*Full-Time Secretary Required*

The setting up of Recommended Standards of Practice for even boiler maintenance would entail a large amount of work and expense but, I say to you, such a set of standards for both maintenance and construction would be well worth any effort and expense involved. Naturally the question arises as to how this can be accomplished.

To begin with, the services of a full-time secretary would be required. Also a limited full-time clerical force. Questionnaires on many already well established maintenance practices could be sent to the membership (one with voting power on each railroad) in a short time, reserving the more complicated and less well established practices in maintenance until later, and not attempting any recommendations on boiler construction until the maintenance standards were well along. These questionnaires would have to be tabulated and either accepted as standard or rejected for another vote on the basis of a predetermined majority requirement.

It is an evident fact that the character of the secretary obtained would in a large measure decide the success or failure of such a plan. Your secretary, to handle such a job, should be of the highest calibre and paid an annual salary which would enable you to hold him.

To defray the expense of such a man and his necessary office force and expense, might require some such plan as the sale of sustaining memberships to each road and perhaps among supply companies for an annual payment. It is possible, however, that after the process had gone on for some time your standards could be printed in loose-leaf form (with a provision that they would be kept up annually) and sold in sufficient quantities to entirely defray the expense involved.

It is a regretable fact that some such procedure as outlined above was not instituted by your association long ago so that such valuable information might be available at this time, yet it is not too late to start and the end will well justify the means.

So gentlemen, I am offering you these suggestions for what you may consider them worth. A good which is worth accomplishing is worth making permanent. As Shakespeare so aptly said: "The evil which men do lives after them—the good is oft interred with their bones." This may be a way of preventing one such interment.

*President Moore:* Thank you very much. I will ask Mr. Christopherson to respond to Mr. Mitchell.

*Mr. Christopherson:* Mr. Mitchell, Mr. Chairman, Master Boiler Makers: It is a great pleasure for me to have listened to Mr. Mitchell's address. I don't think I am quite able to tell just exactly how I feel but I believe he has given us quite a lot of food for thought for us to think about. The only tribute that I can pay to him this minute is that we give him a rising vote of thanks for his able address. I wish you would rise and give Mr. Mitchell your thanks that way. (Applause, the members rising).

*President Moore:* We are now down to the reading of the Committee Report on Topic No. 3, the topic continued from 1938: "What Means Have or Can Be Suggested to Further Improve Circulation and Other Conditions in the Locomotive Boiler to Improve Steaming Qualities and Eliminate Leaking Staybolts and Cracking of Firebox Sheets?" The Chairman is Mr. Carl A. Harper, General Boiler Inspector, Cleveland, Cincinnati, Chicago and St. Louis R. R., or the Big Four.



# Topic No. 3

## WHAT MEANS HAVE OR CAN BE SUGGESTED TO FURTHER IMPROVE CIRCULATION AND OTHER CONDITIONS IN THE LOCOMOTIVE BOILER TO IMPROVE STEAMING QUALITIES AND ELIMINATE LEAKING STAYBOLTS AND CRACKING OF FIREBOX SHEETS?

C. A. Harper, Chairman
M. E. Steinbuck, Vice Chairman
William Henry    Frank Yochem
Robert D. Merk    Thos. F. Kilcoyne    E. J. Reardon

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

In the study of this topic your committee has deemed it advisable to divide the question into several separate divisions, due to its vast spread, for the purpose of consolidating and closely grouping opinions and avoiding duplications of ideas. In order that you may understand how we went about drawing up this report we wish to explain that the committee members were requested by the Chairman to gather, so far as time permitted, a more or less consensus of his road or associates on this question, and forward the results of this survey to the Chairman for consolidation. The individual reports which were submitted by several members of the committee were then consolidated into a preliminary paper, which was then submitted for the individual committee member's approval and any further comments he cared to make—the additional comments being included in this report.

That there is a need for improved circulation in our locomotive boilers is doubted by none. It is a well known fact that positive and consistent circulation of the water throughout the boiler is necessary in order to maintain a uniform temperature in all parts of the boiler. Unless there is approximated a uniform temperature throughout the boiler, stresses and strains of a violent nature at many different points are set up, the results of which we boiler men see every day as manifested in leaking and broken staybolts, warped and cracked firebox sheets and deterioration of the water surfaces of the boiler in general. For this reason the consideration of boiler water circulation is of vital importance to the boilermaker's art. Lack of circulation not only seriously and adversely affects the cost of boiler maintenance, but it also has a very pronounced effect on heat transmission, which is the major determining factor of the efficiency of a boiler. We know, too, that anything done towards improving circulation will also result in better performing locomotives with a consequent closer adherence to operating schedules, fewer failures and larger trains, in addition to the monetary savings that will be derived through more miles between shoppings, less terminal servicing, less fuel and water, and a reduction in the number of days out of service per locomotive. Considering the many sides of this question it can readily be understood that this subject probably is, from a dollar-and-cents standpoint to the railroads, one of the most important that could be dealt with by this Association.

That the importance of this phase of locomotive boiler construction and maintenance is fully recognized by prominent boiler designers and research engineers is well illustrated by what Hutton has to say in this regard in his "Steam Boiler Construction." We quote:

> "Free and active water circulation is the life of evaporation. The more rapid and perfect the circulation, the higher the evaporative efficiency of a particular heating surface. Circulation is a more important factor in the distribution of heat than either the nature or thickness of the metal through which the heat is transferred. The quantity of heat which can be transmitted to water in a given time is limited only by the rate at which it can be carried away from the heating surface by the convection currents of water."

