The Causes of Boiler Explosions*

The Majority of Accidents are Traceable to Poor Design and Careless Operation

By S. F. Jeter

Broadly speaking, there is one explanation for all boiler explosions; namely, the boiler or some part of it is too weak to withstand the stress brought upon it. There are many causes contributing to such weakness, and a definite cause can usually be given for most explosions.

Public opinion is being aroused to the fact that many boiler explosions are preventable, as evidenced by the present agitation for laws governing the construction and operation of boilers. The lead of the city of Philadelphia has been followed and improved upon by the State of Massachusetts; also Ohio and several municipal governments now have boiler laws patterned after those of Massachusetts, and similar action is being considered seriously by a number of other States and cities.

FAULTY DESIGN.

One cause of boiler explosions is faulty design, as they are frequently constructed too weak for the pressure to be carried. This does not mean that the boiler will necessarily explode as soon as the pressure is raised. Explosions from this cause usually occur after years of use, the overload on the parts having had time to gradually weaken them until they are no longer capable of resisting the excessive strain.

Of course, a manufacturer has practically no control over the steam pressure to be used on a boiler, after it has been delivered to the purchaser. But if the manufacturer should stamp his name and the safe working pressure for which it was designed on each boiler built, it would act as a protection to his reputation in the event of excessive pressure being used. Proper inspection and fixing of pressures by experts is the logical remedy for explosions due to this cause.

A fault of design which often leads to an explosion is the adoption of a shape which tends to deform under pressure. In such cases, if the movement produced occurs within narrow limits along fixed lines, grooving or cracking is almost certain to occur, finally resulting in an explosion, unless the defect is discovered before the structure has been weakened to the breaking point. The obvious remedy is to use shapes which the internal pressure does not tend to change, and if this is impractical, to use such forms that the movement produced will occur over considerable areas and not be confined to narrow limits.

Improper reinforcement of openings has occasionally been the cause of boiler explosions. If the openings in boiler work were not generally of such moderate dimensions, this might be a more frequent cause of disaster. No definite information is available regarding the distribution of stresses around an opening in a cylinder when subjected to internal pressure; consequently, the design for the reinforcement of such openings is by rule-of-thumb.

Another fact responsible for many explosions is an arrangement not permitting of accessibility for the inspection of all parts. This is especially so when the inaccessible parts are located where rapid deterioration is likely to occur. No portion of the boiler proper should rest directly on a foundation or have any of its parts buried in earth or ashes. Furthermore, a design which does not permit free circulation of water in all of its parts is liable to produce rapid internal corrosion, for unless a current is produced by the circulation sufficiently strong to remove all bubbles of air that may attach themselves to the surfaces, rapid corrosion is almost certain to ensue. This, if neglected, may result in an explosion.

Air, which is a mixture of about four parts of nitrogen to one of oxygen, together with very small quantities of other gases, dissolves to a certain extent in water. However, the oxygen, being more soluble than the nitrogen, dissolves more readily and the proportion of the gases found dissolved in the water is roughly one of oxygen to two of nitrogen, instead of in the proportions found in the air. When the dissolved air is liberated by the heat, the high percentage of oxygen causes the surfaces on which the bubbles may collect, to be rapidly corroded. This accounts for the severe corrosion of vessels containing water which is merely heated without a strong circulation being produced.

A correct boiler design will provide uniform flexibility throughout. A stiff, rigid part next to one which is flexible is a menace to safety if there is any tendency toward movement between the parts, either due to temperature changes or pressure.

POOR WORKMANSHIP.

Defective workmanship is responsible for some explosions, the barbarous practice of drifting rivet holes having doubtless contributed largely in the past to such accidents. The reputable manufacturer of to-day, however, will not knowingly permit such work.

Failure to properly flare the tubes and nipples in water-tube boilers has frequently resulted in explosions. The safety of the joint between a tube and a plate when expanded and flared or merely expanded, is not a question of the relative strength of such connections newly made. When for some reason connected with the operation of a boiler, a connection of this kind becomes loose, owing to a movement of the parts from expansion or vibration, together with the excessive weight sometimes sustained, the tube or nipple with a flared end is decidedly more safe than one which is merely expanded. The flared nipple usually gives warning of its looseness by leakage before it pulls out.

DEFECTIVE MATERIAL.

Defective material is sometimes the cause of boiler explosions, and the boiler manufacturer is largely dependent upon the producer of the material for protection in this respect. Nothing but material of the best quality should be specified for all parts of a boiler which are called upon to resist the stresses produced by the pressure of steam, and every precaution should be exercised to see that such material is obtained. Cast iron should never be used in any part of a boiler called upon to resist tensile stress.

WILLFUL NEGLECT.

A cause of explosion which is particularly reprehensible, because of its being preventable, is due to an owner's willingness to pit his judgment against more competent or conservative advice. Often boilers are known to be in need of repairs, but the work is put off to a more convenient season. A feed pump refuses to start, and instead of fires being drawn as soon as the water reaches the lowest safe level, a chance is taken that it can be run a little longer. Pressures are sometimes carried higher than reasonable safety would permit, to avoid the expense of larger engines, or better boilers. Boilers are forced beyond a reasonable duty for the heating surface they contain. This is a feature that must be reckoned with more in the future than it has been in the past.

NEGLECT OR CARELESS OPERATION.

