March 22, 1955 D. DALIN ET AL 2,704,534

METHOD OF AND APPARATUS FOR REGULATING AND IMPROVING THE CIRCULATION IN STEAM GENERATORS

Filed Dec. 13, 1950 2 Sheets-Sheet 1

Fig. 1.

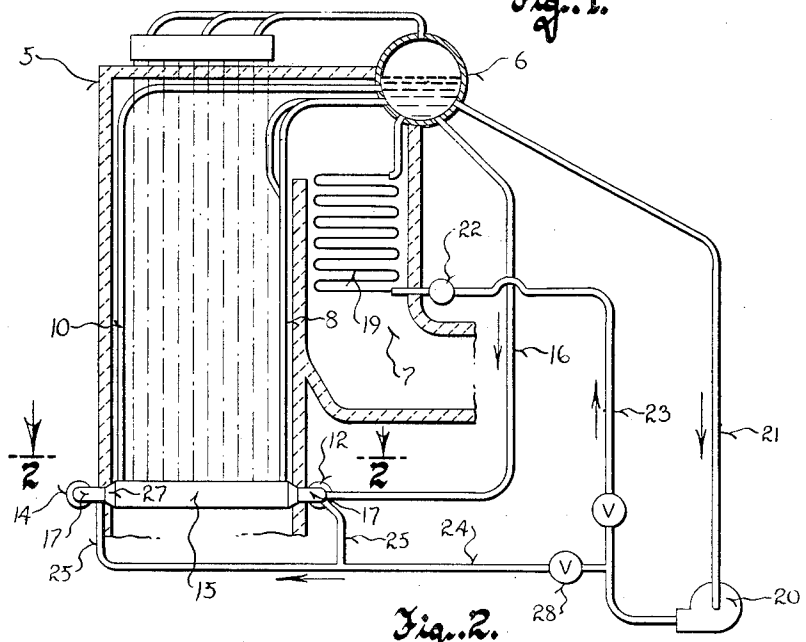


Fig. 2.

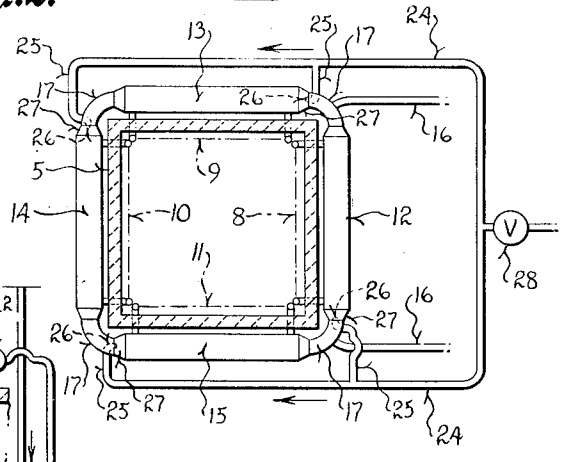
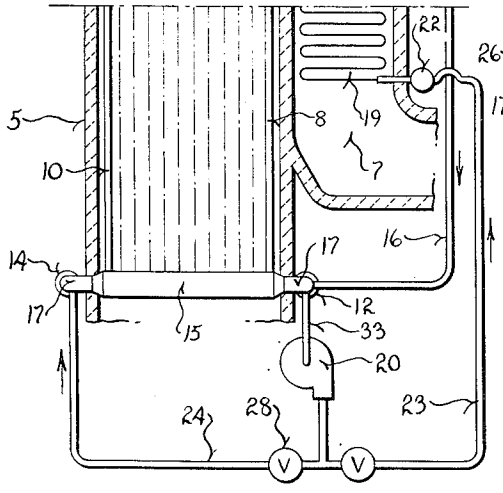


Fig. 3.



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Fig. 4.