Along this same thought we find that the well-known authority, Dr. Breckenridge, has this to say:

> "The velocity of circulation of water in a boiler is equal in importance to the velocity of gasses on the outside of the heating surface. The amount of steam formed increases directly with the rate of heat transmission, and if the scrubbing action of the circulation of water is insufficient to remove it from the heating surface, the resistance due to the layer of steam formed will rise with the rate of making steam. Lack of adequate circulation of water in a boiler is a check to capacity."

As hereinbefore stated, we have tried to break our subject down into several different sections, namely: "Conditions Adversely Affecting the Circulation in Locomotive Boilers," "Corrections Applicable to the Present Type of Locomotive Boiler," "Corrections Applicable to the Design of New Boilers," "Miscellaneous Items and Problems Created by Poor Circulation," and "Recommendations as to Angles for Future Study."

*Conditions Adversely Affecting the Circulation in Locomotive Boilers:*

Almost without exception it seems to be the universal opinion that the primary factors affecting good locomotive boiler circulation do not involve so much the fundamental design of the present boiler, but rather result from (a) the entrance and impingement of feed water at low temperatures, (b) improper water conditions, and (c) poor firing practices.

While much has been and is now being done to correct these problems, yet it is always true that the state of absolute perfection is never attained in anything, and no exception of course exists with regard to the mobile boiler unit as applied to steam transportation service. We believe that more concentrated effort should be applied towards correcting low temperature methods of feeding water to the boiler. A great deal has been done along the lines of providing better circulation in the water legs through the use of special appliances in the fireboxes, and these devices, such as arch tubes, syphons and circulators, are without doubt well worth their application and do accomplish much in improving circulatory conditions at the firebox end of the boiler. However, a great deal of the theoretical benefits to be derived from such devices, we believe, are more or less nullified by contact between the entering low-temperatured feed water and the normally hot boiler water, which results in the trapping of entering water at the start of its cycle. While it is unquestioned that the improved methods of feeding preheated water to the boiler, such as the exhaust steam injector, feed water heater, automatic live steam valve and heat booster, have gone a long way towards improving this situation, yet it is commonly agreed that the only ideal condition in this respect would be for the feed water to enter the boiler at approximately the working boiler water temperature; whether it is feasible or possible to do this is a question which it would seem to your committee to be one that is worthy of deep thought and research on the part of ourselves and our accessory company friends who have done so much for us in this direction in the past. Until such time as something similar to this can be accomplished the use of exhaust steam injectors, feed water heaters, automatic live steam valves, heat boosters, spray and mixing nozzles, etc., to increase the temperature of the injected feed water before it comes in contact with the various internal parts of the boiler, and the syphon, circulator and arch tubes to forcibly drive the hotter water to the more remote parts of the boiler is earnestly recommended to your consideration in trying to bring about the ideal of a continuous and steady flow of boiler water from the firebox to the front tube sheet and back again, uninterfered with by entering feed water.



Now let us consider what we have chosen to call the "secondary" factors adversely affecting circulation: Chief among these is the accumulation of scale and sludge, resulting from water of poor boiler quality, which forms in the boiler and is deposited particularly at the forward end between the flues and tubes, thus preventing the incoming water from freely finding its proper circulatory path to the bottom of the shell and back to the firebox surfaces. This, of course, is brought about by the naturally poor circulation in the front end allowing the comparatively motionless water to drop its load of precipitates at the front, which, as it accumulates, further adds to the poor circulation troubles at that location.

Another so-called secondary factor affecting circulation is the location on the boiler at which feed water is injected. Several different points of injection are commonly used, and there seems to be some disagreement as to the proper location, and this will be discussed at further length under the section covering methods of correcting our problems.

Firing practices result in another secondary factor affecting circulation and other conditions in the locomotive boiler. In this connection your committee desires your further indulgence while we quote from another authority, Haven and Sweet of the Massachusetts Institution of Technology:

> "The expansion of locomotive boilers when heated is too well known to cause comment. It is not unusual for boilers to travel backward on the expansion pads or waist bearer or furnace bearer sheets an inch and more. The expansions within the firebox, likewise, are very considerable. From cold to hot, large fireboxes expand in width one-quarter of an inch, and in length from flue sheet to back head one-half inch and in diameter of barrel at the combustion chamber five-eights of an inch. The effect of rising temperature on steel plate is tremendous and irresistible.
>
> "The destructive forces of expansion are brought into action when a boiler is fired up, especially when the boiler has been filled with relatively cold water or when the hot water supplied from the filling plant has remained in the boiler a number of hours before starting the fire. The firebox plates, because of the enormous quantity of cool water at their backs, warm up very slowly, and the upper sheet adjacent the mudring is so tardy that the hand can be held against the steel at the very time the engine is ready to pop.
>
> "The expansion which occurs when a boiler has been working several hours and is equalized in temperature are of small consequence compared with the destructive forces of expansion during firing up.
>
> "Cooling down strains are almost as grave as the firing-up ones, the only difference being that they occur in reverse order; therefore the remarks herein contained relative to strains in firing-up are equally applicable to cooling down.
>
> "It is the sudden heating of one part while other parts adjacent thereto remain relatively cool that causes the distortion which ultimately cracks the steel."

The foregoing brings out very clearly the important role that firing practices play in the amount of trouble to be expected from staybolts leaking, firebox cracking, etc.

It has been further brought out in our survey that locomotives equipped with maximum 3½" diameter superheater flues containing unit pipes cause considerable trouble with flues stopping up, this condition also having a very great effect in retarding circulation.

