLES.
FINAL FATIGUE FRACTURE (BOLT)	42,737	54,646 AVE. CYCLES



SKETCH NO. 4
ALL WELDS MADE IN VERTICAL POSITION WITH E-6013 ELECTRODES.

D-60° INCLUDED ANGLE GROOVE WELDED STAYBOLT.
TENSION ——— 34,950 LBS. AVE. LOAD
COMPRESSION —— 52,275 LBS. AVE. LOAD
FINAL FATIGUE FRACTURE (BOLT) ———
11,125 AVE. CYCLES.

	Average Cycles
2 weld passes:	
Initial weld crack	20,794
Final bolt fracture	54,646
60° included angle, all welded:	
Final bolt fracture	11,125



SKETCH NO. 5 - ANCHOR BASE CLAMP BLOCKS

Some samples are shown on Photograph No. 4 before being tested and Photograph No. 5 shows final fractures of specimens after fatigue test.

From these results it appears that the standard threaded and seal welded staybolt is superior in tension and compression to the standard driven staybolt, but slightly less in tension than the other welded designs, and slightly higher in compression than single pass design Miller-Grant staybolt. However, the seal welded staybolt is apparently superior in resisting fatigue compared with the other design staybolts. Consequently, since the standard threaded and seal welded staybolt showed superior to the standard driven bolt, and is more economical to apply due to the standard tools already available and in use, therefore the seal welded threaded staybolts are recommended on the Santa Fe over the other welded joints of staybolts investigated.

Mr. Service (at conclusion of prepared remarks) I might add you could probably use the higher tension strength electrode like the 2520 as referred to in your 1948 proceedings. That would probably increase the efficiency of the seal-welded Miller-Grant bolt but it would likewise increase the efficiency of any seal-welded bolt.

This is nothing but a comparative test for our own information. We thought it was worthwhile presenting it to the Association.

Thank you. (Applause)

Mr. Christopherson: I had an opportunity to see the figures on the compression and the tension test made by the late Professor DeForest of the Massachusetts Institute of Technology. The seal-welded bolt did show practically the same figures as Mr. Service has here today, which proves that Mr. DeForest, although he was no Boiler Maker, was a darn good professor, he knew what he was doing. I believe that the late Mr. Huston in one of his papers included DeForest's experiment and it was put in the proceedings. It was practically what you got.

Before turning the topic over to the President I want to personally thank all the members of this committee for the outstanding work that they did, and I want to especially thank Dr. Greenslade and the Flannery Bolt Company.

President Heidel: Thank you, Dr. Greenslade and Mr. Christopherson. Topic No. 2 is now open for discussion. Let's hear what you have to say.

DISCUSSION ON TOPIC No. 2

Mr. F. D. Beeland (Boiler Foreman, Georgia R.R.): I would just like to say that I have been coming to these meetings since 1938 and this is the first time that I have ever taken advantage of the opportunity I have had joining in the discussion but you got to talking about something which got my enthusiasm aroused. I know seal-welded staybolts are all right. I tried them in 1938. At that time we had quite a few engines that were giving us trouble leaking at the fire line. We put in a new set of sidesheets. We selected just a small area, ran hollow bolts from the outside, let them stick out $\frac{3}{16}$" inside and welded a bead around just like a flue; about 100,000 miles later we had to take those sidesheets out because the rest of the bolts were all cracked around, but the ones we had welded in in 1938 were still good, no sign of leakage at all.

Mr. President, with your permission I would like to discuss another subject. I believe everybody in this room is vitally concerned with reducing the expense of operation of steam since the coming of the diesel. I wonder if there is any chance of getting this Association to investigate the possibility of eliminating the two-year rule on removal of staybolt caps. I don't believe it is necessary now if we have a good boiler inspector. After a hydrostatic test in our case we found very few broken staybolts. I would like to see the time for removal of flexible staybolt caps extended to four years. It would reduce expenses considerably.

Thank you.

President Heidel: That last matter that you referred to has been brought up before the Executive Board, and no doubt in the future it will be brought up again for consideration.

I would like to call upon Mr. Miller at this time for a few remarks.

Mr. Howard L. Miller (Metallurgist, Republic Steel Co., Cleveland, Ohio): Mr. Chairman, I just had the opportunity of looking over Mr. Service's paper for the first time this morning and that work done was very interesting. However, we are considering two different types of failure in staybolts. One is the breaking of staybolts in the breaking zone, and the other is the failure of the joint between the staybolt and the plate in the hot zone on the firebox sidesheet.

