Topic No. 4

APPLICATION OF STRAIGHT VERSUS TAPERED RADIAL STAY-BOLTS, TAPER PER FOOT, TAPS AND REAMERS USED, AND SERVICE THAT IS BEING OBTAINED, COAL AND OIL BURNING LOCOMOTIVES.

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To the Officers and Members of the Master Boiler Makers' Association:

Normally the crown sheet of a locomotive firebox is, on account of its shape and staying, stronger than any part of the firebox, but owing to its location it is the most vulnerable part of a locomotive boiler.

The difference of a few inches of water level can make it the potential cause of a major disaster. Devastating results will accrue from an overheated crown sheet in spite of the best of workmanship, material, and design. No type of crown bolt has been devised that would prevent an overheated crown sheet giving way. The question is, can we, by the application of various types of crown bolts, produce areas in the crown sheet which have ample strength to resist firebox temperatures and boiler pressure under normal conditions, yet when subject to low water condition the sheet will have areas weak enough to pull away from the bolts sufficient to quench the fire, yet will not rip apart.

Whilst the subject of tapered versus straight radials is one which covers a large field yet these must be considered in relation to the button-head type of bolt. Although the majority of railroads favor the taper crown bolt in preference to the button-head type of bolt, there are still a number of railroads which use the button-head. One of our largest railroads uses exclusively a flat or panhead type of bolt in their non-syphon locomotives, having discarded taper bolts in favor of this semi-button type of bolt. It is claimed, that where alternate sections of straight radial bolts and button-heads have been applied in every case of low water, engine crews have been able to step off of cab, no rupture of crown having occurred as the result. It is conceded that the taper bolt is easier to apply and maintain than the button-head; yet when the latter is applied properly will give no further trouble for years.

Many of us are only just awakening to the fact that the best method of overcoming leaky stay and crown bolts is to maintain efficient water treatment, keep your crown and staybolts free from incrusting scale and a properly applied bolt will give no trouble.

TESTS TO DETERMINE THE RELATIVE STRENGTH OF VARIOUS TYPES OF CROWN BOLTS

Committees of this association during the past twenty-seven years have made careful tests to ascertain if possible the relative holding power of various types of crown bolts. Straight radials, taper radial ranging in taper from ½" to 3" to a foot, with heads riveted over, and button-head types of bolts.

A test was conducted during the year 1910 to determine the holding power of button-head versus tapered radial staybolts as applied; also when overheated to a temperature of a dull red, and there was a slight difference on the average as follows:

SUMMARY OF TESTS

Button-head radials

Average pulling load required. At 70 degrees Fahrenheit—34,942 pounds.
Average pulling load required. At 860 degrees Fahrenheit—15,230 pounds.
Decrease in holding power due to heating—56.4%.

Taper-head radials

Average pulling load required. At 70 degrees Fahrenheit—31,599 pounds.
Average pulling load required. At 820 degrees Fahrenheit—15,317 pounds.
Decrease in holding power due to heating—51.4%.

The results showed that the button-head radial stay failures occurred at the head and pulled through the sheet, whereas, the tapered-head sheared off head and stripped the threads on bolt and in sheet, but an equal number failed in the body of radial staybolt.

Further tests of straight radial staybolts were made in a like manner with the following data obtained:

Pulling load required. At 70 degrees Fahrenheit—30,050 pounds.
Pulling load required. At about 800 degrees Fahrenheit—11,780 pounds.

The latter test indicates very similar results as to the failures found on some of the taper-head radial stays (hammered type), except that no failures occurred in the body of the stays; each failure occurring in the threads of bolts and sheet.

Based on these findings it appears that the taper-headed design bolt was slightly stronger than the straight bolt when it is assigned to carry these loads, and although the button-head design indicates a higher strength, its head design permitted a mass of metal to be exposed to overheating that indicated it was detrimental to economical and efficient operating conditions.

Again in 1921 this association sought to ascertain as to which was the most efficient type of crown stay, the taper or button-head.

The following results of a pulling test made at that time clearly indicates the greater holding power of the button-head over the tapered hammered head when pulled both hot and cold.

Test No.	*Condition of pull*	*Where broken*	*Kind of head*	*No. lbs.*	*Remarks*
1	Cold	Head pulled off	Button-head with ⅕ head drilled off	23,750 lbs.	Plate dished ¼"
15	Cold	Bolt broke 3" from head	Full button-head	29,510 lbs.	Plate dished ⅛"
4	Cold	Head pulled through sheet	Hammered head with taper 1½" in 12"	19,400 lbs.	Plate dished 5/16"
14	Cherry red	Head pulled off	Full button-head	7,100 lbs.	Plate dished 9/16"
7	Cherry red	Head pulled off	Button head with ⅛ head drilled off	7,730 lbs.	Plate dished 5/16"
11	Cherry red	Head pulled through sheet	Hammered head with taper 1½" in 12"	2,900 lbs.	Plate dished 5/16"

All of the above tests with the exception of those made cold, were made with the heat as near the same temperature as it was possible to get them, that is about a cherry red. It can be seen that as long as the sheet is cold the hammered head type of bolt is of ample strength and even when the sheet is cherry red it takes 2,900 pounds to force the plate from the bolt.