Also, our survey would further indicate that circulation is greatly affected through the mediums of poor valve setting, valve and piston blows, improper size exhaust nozzle and smoke stack, and improperly drafted locomotives.

*Corrections Applicable to the Present Type of Locomotive Boiler:*

Correcting the problem of injection of low-temperature water is one which has hereinbefore been discussed to some extent in connection with the section covering adverse circulatory factors. No method now exists, so far as we know, by means of which feed water at boiler water temperature can be injected directly into the boiler. However, there are a number of very beneficial devices on the market by means of which this goal can be approached to some degree, among these being the exhaust steam injector and feed water reheating equipment as well as the auxiliary heat booster for use with these devices to further increase the temperature at which the water is injected. Unquestionably these appurtenances can accomplish much towards improving circulation. It has been brought out in our survey that a matter of prime importance in connection with the use of such devices is to see that they are maintained in such condition that the maximum possible temperature of feed water is obtained at all times. Too, our attention has been called to the fact that water pumps should not be used while locomotives are standing or drifting; but we believe this latter evil can be overcome to a very large extent through the use of special devices recently placed on the market for automatically preventing such abuses by careless or improperly instructed employees.

It has been brought out in our study that it might be advisable to inject the water at several locations on the boiler, instead of at one location as is the universal practice, thereby spreading the mixture of the water over a wider area with a consequent less effect on circulation and less shock to the internal boiler surfaces. So far as the information at hand is concerned, there is no evidence that this scheme has been tried.

With regard to the proper location of boiler checks, our survey indicates that all are in agreement that this is near the front end of the boiler, but there are some differences of opinion as to whether the correct point is at the top or side. From data received, it would seem that with the use of the top check results have been most satisfactory. When the top check is used it is recommended that the water enter the boiler over a baffle plate or through a recently developed spray nozzle which spreads the water entering the boiler, thus helping to prevent the sludge and scale accumulations at this location and providing for a better condition in connection with the final contact between the two bodies of water of different temperatures. With top delivery over baffle plates or through a spray nozzle the water has a better chance to become heated, thereby lessening the temperature differential at the moment of impingement with a resultant less shock on boiler plates. Two members of the committee report that in their experience when a change was made to a top delivery of water to the boiler, staybolt and side sheet troubles were very materially reduced.



As to sludge and scale accumulations affecting free circulation, all agree that this condition is being successfully minimized through the use of boiler feed water treatment, proper adherence to blowing schedules to keep the dissolved solids below the foaming level, and the regular washing out of the boiler. As evidence of the benefits to be derived from water treatment, we cite you to the many instances where such treatment, once it has been tried on a railroad, has produced such wonderful results in improved performance and lowered costs that they have been influenced towards the gradual extension of the system until the entire railroad has been equipped for treatment. The detrimental effects of scale deposits on internal surfaces are too well known to justify spending any great amount of time discussing them here, but we would like to refer you to what the Howden Boiler Company of Glasgow has to say with regard to boiler cleanliness. We quote:

> "It is impossible to injure fairly clean plating over the hottest possible fire under highest forced draught if the steam globules immediately after formation arise upward from the plate surface to the steam space and are replaced by the surrounding particles of water not yet evaporated."

and along this same line we find that Dr. Breckenridge has this to say about the importance of preventing deposits of an insulating nature on the heating surfaces:

> "It is clear that in order to have heating surface efficient it must be kept free from soot and scale, and the bubbles of steam must be removed from the surface as fast as they are formed, so that the water can come directly into contact with the metal. This last requirement emphasizes the importance of circulation in the boiler. The faster the circulation of water the faster are the bubbles of steam carried away and the better is the contact between the metal and the water."

Further in connection with the accumulation of sludge at the front end between the flues, tubes and sheets, it has been suggested by two members that a periodical blow-down arrangement be applied to the bottom of the first course adjacent to the front tube sheet to provide a means of cleaning such accumulations which have a tendency to slow circulation in this location.

Our observations lead us to believe that a study of firing practices should be made, particularly at lay-over points and terminals, because at the time of the fire-up many of the destructive forces of expansion are brought into action. Certainly there are correctable conditions in connection with present firing practices that demand more study which should result in improvements in this respect.

It has also been suggested that in addition to good maintenance a further improvement can be made on grates used in locomotives equipped with a brick arch, that after the necessary percent of grate opening has been determined, the grates be applied with that opening graduated from front to rear, arranging for from 30 to 50 percent greater opening at the front than at the rear of firebox so that the lesser openings would be at locations of the greatest draft, the distribution of the openings to be determined through proper tests.

It is generally believed that the use of firebox syphons and circulators as well as arch tubes do much towards increasing circulation in the boiler, as these devices, as previously stated, have a tendency to force the current of heated water to the forward end of the boiler where the great portion of our problems exist.

## CORRECTIONS APPLICABLE TO DESIGN OF NEW BOILERS

Last year we heard our good friend and fellow member, Mr. W. R. Hedeman of the B. & O., report on the wonderful results they had been obtaining from the use of their water-tube fireboxes. We have information from him that at present they have twelve such locomotives running, which have accumulated an additional 678,000 miles since his last report, the total now being 4,678,000 miles of service since built, which naturally speaks for itself. He assures us that the service obtained from these locomotives has been very gratifying and satisfactory, that with the rapid circulation with this type of firebox, interior barrel conditions have been materially improved. We believe this idea may be a partial solution to at least some of our problems, and in the design of any new locomotives it should be given careful consideration.