The Miller-Grant staybolt was designed to perfect a joint between bolt and plate with a minimum amount of metal projecting into the firebox area, and the bolt was designed to give the mechanical support to the plate due to the beveled head and to support it by the weld to seal the joint between the bolt and the plate. These bolts were developed to apply in the zone where the distortion between inner and outer plates is at a minimum and where consequent stresses on the joint from bending are very low. The results on the fatigue tests could have been influenced in favor of the threaded bolt by the stress causing the bolt to work loose in the plate and prolong the fatigue life of the bolt. The stress on the Miller-Grant bolt is concentrated at the fillet of the bolt because the welded area is farther removed from the neutral axis of the bolt and the bolt is much more rigid in the plate than the threaded bolt.

The number of failures by broken bolts is a very small factor at present in comparison with the number of bolts which fail in the joint between plate and bolt and cause a cracking and removal of the sidesheets.

We have obtained a permit from the A.A.R. to make one test application on hot sidesheet plate. I hope that by your next meeting that test will have been applied and we may have some results to report by that time.

Mr. Godwin: Mr. Chairman.

We on the Canadian National are threading staybolts on a Land-maco horizontal machine, squaring of the bolt end is not required for this threading operation. Therefore we don't square the staybolt for application; bolts are applied by using a chuck or adapter on the air motor. We are saving a considerable amount of money by eliminating the squaring operation and are having a lot of success from this method of application, but the adapter is not as good as it could be. I was wondering if any of the members here are using this method of applying bolts, and what type of chuck or adapter do they use?

President Heidel: Has anybody had any experience with the Adapter who could answer that question?

Mr. Geo. Cousins (Foreman Boilermaker, Steel Company of Canada, Hamilton, Ont., Canada): We have heard this afternoon quite a lot about steel staybolts. In my line of business in our small repair shop this was quite a novelty when the previous gentleman talked about steel and the other one talked about *mild* steel. In staybolt practice, I would like to know the carbon of this mild steel. We know the less the carbon in any steel the more the ductility. Perhaps you gentlemen will give me a lineup on that.

Mr. Service: The analysis I don't have for the L-210 mild steel, but it is low in carbon, between .08 to .15 carbon. It will produce approximately the same strength staybolt as iron, but it is a steel staybolt just the same.

Mr. L. E. Wallace (Gen. Boiler Inspector, L. & N. R. R., Louisville, Ky.): Mr. President, our Railroad ever since I can remember has used a refined iron for staybolt material. We procured this material from the Ewald Iron Company of Louisville, Ky. which has recently dissolved making it necessary to find a new market for staybolt material and it is contemplated to go to steel. Personally, I have had no experience with the steel bolt and I am just wondering if some of the members whose railroads use steel for staybolts could enlighten me as to its success and other characteristics as compared with the iron bolt. One of the things I would like to know, are they applied promiscuously with the iron bolts; that is, adjacent to an intermingling with the iron bolts? I would appreciate anything that they could give me along this line as I have had absolutely no experience with steel staybolts.

Mr. Service: In the test that I just read the L-210 mild steel was referred to in the test because we have applied two sets of side sheets with this material. However, we are also using a new standard now, Byers iron, which is, I understand, made by a similar process as they make steel. In other words, the piling as used for iron bars is not used because it is known as a puddled iron. As a consequence the slag inclusions in the rolled iron simulates steel.

Mr. Wallace: I would like to know also if you have any difficulty in threading the steel bolt.

Mr. Service: You have to maintain any die sharp to obtain good threads, regardless of whether you use iron or steel, and you do have to watch for keeping the dies sharp with steel, more so than with iron.

Mr. Wallace: It comes to my mind that the tensile strength of the steel staybolt approaches or is as great as that of the side sheet material. Do you think that that would cause the sheets to crack more than the iron bolt will? That is, by the unequal expansion and contraction of the bolt in the sidesheet?

Mr. Service: That remains to be seen. The Brinell hardness of the L-210 mild steel is 148. Therefore, this steel was used because the test previously referred to for the Miller-Grant bolt had similar Brinell hardness and was used to determine some comparative information.