Boiler explosions are also the result of neglect or carelessness in operation. Scale and deposit are often allowed to collect in quantities that are dangerous; connections to water columns are allowed to become stopped; oil is permitted to enter the boiler with the feed water; repairs to settings which may affect the safety of the boiler are neglected; safety valves are not regularly tested to ascertain if they are in operating condition; or occasionally an owner who discovers the safety valve leaking, with an eye blind to every consideration except the prevention of loss of steam, places a stop valve on the connection to the safety valve or plugs the outlet. A steam gage may register incorrectly and the engineer screws down on the safety valve in an endeavor to make the gage show the correct pressure.

Again, the steam pressure may not be sufficient to produce the results desired and the safety valve is deliberately made inoperative to overcome the difficulty. All of these conditions have been the cause of boiler explosions in the past and they probably will continue to contribute their share in the future until the steam user is more thoroughly educated in the matter of the risk he runs by such carelessness.

TUBE FAILURES.

Tube failures, which are chiefly confined to the water-tube type of boiler, are a source of grave concern to the boiler-insurance interest because it is difficult to guard against the usual failure of this kind by inspection. A defective weld usually does not show on the surface of the tube, and even where the surface indications would lead to suspicion, a large percentage of the tubes in water-tube boilers are beyond the reach or vision of the inspector. The thorough inspection of tubes before they are placed in the boiler, while very unsatisfactory, even taken in connection with the mill test, is about the only protection possible against accidents due to this cause.

The seamless tube will prevent accidents due to defective welding, but tubes made by this process are not always of uniform thickness, and with the cold-drawn product there are apparently internal strains produced by the process of manufacture which sometimes cause the tubes to break when merely heated. If cold-drawn tubes are used for boiler purposes, the annealed stock should be obtained. Hot-drawn seamless tubes are now meeting with considerable favor among engineers for boiler purposes.

A considerable percentage of tube failures occur without the slightest evidence as to their cause. A welded tube frequently breaks through the solid metal away from the weld, without being corroded or weakened in any way that may be detected by the eye, and without evidences of overheating. There must be some reason for such failures.

It is a fact that while pressures and rates of driving have been remarkably increased during the past 15 or 20 years, no increase in the thickness or strength of tubes has occurred. That the thicker tube is safer seems to have been demonstrated by a number of cases where heavy tubes have been used in place of those of standard gage, and tube troubles have ceased. Of course, it can be contended that the theoretical factor of safety is higher on tubes even of standard thickness than on almost any other portion of the boiler. However, under operating conditions accompanying high rates of driving, is it not possible that there are decided fluctuations in the temperature of the material in the tubes? The rapid formation of steam bubbles removes for a certain interval of time the water protection from the inner surface of a tube, and the thinner the material, the higher will its temperature rise during a given time in which it is not protected. It is conceivable that the structure of the metal in a thin tube may be affected in time by this constant change in temperature until it gives out, while the thicker tube might not be affected to the same extent by this means. This idea is only advanced as a possible explanation for some of the tube accidents which seem to defy definite causes being assigned for them.

The thicker material in the case of welded tubes will make it more certain that the required strength is obtained in the weld; also, surface imperfections in the material would not affect the strength to the same degree in the thick tube as it would in the lighter one.

The importance of the question of tube failures to the operator of boilers as well as to the insurance interest can be appreciated when it is realized that the toll of loss of life and limb exacted by such failures probably exceeds other classes of boiler accidents when the relative number of fire-tube and water-tube boilers in use is considered.

OTHER CAUSES.

Corrosion has been the cause of many serious explosions, but with boilers built accessible for inspection, explosions from this cause may be reduced to a minimum where the boilers are under the care of a competent inspection service.

A source of explosions, external to the boiler itself, but which has produced very serious disasters, is the improper arrangement of steam piping. It is very dangerous indeed to attempt to connect a boiler to a steam line where the piping is arranged so that water pockets may be formed. A water-hammer is likely to result in such cases which may break the pipe connections, and this in turn may produce an explosion of the boiler itself.

Very disastrous explosions have been due to hidden cracks or so-called lap-seam cracks. The cause of these defects is either the form of seam, poor material, improper shape of the joined ends of the sheet, or the abuse of the material in the process of manufacture; possibly it may be a combination of some of these causes. That the form of seam alone is not the only factor is well demonstrated by the fact that all lap seams do not fail in this manner and also that some seams of the butt-joint type have thus failed.

It is readily recognized that with every possible precaution, boiler explosions cannot be entirely eliminated, but their number may be lessened materially. A proper inquiry into all accidents of this kind by government officials qualified and clothed with ample authority would tend to reduce the number of explosions.

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Colored Coatings for Metal (Metallochromy.—Immerse the platina pole of an electric battery of four to six cells in a solution of sugar of lead or of a manganese salt (1 part of potassio-manganous sulphate, 12 parts of water, or 1 part of chloride of manganese in 8 parts of water, or 1 part acetate of manganese in 15 parts of water) and we shall obtain, on the positive pole, colored rings. The same effect is produced if we connect the positive pole with a platinized metal article. On brass we obtain the colored coatings by boiling litharge in a potash solution of 18 to 22 deg. Bé. and connecting the brass object with the positive pole, the negative pole terminating in a platinum plate immersed in the fluid. From time to time, litharge is added to the fluid. If the current is too strong the coloration obtained is imperfect.