We have received a recommendation that the foundation ring be constructed considerably wider than at present in order to adequately accommodate blow-down systems that are generally applied with blow-down arrangement to the bottom of the first course. It is further stated that if the foundation rings were increased in width from the conventional 5.5 inch to a 7.5 inch width this would increase the water supply 36 percent at the point mentioned and this should also be very beneficial in high temperature fireboxes.

It has been recommended that superheater flues 3½" in diameter are not large enough to be practical on coal burning locomotives, and it has also been suggested that superheater unit bands be so applied as to offer less resistance to the cinders and clinkers passing through the flues.

## MISCELLANEOUS ITEMS AND PROBLEMS CREATED BY POOR CIRCULATION

In the course of our study we brought out a number of miscellaneous items which although not directly involved in affecting circulatory conditions, yet were a result of those conditions. Among these was the grooving and corrosion of bottom flues on water side at front flue sheet. Opinion is not unanimous that this is a fault of poor circulation, some believing this to be due to an electrolytic action, at least as a contributing cause, while others think this to be wholly due to free oxygen effects which go undisturbed due to sluggish circulation. The committee is inclined to believe that this flue trouble is brought about by the metal being distorted under stress and vibration allowing the metal to be easily attacked by free oxygen, and we are also of the belief that this can be corrected to a great extent if circulation at this location can be speeded up enough to prevent the fresh water from resting too long in this location. This condition, of course, is aggravated when flues of a lighter gauge or those that have deteriorated from usage have been applied to enlarged holes and not properly shimmed. In some instances it has been found that the metal has been distorted or expanded beyond its natural elastic limit due to excessive or eccentric rolling in order to accommodate these larger flue holes or through the use of improperly designed rollers. A corrective measure that has been suggested is the application of new material to front end of flues throughout the effective area and it is stated that under this arrangement flues can generally be operated from shopping to shopping without grooving through. It has also been suggested that another good preventative measure is the sue of copper ferrules in the front flue sheet. The committee is of the opinion that we should go further than temporary measures, however, in our effort to correct this condition, by following recommendations similar to those described under the section covering correction of circulation problems.



Another angle closely associated with those already discussed in this report is the cause for leaking staybolts. The committee believes that staybolt leakage is influenced very greatly by all the factors connected with circulation, which have been previously discussed. However, the committee also recommends that in the application of staybolts the best workmanship possible should be used. In that connection one of our members has made the claim that the practice of using a small button on staybolt hammer, which drives the bolts first in the center, upsetting them through the sheet, and in a second operation using the ordinary flat button to lay up the edges of the bolts, has been very successful in improving staybolt conditions.

## RECOMMENDATIONS AS TO ANGLES FOR FUTURE STUDY

It can readily be seen from the foregoing report that the subject in its present form is a very broad one, involving many and varied parts and conditions in the boiler, which for one committee to cover in one report is a considerably larger job than it is convenient to handle. To gloss over these matters briefly without coming to any more or less definite conclusions is, in our opinion, doing very little towards advancing the solution of our problems. It is therefore our recommendation that certain particular angles of this subject be studied to a conclusion, enabling us to make some definite recommendations, that as soon as possible after the close of this meeting a committee be appointed on Topic No. 3, who will, as soon as possible, inform all members of the Association as to the lines along which the investigation of the angle will proceed, a careful study be made accordingly throughout the coming year by all individual members on their respective roads and the results of this study made available to the committee for next year so they may assemble, draw their conclusions therefrom and present recommendations at our next meeting. It is therefore our recommendation that Topic No. 3 in its present form be continued, but sub-divided for detailed study during the next year as follows:

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

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

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

*Mr. Harper* (Continuing): At this time I want to thank every member of the Committee who so freely helped in furnishing information, as well as a lot of others that I asked for information to compile this paper. (Applause).

*President Moore:* That was a very nice paper, Mr. Harper. The Committee is to be commended on the splendid showing on this subject.

I have a telegram from Mr. William Henry of the Canadian Pacific Railways, Vancouver, Canada, who is unable to attend our meeting.

*Mr. Kearn E. Fogerty* (C. B. & Q. R. R., Aurora, Ill.): Before this report is accepted, which is very good, I would like to ask if I understood correctly that there were two members of the Committee that did not agree on the circulation proposition. If that was a fact, I would like to ask them to get up and address this meeting as to why they do not believe in that. I might have that wrong.

*President Moore:* I believe you have, Mr. Fogerty. The topic is not yet open for discussion, and before we go any further with this topic we will have a picture on "Circulation of Water in the Boiler," by Mr. C. M. Rogers of the Locomotive Firebox Company. After these pictures are shown the topic will be open for discussion.

Following showing of the motion picture, Mr. Rogers read his prepared paper on Topic No. 3.

By C. M. Rogers,

*Locomotive Firebox Company*

The absence of water circulation in locomotive boilers has been the subject of discussion among railroad men for many years, records indicating that this problem was of considerable moment in the early days of locomotive operation. Pitting and cracking of sheets and flues, the presence of scale and mud accumulation have harried railroad men all these years. Many people have endeavored to develop a satisfactory means of establishing through circulation in the boiler as a potential means of overcoming the conditions with which they had to contend, not really knowing that the desired results would follow but reasoning correctly that they would.

Examples are numerous to prove that dormant boiler water often destroys the metal with which it comes in contact. Water arches and circulating tubes of various kinds have been installed but with moderate success. Brick arch supporting tubes came into general use with a degree of effect upon circulation but the introduction of Nicholson Thermic Syphons proved to be the step that succeeded in establishing complete circulation of boiler water.