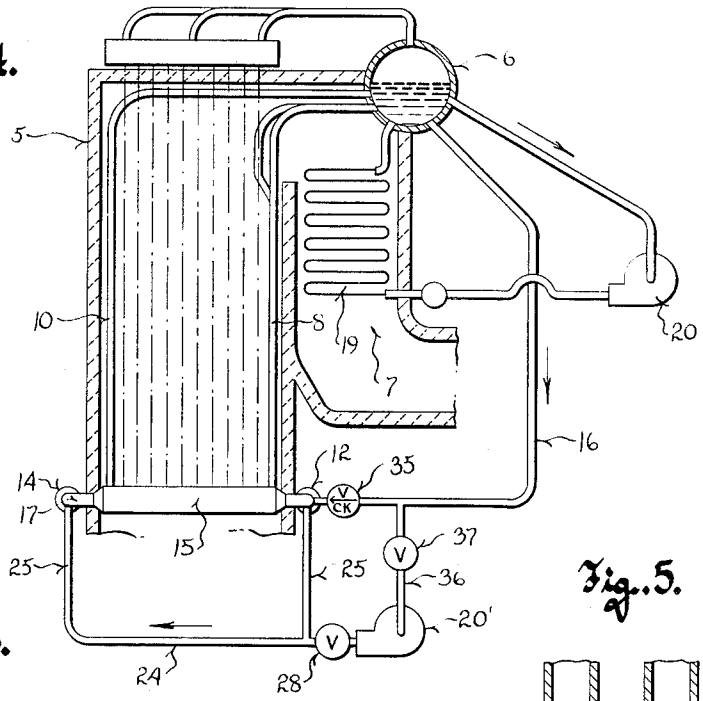


Fig. 5.

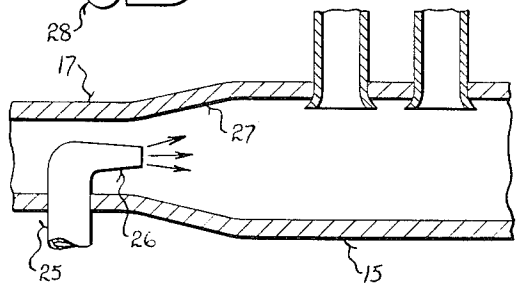


Fig. 6.

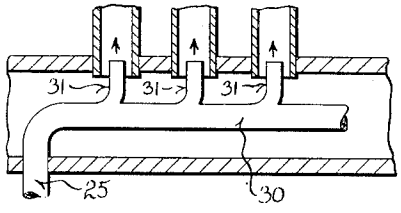
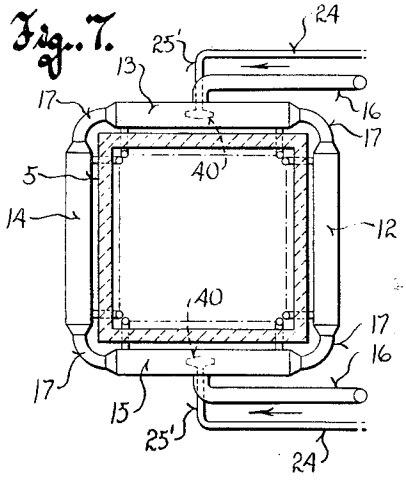


Fig. 7.



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METHOD OF AND APPARATUS FOR REGULATING AND IMPROVING THE CIRCULATION IN STEAM GENERATORS

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8 Claims. (Cl. 122—407)

This invention relates to steam generators and has more particular reference to steam generators of the water tube type.

Steam generators in which boiler water circulates through the tubes by so-called natural circulation, due to the difference in specific gravity between cold and hot water, have certain disadvantages. First of all a great space is required for the natural circulation tubes, especially for those parts of the boiler where heat is transferred to the tubes mainly by convection.

As a rule there is adequate space for the natural circulation tubes in the combustion chamber of the generator, which in any case requires a certain volume determined principally by the firing method employed and by the properties of the fuel used. Excessively large banks of tubes, however, are required in those parts of the boiler lving outside the combustion chamber or furnace, namely for the convection surfaces located in the waste gas passage leading from the top of the furnace.

In a few steam generators employing natural circulation tubes in the combustion chamber these convection surfaces have been designed for forced circulation to thus materially reduce the space requirements for the convection heating surfaces.