TEST OF STEEL CROWN BOLTS

Presuming that these previous recorded tests were made with iron staybolts it was thought to be of value to this present investigation and purpose of this topic if a test could be made of steel crown bolts as a comparison with the previous tests. Through the courtesy of the management of a railroad using all steel staybolts this was arranged. Three types of crown bolts were tested. Straight threaded bolts with hammered heads, tapered threaded bolts (1½" in 12") with hammered heads, and a button or panhead type of bolt. These were applied to section of ⅜" firebox steel plate. One of each type of bolt was pulled at room temperature, and one of each type was pulled with plate and bolt heated to a dull red, about 750 to 800 degree Fahrenheit.

These tests were made on a "Riehle" testing machine with the following results. All bolts made from 1 5/16" steel bar stock with ends upset in bolt machine.

Test No.	*Condition of pull*	*Where broken*	*Kind of head*	*No. lbs.*	*Remarks*
1	Cold	Head pulled off and bolt out of sheet	Straight hammered head 1⅛" diameter	33,020 lbs.	Plate dished ¼"
2	Cold	Head pulled off and bolt out of sheet	Hammered head with taper 1½" in 12" diameter 1⅛"	33,250 lbs.	Plate dished ¼"
3	Cold	Body of bolt elongated	Panhead bolt, 1⅛" dia., taper ½" in 12"	42,300 lbs.	Plate dished ½"
4	Dull red	Head pulled off and bolt out of sheet	Straight hammered head 1⅛" diameter	31,200 lbs.	Plate dished ⅜"
5	Dull red	Head pulled off and bolt out of sheet	Hammered head with taper ½" in 12" diameter 1⅛"	34,850 lbs.	Plate dished 7/16"
6	Dull red	Body of bolt elongated	Panhead bolt, 1⅛" dia., taper ½" in 12"	41,750 lbs.	Plate dished ½"

It will be noted that in each test of the straight threaded bolts and the tapered bolts they failed by pulling out of the sheet, whereas in both tests of the panhead bolt the head held, the point of failure was in the body of the bolt which yielded.

The behavior of the heated taper bolt was rather interesting, although both were made at the same time from the same material, it required 1,600 more pounds to pull the tapered bolt heated than it did to pull it cold.

The test however clearly indicates the superior strength of the panhead bolt over the taper and straight radials.

COMMITTEE NOT UNANIMOUS

As you are aware, topic committees are selected in order that the subject under consideration may be presented from as large a field of knowledge and experience as possible. Thus the final report is a composite of the individual reports and not necessarily the opinion or experience of the writer of the final report. Naturally there would be divergence of opinion based upon differences of conditions, which govern the practices of the various railroads.

However, in the first place, this committee is unanimous as to the superiority of the tapered bolt over the straight radial crown bolt, also it is agreed that the taper bolt is both easier to apply and to maintain than the button-head or panhead type of bolt. A member of this committee states:

"I have always been an advocate of the taper bolts for crowns and have seen it develop and made standard on several larger and smaller railroads. The advantage of this type of bolt is freedom from crown leaks. In cases of slight low water, re-driving will make crown as good as before it occurred in many cases, and can be accomplished with light hammers without holding on bolts, whereas in the case of button-head bolts in same difficulty the bolts must eventually be removed and re-applied—a long and expensive operation.

As concerns straight bolts I have had varied experience of their use in crown with hex nut and with light copper gasket under nut; also straight

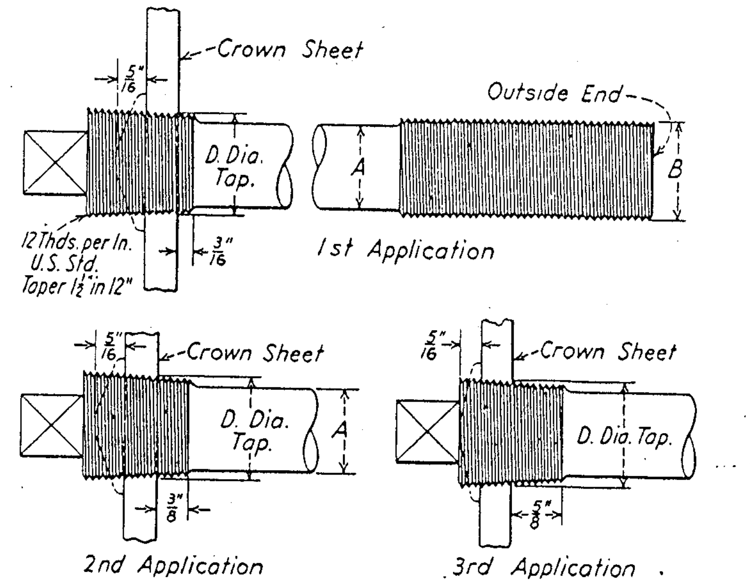

Table Showing Method of Application

A	B	D: 1st Application	D: 2nd Application	D: 3rd Application
1"	1 1/8"	1 5/32"	1 3/16"	1 15/64"
		1 9/32"	1 5/16"	1 23/64"
		1 7/32"	1 1/4"	1 19/64"
		1 11/32"	1 3/8"	1 27/64"
	1 1/4"	1 9/32"	1 5/16"	1 23/64"
	1 5/16"	1 11/32"	1 3/8"	1 27/64"
	1 3/8"	1 13/32"	1 7/16"	1 31/64"
	1 7/16"	1 15/32"	1 1/2"	1 35/64"