The construction of the Syphons exposes large areas of heating surface to the hottest part of the fire and circulation is induced by the evaporation of water inside the Syphon walls. This evaporation takes the form of steam bubbles which develop and depart from the heating surface in large quantities. An idea of the rapidity of the production of steam is gained by noting that a cubic inch of water expands into 117 cubic inches of steam. Develop this enormous increase in volume into the quantity of water evaporated per hour on a locomotive, say one million cubic inches of water converted into 117 million cubic inches of steam, and we have an impression of the force involved in the action of steam bubbles. A very large part of this work of evaporation is performed in the Syphons, thus stimulating a water tube boiler.

The natural movement of steam bubbles is upward. Being lighter than water, the enormous quantity of steam bubbles constantly being formed inside the Syphons pushes and pulls the surrounding water along with them into the space above the crown sheet. This constant action produces a powerful suction or pump effect which pulls a continuous new supply of solid water through the Syphon necks from the lower part of the boiler to replace the combined steam and water being discharged from the Syphons at the top. This displacement of water by steam bubbles and consequent pull of water into the Syphons is calculated to cause water to pass through the Syphon necks at a velocity of five lineal feet per second. Much more water enters the Syphons than it is possible to evaporate in the brief passage from throat to crown sheet, thereby maintaining proper temperature of the Syphon parts.

Upon leaving the Syphons through the opening in the crown sheet, the water moves forward vigorously through the upper part of the boiler shell to the front flue sheet, then downward and backward through the lower part of the boiler, thus completing the circuit. The hottest water from the firebox end thoroughly mixes with the cooler water at the front and the cooler feedwater entering the boiler in that vicinity, thus practically equalizing the temperature throughout the boiler.

This action has been proved by means of thermometer tests. It is known that boiler water temperature varies fifty or more degrees between the front and rear of boilers without the Syphons, but tests show practically the same temperature of water throughout the entire Syphon-equipped boiler.

Firing-up tests prove that boiler water temperatures are equalized on Syphon boilers before steam pressure is indicated on the gauge.

The upper necks of Duplex Syphons, being connected to the side sheets, stimulate circulation in the side legs of the boiler.

Conclusions reached as a result of these temperature tests are strengthened by study of the water movement in the working model of a Syphon-equipped boiler many of you have seen at the various conventions. From these conclusions, the animation to depict circulation was prepared and inserted in the motion picture you have seen.

The difficulty of securing positive evidence that water circulates throughout a working boiler as a result of Syphon action is apparent. Of this much there is ample proof—water does flow upward through the Syphon as crown sheets plainly show the cooling effect in case of low water.

We hope to present on the screen additional proof of the forward movement of water in the upper part of the boiler. You will recognize novelty in the feat of photographing the interior of a full size locomotive boiler while working at full power.

The action of the Syphons in establishing circulation serves to precipitate foreign solids where they may be readily removed and while it cannot be expected that such foreign substances will be eliminated entirely from the heating surface, an improvement has been noted.

Many reports of the beneficial effects of water circulation have been received. By direct comparison between locomotives of the same class and service, flue mileage has been increased between 40 and 100 per cent in favor of locomotives equipped with Syphons. This evidence has been repeated so many times that it would seem to be a definitely correct statement that circulation does readily extend flue life.

Another well-established indication of the good effect of water circulation is the reduction in the number of broken staybolts. In these days of high pressure locomotives, many extreme cases of broken bolt complaints may cause one to overlook the benefits derived by circulation but the fact remains that fewer bolts break on Syphon-equipped locomotives than on non-Syphon locomotives.

Information received from the railroads to verify the favorable effect of circulation is usually in the form of a statement; for instance, a comparison of broken stays between three Syphon and three non-Syphon locomotives during one year, the locomotives having the same age and practically the same mileage working in the same territory. On the non-Syphon locomotives, a total of sixty-eight stays and ninety radials in scattered locations were broken during the year. On the Syphon locomotives, thirty-eight stays and no radials were broken during the same period. The broken stays on the Syphon locomotives were all located in the lower part of the door sheet where circulation is the poorest, or none at all is present.

Another comparison between four Syphon and four non-Syphon locomotives illustrates staybolt and radial renewals for one year on account of breakage. On the non-Syphon locomotives the total is 284 bolts, while on the Syphon locomotives there were only fifty-seven bolts broken. The following year the record for the same locomotives shows non-Syphon locomotives required the renewal of 238 bolts while only sixty bolts were renewed on the Syphon-equipped locomotives.

Another report indicates that, up to and including the year 1928, fifteen Syphon-equipped locomotives broke 327 staybolts and radials with an average of 17,886 miles per broken bolt, while sixty-five non-Syphon locomotives broke 4,004 bolts with an average of 4,060 miles per broken bolt, over four times as many miles per broken bolt on the Syphon locomotives. This statement was made of locomotives of the same class and in the same service operating on the same division for an equal period of time.

Perhaps the most accurate record of staybolt performance began in 1924 when ten new Santa Fe type locomotives were placed in service, five with Syphons and five without. For several years, the railroad maintained a detailed record of staybolt failures on these locomotives. During a period of 28 months of which the record was revealed, there was a total of 358 staybolts renewed on account of breakage on the five non-Syphon locomotives in addition to a complete renewal of staybolts and radial stays in all of these five locomotives. During the same period of twenty-eight months, there were only twenty-eight broken staybolts on the five locomotives equipped with Syphons. There was no complete renewal of staybolts and radial stays on the Syphon locomotives.