Mr. Wallace: I understand that the Missouri Pacific has been using this bolt for approximately ten years. I wonder if there is any Missouri Pacific man in the audience who could give me more reaction as to what they have done on his railroad, or a Milwaukee man. I understand the Milwaukee has been using them.

Mr. Miller: Is a representative of a manufacturer of that material allowed to speak? The A.S.T.M. specification is what you would call A204. That means that the nickel content is around 1½% and the carbon is .10%. That specification is used by the Milwaukee, the Missouri Pacific, the Frisco in the Middle West, the Canadian National and the Canadian Pacific. The Mayari steel specifications used by some of the eastern roads all average about 40,000 yield point and 60,000 tensile, and between 125 to 150 Brinell hardness. You should not use a bolt that has a Brinell hardness much more than ten points greater than the plate or the bolt will have a tendency to work loose in the plate and cause the plate to fail rather than the bolt.

As far as the breakage is concerned, we have found over a period of time on the roads that we have mentioned that the steel staybolts outlast the wrought iron bolts. We also found on another road that the wrought iron bolt outlasts the steel staybolt; that was on the C. & O. In driving up, the wrought iron packs up farther on the sheet under cold heading than the steel bolt does. In the case of the sidesheets on the C. & O. where high heat is engendered, they have better luck with steel staybolts in the crown sheets than they do in the sidesheets.

Each one has his own ideas of what makes a good driving bolt. I have heard some objections to seal welding of wrought iron bolts on account of splitting under driving. I don't think a steel staybolt when it is seal-welded has more chance to split along the grain after seal-welding than a wrought iron bolt when it is seal-welded.

Have I answered your question?

Mr. Wallace: Yes, sir. I was more or less interested in this thing because it is something new to me. I don't know what to expect a year

or two years or three years from now. I don't know whether we are going to have a lot of broken bolts or whether they are going to prove out better than the iron bolts. I have had no experience personally. With iron bolts we have very few broken staybolts and I was just trying to seek out some information from some of you gentlemen who have used these staybolts for some length of time, which I understand some roads have, that could maybe give me something to go on.

Mr. Miller: They averaged 200 broken bolts per month before water treatment. They started putting in steel staybolts and finally adopted them because they were not replaced as often. Part of the reason that they are not breaking bolts like they used to is because of their water treatment.

Mr. Barrett (Canadian National): The Canadian National has been using all-steel bolts for the past twenty-five years or more and from our records and experiences we know that we have comparatively no trouble at all in the application and the maintenance of steel bolts. Broken bolts in our Roundhouses are negligible; in fact, it is a very rare occurrence in going around in our hard water districts to find it necessary to replace broken steel staybolts. We have had no difficulty in the manufacturing, nor in the driving of these bolts.

To go back to our previous subject of the seal-welding of staybolts, there is no reflection on Dr. Greenslade that the men in this Association are more interested in the practical side than the theoretical side. As you note by the discussion, everybody wants to know what results we have obtained from seal-welding and the use of this or that kind of bolt.

As Mr. Godwin pointed out in his paper, we have not had a great deal of success yet in the application of seal-welding staybolts. Personally, I do not see any reason in some of our districts that is the hard water districts — where we get from 8 to 12 years o. life out of a sidesheet, why we need to go to the seal-welding of staybolts when we have no trouble, when at any time you look in the firebox everything is as black as your hat. But on our so-called "good water" districts, where we have the silica content, and in those districts we have more trouble with oil, we do find that we have a certain amount of trouble with our sidesheets, it is in those districts which we have been trying out the seal-welding of staybolts that we have not yet met with any success to any degree. We are now applying oil separators, and we are hoping and believing that we shall have a considerable amount of success in the elimination of oil, and then in conjunction with the high water treatment which silica requires we feel that even in those districts where we have some trouble in sidesheets it will be eliminated. As far as our hard water district is concerned, by water treatment we have eliminated practically all of our troubles as regards staybolts and our staybolts far outlive the life of our sidesheets.

Thank you. (Applause)

Mr. Miller: I understand that the Steel Company of Canada has a license from duPont to use an explosive method of setting staybolts. Have any of those tests ever been put into effect?

Mr. Barrett: Not on our road. We did not go to the explosive method of driving staybolts. When Mr. Huston was over there we found that owing to the costs and the results we were getting from our present method, the additional expense of the explosive method of driving staybolts was not justified, so we never adopted it.