Fig. 1

to low water, will wear out the firebox. We have crown sheets now in some of our locomotives 15 years old in which there has never been any renewal of those crown bolts—no leakage except where we have low water.

My personal experience and opinion is that the straight type radial stay or crown bolt is the safest, and safety is what we are looking for.

Thank you.

Mr. Fegan: Gentlemen, I have noticed that a great deal of stress has been given this discussion on the tying up of crown sheet and thereby causing a violent explosion should it let go. You will notice that the design as shown in the program is not a solid application. Each alternate section of four rows is of the straight hammered head type and it is in this feature that, in my opinion, we receive the safety measure.

I have worked on crown bolts back to the old type of 35 years ago, including the nut and countersunk design, and later the pan and button-head type, and I fully recall the trouble experienced. A few years ago when attending this Convention the late Mr. Pack, Chief of the Interstate Commission, held the floor for two hours recommending favorably the taper hammered head bolts. I conveyed this information to the Canadian National at the time and, whether it had any bearing or not, they more or less adopted it. About 15 years ago they started to go back to the pan-head bolt and some applications were made. On following up these installations it was found after a period of aboue five years that we ran into considerable trouble inasmuch as they leaked, cracked out, and wasted away at the thread, and when removing these bolts it was possible in some cases to drill bolts in wrapper sheet and with a couple of taps with punch and hammer knock them through into the firebox.

About ten years ago, and especially in the last five years, more attention has been given to the proper design and fit, especially in regard to the contour of the bolt head fitting the radius of the crown. With these up to the present time we have received good results.

In regard to our layout—"A chain is as strong as its weakest link"—that's an old one—and in this crown sheet the straight bolt zone, or the weak link, principally the one just ahead of the arch, is in my opinion the critical point in a crown sheet and not the front or the highest point that has been referred to.

Within the last two years we have had on the territory I cover two minor failures due to low water. One was the case of a passenger, engine on a heavy train—the water glass broken—this engine was of the Pacific type. On examination at the terminal I found that four bolts in the zone that I speak of, just ahead of the arch, had partially pulled away. That was sufficient to practically put out the fire in that locomotive and save further disaster. The other failure referred to was that of a Mikado engine. I am not just sure whether the low water took place on arrival at the pit or on the road, but it apparently was over high temperature. This also had in the same zone three bolts badly sprung which leaked sufficiently to draw the attention of the ashpit man who reported it to the foreman. Again the weak link was the tell-tale.

Now, in my opinion with this installation we are dealing not only with the point of safety, but also with a principle that overcomes major accidents.

Every second zone is "tied," as many of you gentlemen wish to term it, but in between these we have the zone that will release pressure and avoid the rupture for the entire length of the crown sheet. That in my opinion is the important and governing factor of our present installation. The possibility of the wasted thread mentioned by many of you gentlemen remains to be experienced with the present careful application.

I again state under this subject that efficient water treatment is very essential and necessary to obtain satisfactory performance of crown bolts.

Thank you.

Mr. Barrett: Is there any further discussion on the subject?

Thank you.

President Buffington: There seems to be no further discussion on the subject. I notice that the Committee has not been unanimous, so I want you all to get that. I also notice something else that I will pass out to you fellows. The man who says you can put the bolts in the crown sheet to last the life of the firebox—that sounds pretty big. But I want to caution you fellows that when you have classified repairs you take a few of those bolts out up in that hot place he spoke about just to see what kind of threads you have, because if you have an explosion it would be a contributing factor. I am just adding a word of caution. Don't feel too safe. Those things exist.

I would like to know what you want to do with this topic. Do you want to carry it over?

Mr. Haase: I move you, Sir, that the topic be closed.

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

President Buffington: Now we come to the Good of the Association. Do I hear any remarks now under that topic? We have time enough for this now.

Mr. Gilley: Two years ago one of the speakers at our meeting made a suggestion that this Association consider the recommending of standard practices to the Mechanical Section of the A. A. R for their adoption. Nothing has ever been done along that line and I should like to suggest to the Executive Board that they consider doing that.

Thank you.

President Buffington: Do I hear any remarks on this subject?

Mr. Haase: I move that the matter be referred to the Executive Board.

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

President Buffington: Is there any more business to come before the Association for the good of the order?