It became necessary several years ago to renew the fireboxes on all of these non-Syphon locomotives. As compared with this, only one Syphon-equipped firebox was renewed, quite recently, and on the other four Syphon-equipped locomotives, the original fireboxes are still in service. In recent years, it is reported that from five to twenty-five staybolts require renewal each month on the non-Syphon locomotives, whereas on the Syphon-equipped locomotives renewals do not exceed five bolts per month.

Curves plotted to show comparative total cost of maintaining these fireboxes, including the Syphons, gradually diverge during the first five and one-half years the record is available. At the end of that period, the total



cost of maintaining the five non-Syphon fireboxes was $2,546.16 or thirty-three per cent more than the cost of maintenance of the five Syphon-equipped fireboxes.

Some locomotives without Syphons required removal of flues at 60,000 miles while the Syphon locomotives in the same class and territory reached 131,000 miles before this work was done.

Another report stated that in a bad water territory Syphon locomotives made 56,000 flue miles with firebox sheets in far better condition than non-Syphon locomotives that had made a flue mileage of 30,000 to 40,000 when complete removal of flues was necessary. The flues of the Syphon locomotives were not removed at the mileage given.

For some reason, the cracking of back flue sheet knuckles ceased on quite a large number of scattered locomotives after Syphons were applied. While it may be difficult to determine the cause of this, the facts seem significant.

Many other reports of similar nature have been received.

It may not be too far removed from the literal meaning of Topic No. 3 to state that Syphon-induced circulation is the principal means of preventing serious crown sheet failures. The water and steam flowing up through the Syphons continue this movement while the general water level falls considerably below the crown sheet, the lowest recorded being twenty-four inches. Spreading over the major part of the crown, this water cools the sheet until notice is given of impending trouble by the production of the hot or soft spot in the crown sheet in front of the Syphons due to the fact this part is the first to become overheated.

There have been fifty-one cases of low water on Syphon-equipped locomotives that have come to our attention. Most of these have occurred on boilers with full sets of Syphons and the demonstration of "Syphon safety" in those cases should convince the most skeptical. In a very few cases, the fireboxes were not properly equipped with Syphons. I mean by that the Syphon arrangement was not in accordance with our recommendations and as a result trouble occurred. These failures appeared on locomotives not equipped with Combustion Chamber Syphons. While the Firebox Syphons protected the crown in their vicinity, they could not be expected to throw water up the sloping crown sheet over the combustion chamber; therefore, damage occurred from overheating and collapse of the crown sheet over the chamber with serious consequences. On the other hand, five cases of low water that occurred on locomotives equipped with Combustion Chamber Syphons proved that such Syphons would have been the means of preventing the trouble that occurred on the other locomotives to which I refer.

Suffice it to say, circulation of boiler water is very advantageous.

For the purpose of illustrating Syphon-induced circulation, there will follow a movie reel covering various features of the Nicholson Thermic Syphon and in which appears sections of a boiler with indications in animated form of the course of water movement induced by the Syphons. This animation was partly theoretical at the time the picture was produced but was substantiated by observations of a one-eighth sized model working boiler equipped with Syphons that was used for investigation and study. Some of the details shown in this picture are obsolete such as the old lap weld at the crown sheet, but the principles illustrated are still correct.

The second reel to be shown involves the Duplex Nicholson Thermic Syphon, a recent development, which has two intake necks for each Syphon. One of these intakes is connected to the side sheet and the water supply is therefore drawn from the side leg to provide additional stimulation of water in that area. Duplex Syphons are rendering excellent service particularly from the standpoint of maintenance. The functions performed are the same as the conventional Syphons. About forty locomotives have been equipped, the oldest of which is three years, and no defects have appeared.

The third reel was produced for an entirely different purpose by the Electro-Chemical Engineering Corporation, subsidiary of the Dearborn Chemical Company, in collaboration with the Missouri Pacific Railroad. A modern locomotive equipped with Syphons was used on a standing test for the purpose of demonstrating a new automatic blowoff system. The top of the steam dome was equipped with bullseye glasses for the purpose of observing the interior of the boiler below the dome. Hoping to record what they saw for the benefit of others, the camera was used to make photographs through one of the bullseyes and in addition to features of the blowoff system they observed in the glare of powerful lights located inside the dome a very rapid movement of water rushing forward from the rear of the boiler toward the front end, thus verifying previous theories that the action of Syphons produces a thorough circulation of water throughout the boiler.

Mr. Carrick of the Electro-Chemical Corporation commented as follows concerning this third reel:

During the month of August, 1939, motion pictures were taken through six sight glasses located in the steam dome cover of 2-8-4 type Missouri Pacific locomotive 1916 at St. Louis, for the purpose of studying the action of the steam and water inside of a locomotive boiler. The pictures were taken while the locomotive was standing, with the steam valves removed to permit manipulation of the throttle to obtain various exhaust steam back pressures, or rates of evaporation, so the motion pictures would furnish a permanent record of the behavior of the steam and water in the boiler for the various back pressures and various rates of evaporation or steam generation in the boiler. Two special lamp bulbs were placed inside the steam dome for the purpose of producing the required illumination to take the pictures.

The locomotive was equipped with two Nicholson Thermic Syphons located in the firebox, but did not have a combustion chamber. It was also equipped with a Worthington Feedwater Heater. The locomotive was stoker fired during the standing test and it was not difficult to maintain the desired steam temperatures.