Steam generators employing natural circulation of boiler water in the tubes of the furnace walls, however, have another disadvantage in that the circulation of water in these tubes is irregular during the heating-up period. As a result the water might be relatively cold in some tubes while great steam generation may occur in other tubes. This irregular circulation has made it imperative that the starting-up time of the generator be extended over a relatively long period to avoid the risk of damaging the steam boiler from any of several causes, mainly from the heat stresses which might occur in the tubes and their connections. In the case of large boiler installations this long starting-up time is usually a great disadvantage since it might take several hours, and, of course, it is desirable to eliminate as much of this delay as possible.

Also, unless natural circulation type boilers are designed with utmost care it often occurs that certain tubes have an abundance of water circulating through them while other are starved. The starved tubes, of course, have a tendency to become overheated and to fail.

Accordingly it is the purpose of this invention to provide a solution to the above problems. This objective is achieved through the provision of a steam generator of the combined natural and forced circulation type, wherein the furnace tubes or the so-called water wall is designed for natural circulation, while a pump is employed to forcefully circulate water through the convection surfaces located outside the furnace. As a result the convection surfaces may be greatly reduced in size to achieve one of the objectives of the invention.

More specifically it is an object of this invention to provide a method of operating a steam generator of the character described which will eliminate the need for long starting-up periods due to the irregularity of circulation in the furnace tubes. According to this method, some of the water discharging from the pump supplying the convection tubes is diverted into the furnace tubes to improve and increase the circulation of water therethrough and to assure that the water will be more evenly

distributed in the furnace tubes, in proportion to their requirements.

In this manner the temperature of the water in the tubes of the combustion chamber and also the temperature of the walls of these tubes is more uniform over the whole furnace, and such heat stresses or localized heat concentrations as lead to tube failure can be avoided. Moreover, when the need for augmentation for the natural circulation of water through the furnace tubes has passed as, for instance, when the boiler is working under constant normal load, the diversion of water from the pump to the furnace tubes may be discontinued so that only the forced circulation convection tubes are supplied by the pump.

It is also an object of this invention to provide a steam generating apparatus with a circulation system so designed as to enable water to be circulated through the furnace tubes either by natural circulation or by a combination of natural and forced circulation.

Still another object of this invention resides in the provision of a steam generator with furnace tubes designed for natural circulation of boiler water therethrough, and with the tubes comprising the convection surfaces designed for forced circulation by means of a pump, and in which boiler water may be discharged from the pump either into the tubes comprising the convection surfaces alone or into these surfaces and also into the natural circulation tubes of the furnace to improve the circulation of water therein.

With the above and other objects in view, which will appear as the description proceeds, this invention resides in the novel method and apparatus hereinafter described and more particularly defined by the appended claims, it being understood that such changes in the precise embodiment of the hereindisclosed invention may be made as come within the scope of the claims.

The accompanying drawings illustrate several complete examples of the physical embodiments of the invention constructed according to the best modes so far devised for the practical application of the principles thereof, and in which:

Figure 1 is a diagrammatic, vertical sectional view of a steam generator embodying the principles of this invention;

Figure 2 is a cross sectional view of the generator taken on the plane of the line **2—2** of Figure 1;

Figure 3 is a diagrammatic view similar to Figure 1 but illustrating another embodiment of the invention;

Figure 4 is a diagrammatic view illustrating still another embodiment of the invention;

Figure 5 is an enlarged detail sectional view showing one manner of forcefully injecting water into the inlet headers to improve the circulation of water through the furnace tubes;

Figure 6 is a view similar to Figure 5 but showing another manner of improving the circulation of water through the furnace tubes; and

Figure 7 is a view similar to Figure 2 illustrating still another way of improving the circulation of water through the furnace tubes.

Referring now more particularly to the accompanying drawings in which like numerals designate like parts throughout the several views and particularly to Figures 1 and 2, the numeral **5** generally designates the furnace or combustion chamber of a steam generating plant. The installation includes the usual steam dome **6** located near the top of the apparatus, and a waste gas passage **7** communicating with the top of the combustion chamber and leading downwardly therefrom outside the furnace to be connected with a stack (not shown).