Mr. Service: Only recently we have had a bad water condition on a certain district that caused the staybolts to leak at the joints of the nonseal welded staybolts due to an erratic water condition, and the locomotives that were operating into this same terminal with seal-welded staybolts, they remained black. Gentlemen, you can't overlook not having the proper water treatment, that is essential, regardless. One of the important items on any railroad is your water treatment plus your seal-welding.

President Heidel: Before we close this topic, we are on short time right now, I would like to ask Dr. Greenslade for a few remarks.

Dr. Greenslade: One of the gentlemen present, in talking about steel staybolts, asked about the general nature of the materials. They are varied. In our work in the laboratory, I believe that we have conducted vibratory tests on nearly forty different kinds of proposed staybolt steels These steels are usually of the nickel-manganese variety, with the nickel ranging from 0.15% to as high as 1.75% and the manganese from 0.08% to as high as 1.65%. Some staybolt steels are vanadium-manganese alloys containing up to about 0.15% vanadium and up to 1.0% maganese. Others are of the "moly" type, containing approximately 0.5% molybdenum; while still others contain practically no alloying agents at all and are very little different from the better grades of low-carbon steel.

There is one characteristic which is common to all of them. They have low carbon — often as low as 0.03% to 0.05% and rarely in excess of 0.12%.

All of these steels have certain characteristics which distinguish them from wrought iron They are not puddled materials and therefore do not contain slag stringers such as are found in wrought iron. Furthermore, they are not twice piled of slabs or bars and twice rolled, as is wrought iron. Therefore when a section of the metal is polished and etched, the surface exhibits a typical steel pattern rather than the intricate mosaic so typical of doubly-refined wrought iron.

The various brands of staybolt steel cover a wider range of tensile strength than that which is found in wrought iron Some of these steels, such as the molybdenum steel which I spoke of, have very low tensile strengths, comparable to the range covered by wrought iron. Others of the high-nickel variety run up as high as 72,000 or 73,000 lbs. per sq. in.

Due to our limited time I have touched upon but a few of the more general characteristics of staybolt steels.

I might say here that Byers staybolt iron, though mechanically produced, is nevertheless definitely a wrought iron. It is made from what is often called "ingot iron," which is steel with practically all of the carbon burned out; but it is later impregnated with slag by pouring the molten metal, at a temperature slightly above the freezing point, into a bath of slag, much cooler than the iron but still molten. This causes the iron to break up into small globules, which in turn, as cooling takes place, split open and break up still further, forming a solidifying mass of pasty particles. This mass is gathered together and rolled into muck bars and is later doubly refined by twice piling and rolling — the same method as that used in the manufacture of manually puddled wrought iron.

I thank you.

President Heidel: Thank you, Dr. Greenslade, for handling the topics and for your remarks.

Topic No. 2 is now closed.

GOOD OF THE ASSOCIATION

President Heidel: Good of the Association is next on the program. Mr. Stiglmeier, have you anything to say on that subject?

Secretary Stiglmeier: Gentlemen, Under the Good of the Association I would like to ask of the Membership. We would like to get the names of those members who have passed away since the last meeting, this so we can pass the same on to the Committee on Memorials to be included in their report.

Also, we would like the names of those members who have retired from active service. As you know, the rules and regulations state that those members who are in good standing when they retire, are eligible for honorary membership. I don't believe that there is anything nicer that this Association can do for these members when they retire, than to make them honorary members, so I would like to obtain the names of these members who have retired from active service.

You have heard Mr. H. H. Service read a very educational paper on Welded Staybolts. He made mention regarding different sketches. I don't believe many of you would remember these sketches, not being listed in the meeting program, and it is for these reasons, that I will arrange to have these sketches illustrated in the meeting Proceedings with the committee report as has been presented to you on topic No. 2.

One more thing. We have registered up to two o'clock this afternoon 102 members — life, honorary and active; 37 associate members, and 9 new members. A total of 148. Also we have registered 75 ladies and 21 men guests.

President Heidel: Anything from the floor r the good of the Association?

The meeting will be called to order at n[illegible] o'clock tomorrow morning. Please be prompt so that we can start the meeti[illegible] on time.

If there is nothing further for the good of the Association, the meeting is adjourned until nine o'clock tomorrow morning.

. . . The meeting adjourned at four forty-fi[illegible] o'clock . . .