The motion pictures and observations made through the sight glasses showed various rates of flow of the water under the steam dome from the firebox to the front portion of the boiler, the rate of forward flow being the greatest with the highest rate of evaporation. While the locomotive was standing with the blower valve open the water would flow forward at a relatively slow rate and while working the locomotive at twelve pounds exhaust steam pressure the water would rush forward under the dome at high velocity.



The motion pictures also show the water containing more or less large quantities of steam bubbles and reaching a frothy stage. At all times the water level at the steam dome, ten feet away from the back flue sheet knuckle, was at approximately the same level as the water over the crown sheet, as determined by Foam-Meter electrodes and indicator paddles at these different locations. However, the frothy or bubbly water level at the steam dome was frequently observed to be six to ten inches above the level of the water shown in the water column gauge glass.

The motion pictures clearly show the conditions existing inside of the boiler before and at the time the boiler foams as being due to the foamy or steam-swollen water closing off the steam space sufficiently to cause the steam flowing from the firebox zone into the dome to reach extremely high velocity over the surface of the forward rushing water, to whip the water upwardly into the steam dome, causing it to bombard the sight glasses located in the dome cover and be entrained with the steam flowing into the dry pipe. Three-eighths inch sash chains suspended at various points under the sight glasses clearly indicated the high speed of the steam and the shearing action of this high speed steam over the foamy water surface whenever the steam space was restricted by the swollen or foamy water.

The motion pictures also show the application of a foam collapsing trough under the steam dome. The depth of this trough was about sixteen inches, with the closed bottom approximately two inches above the top flues and the open top of the trough about one and one-half inches above top of water glass. The motion pictures also show the frothy or foamy water overflowing the top of the trough and being blown out through an automatically operated blowoff valve developed by the Electro-Chemical Engineering Corporation as an improvement over the standard Signal Foam-Meter Equipment. Some of the views inside the boiler show large amounts of scum floating on the surface of the quiet water in the trough, with the water flowing rapidly forward on the outside of the trough.

As far as is known these are the first actual motion pictures ever taken showing the behavior of the steam and water inside of a locomotive boiler and they clearly show the rapid forward circulation of the water in the boiler during periods of steam generation. Furthermore, because these pictures have cleared up a number of problems as to what actually exists in the boiler before and at the time the boiler foams, more pictures are expected to be taken under greater illumination on various types of boilers, using various types of boiler feed waters and while the locomotive is in actual service.

*President Moore:* Messrs. Rogers and Carrick, on behalf of the Association, we wish to thank you and your company for your wonderful contribution to the afternoon's education of our membership.

## DISCUSSION

*Mr. Service:* Mr. President, Members of the Association and Guests: The reading of this Topic No. 3, to me, I believe is the most interesting topic that we have that comes before us as Master Boiler Makers. During the past two years I have made a little study of this topic myself and I was glad to see where others beside myself, such as the members of the Committee, found many of the things that I have found.

When speaking of conditions to which I am going to refer I have in mind 300-pound pressure oil-burner locomotives and in bad water districts. On the Santa Fe Railroad thermic syphons, circulators and arch tubes are in a good many of our fireboxes. Based on my observations, I can hardly see at this time any difference as far as leaky staybolts are concerned in a bad water district.

That leads up to a little further investigation, based on my inspections and other inspections of Assistant General Boiler Inspectors. There is one locomotive in particular, No. 3460, the class locomotives which is a No. 4-6-4 type, not equipped with a combustion chamber. However, this boiler has a top boiler check located where the water enters the steam space toward the front end of the boiler, and this particular locomotive is also equipped with a nickel steel firebox and the cool down leakage at staybolts on that particular firebox has not been so pronounced as it has been on the other five, although they all leak. Also, the performance of the back flue sheet knuckle of that nickel steel firebox has made up to today about 253,466 miles and is still going. Based on my last inspection of about thirty days ago, there was no indications of cracking. However, the other remaining five locomotives of the class have all failed, the average miles being 145,306 miles. The difference in favor of that one locomotive is 108,160 miles.

It is a little difficult to say that the boiler check was responsible for that, still at the same time it is also difficult to say that the nickel steel was responsible for it. The designs were the same on the other locomotives as far as the firebox design was concerned and they were operating in the same districts.

Therefore, I think that the Committee is right when they state that, further consideration should be given to the application of feed water into the boiler and the other remarks in the Committee report pertaining to the various devices that will apply hot water to boiler. The more uniform temperature secured as compared to what the steam or hot water is in the boiler is bound to have a beneficial effect.

There is another point that I wish to bring out, and that is the drafting of a locomotive and the improper impingement of heat on the sidesheets of a locomotive, and the two may go together. An over-sized burner and a locomotive improperly drafted can concentrate the heat on your sidesheets to such an extent that with light water conditions you cannot keep all the staybolts tight and cool down leaks will result.

I have recently used a micrometer on the side of the firebox sheet, that may sound funny but it is a fact. However, when measuring these sidesheets I found that instead of being 13/32", they were 1/2" plus toward the center of the sheet.

That means what? You hear about the thickness of scale on the water side and its effect. Now we have something else that, in my opinion, is just as important. If you have an excess in thickness of sheet it means that you have to carry higher temperatures in your fireboxes for transmission of that heat from the firebox side of sheet to the water side to secure the necessary steam and to compensate for the difference in thickness. When we do that, as we must do in this case, we raise the temperature of the staybolt heads accordingly and the result is when you shut off your



oil fire you have a more rapid cooling. In addition to that, the staybolt heads show that when they were curling at edges. You know what I mean by that, I think.

Therefore, I think that the Committee should consider some of these things also in addition to the A, B and C Topics.

There is one more item I wish to dwell upon and I am governed from experience more than anything else. Back about 1927 we purchased some locomotives with copper bearing steel in the back flue sheets. Inside of two years' time everyone of those flue sheets were removed caused from cracks in the flue bridge. When asking for an analysis of the present steel I find that we have an excess copper in these side sheets I referred to that are 1/2" thick. So you have a combination there of two other things: excess thickness and a high content of copper which, in my opinion, produces a certain amount of hot short. When that rapid cooling takes place at your staybolt heads the leak starts and runs down your sheet, producing these small minute cracks, and when you examine them with a magnifying glass there isn't only one but five. These eventually go through the sheets and in bad water districts it shows up quicker regardless of what kind of device you have in the firebox to help your circulation.

*President Moore:* That is a very nice contribution to this topic. You can see now why some of these boiler inspectors lie awake at night and worry. They have plenty to worry about.

*Mr. G. E. Stevens* (Boston & Maine R. R., Malden, Mass.): I would like to ask the last speaker if the flue sheet he said gave such service was a hot or cold flange.

*Mr. Service:* The Baldwin Locomotive Works has a practice, I believe, of pressing them hot.

*Mr. Harper:* Mr. President, before you close this topic I cannot overlook thanking Mr. Rogers for his contribution of moving pictures and his description of the circulation produced by their device.

In that connection, if this topic happens to be carried over for the following year I would like to see every individual boiler maker in our organization write a story on some part of it because every man in these United States and Canada is interested in locating the cause of a lot of our bad conditions today. We are getting to them one by one. We have the water problem pretty well along, but still we have leaky staybolts, cracked sidesheets, split flues and a lot of other conditions, that circulatory conditions, unquestionably play a big role in causing such troubles. This organization is certainly in a very favored position to gather a lot of information that will be valuable to all our railroads. If the subject comes up next year, every member should give it some serious thought. (Applause).

*Mr. Service:* I would like to clarify one remark I made. I want to show it to you on the blackboard. This is the shape of the sheet you buy from the factory (draws diagram). You have two syphon openings slotted in the crown sheet. The sheet measured correct at the edge 13/32" at this location, all parts with excess thickness varied from 2/32" to 3/32" plus. The location where we had all of these minute cracks was where the most important impingement of the fire was located. It resulted in taking the side sheets out, but there is where the damage was done. If that plate, in my opinion, would have been the proper thickness throughout we might not have run into that excess cracking at the staybolt holes. The center section of the sheet was the thickest part—½" plus.

There is another point that I wish to bring out. As I understand, the manufacturers dress their rollers weekly when rolling their sheets but I don't think there is any tolerance allowed for over-size, although they cannot go below a certain limit under size. That might be something for the manufacturer to study and helping the boiler makers at the same time.

*Mr. Christophersen:* I think this is a very live topic, and I believe I have encountered nearly all kinds of circulatory elements as applied to locomotive boilers since 1900.

Around that time circulatory inventions were tried out like the steel arch. This arch was a connecting link between the two side sheets and flue sheet. Water bars connecting the back flue sheet with the door sheet and from the back flue sheet to the crown sheet were used. So that the idea of circulation even in those early days was very evident.

I have also had experience with locomotive water tube boilers on which circulation was perfect. The first invention that really did some good to a locomotive boiler was the Nickerson Thermic Syphon; and it was noted in comparison with other circulators that no sludge or mud was found in the barrel of the boiler, so equipped. Comparison between an arch tube, syphon, and duplex syphon, and arch circulator has also been made in regard to sludge or mud in water space at mudring and there has been no great difference found as to the depth of mud at mudring, all being the same height.

We have on the New Haven a device attached to the present syphon, about which I really cannot say much owing to fact that we have only had it in service for eight months. But it has several additional bodies attached to the two syphons reaching from the first row of bolts in the top of the syphon down to the side sheet and connected between the second and third row from the bottom up. The body is about 7¼" x 3¼" in the opening. On previous mentioned circulators the sludge or mud accumulation at the mudring is about 8" high. We are as yet unable to find any trace of mud on the bottom or any place else in the boiler with this new additional device. The locomotive is in high-class freight service, pulling one of our fastest trains and has never up to date lost more than one day out of service and that is the boiler wash date.

*President Moore:* Have you anything to say on that subject, Mr. Milton?

*Mr. Milton:* Mr. President, I am here but I am not going to say a word only this, what is the matter with you fellows out there? Get up and say something. This is a topic you are all bothered with.

*President Moore:* You heard what Mr. Milton said. How about it? Are we done with Topic No. 3?



The next topic to take up will be Topic No. 5: "What Standard Practice Can This Association Recommend for Locating Height of Crown Sheet, Water Glass and Gauge Cocks and Low Water Alarm Drop Pipe, and What Dependable Standard Means Can Be Recommended for Marking Water Level and Highest Point of Crown Sheet on Boiler Head?"

The Chairman is E. H. Gilley, General Boiler Foreman, Grand Trunk R. R., and the other members of the Committee are W. B. Graham, Chief Mechanical Inspector, Gulf Coast Lines; O. H. Kobernik, General Boiler Inspector, New York, Chicago and St. Louis R. R.; Wm. H. McKeown, Federal Locomotive Inspector, I. C. C.; and S. S. O'Connell, General Boiler Foreman, Erie R. R.