The generator is provided with banks of tubes **8**, **9**, **10** and **11** in the combustion chamber, arranged in an upright fashion therein to form the usual water wall for the furnace. These tubes are designed principally for natural circulation of boiler water therethrough and, for this purpose, the banks of tubes **8**, **9**, **10** and **11** are supplied from inlet headers **12**, **13**, **14** and **15** respectively, one for each bank of tubes, and connecting with their lower ends. The adjacent ends of these headers are communicated with one another by connectors **17** of slightly smaller diameter than the headers. Boiler water

from the steam dome 6 is conducted into the headers by means of two downcomers 16, the lower ends of which join with the connectors 17 at the opposite ends of the inlet header 12. The upper ends of the furnace tubes, of course, are connected with the steam dome 6 in the usual manner so that steam or steam water emulsion generated in the furnace tubes may rise upwardly therein and discharge into the steam dome. Since the tubes 8, 9, 10 and 11 are disposed directly in the combustion chamber, heat is transferred to these tubes mainly by radiation.

The steam generator of this invention is also provided with tubes defining one or more convection heating surfaces, such as the surface indicated at 19 and located in the waste gas passage 7 outside the furnace, to abstract as much heat as possible from the waste gases discharging from the furnace.

According to this invention the size of the convection heating surface 19 may be materially reduced by the forced circulation of boiler water therethrough. For this purpose a circulating pump 20 is provided having its inlet connected with the lower part of the steam dome by a downcomer 21 so as to communicate with the water space in the dome, and having its outlet communicated with the inlet header 22 of the convection tubes or heating surface 19 by means of a duct 23. Boiler water thus may be forcefully introduced into the convection tubes 19 and the steam or steam water emulsion which is generated in these tubes is conducted into the steam dome in the usual manner.

If the furnace tubes 8, 9, 10 and 11 have only natural circulation of boiler water therein while the tubes of the convection surface 19 have boiler water forcefully circulated therethrough, as has been done in a few cases, the starting-up time of the generator is quite critical and must be extended over several hours to prevent such localized concentration of heat in different portions of the furnace tubes as might result in these tubes burning out or otherwise failing. Such heat concentrations occur because of the irregularity of flow of boiler water through the furnace tubes, and it is often possible that certain of these tubes may receive an abundant supply of boiler water while others have practically no circulation therein.

This, of course, is highly objectionable, as it is impossible to maintain the furnace tubes at anywhere near even temperature, and the heat stresses which develop in the tubes and their connections may easily result in serious damage to the generator.

According to this invention the circulating pump 20 which forcefully delivers boiler water to the convection tubes 19 in the waste gas duct 7 is utilized to improve the circulation of boiler water through the furnace tubes during the starting-up time, or at any other time desired. For this purpose the inlet headers 12, 13, 14 and 15 of the furnace tubes are communicated with the outlet of the circulation pump 20 by means of a duct 24 joined to the line 23 leading to the convection surface, and branch ducts 25 leading off of the duct 24 and into each of the inlet headers. One of these branch ducts extends into each connector 17 and as shown in Figure 5 has a nozzle 26 on its extremity inside the connector directed to discharge into one end of the adjacent inlet header. The discharge end of each nozzle preferably is located in the small diameter end of a section 27 of the connector which diverges toward the adjacent end of the header. Hence, boiler water forcefully discharging from the nozzle 26 into the larger diameter header thus establishes an injector action promoting the flow of boiler water through the connector and into the header to raise the pressure therein to a value somewhat higher than that due to the static head alone.

One of these nozzles 26 is supplied for each of the headers, and the nozzles may induce circulation of water in the headers in a counterclockwise direction as seen in Figure 2. As a result of such forceful injection of boiler water into the inlet headers during the starting-up period, the pressure in the headers is increased and the circulation of boiler water upwardly through the furnace tubes is greatly improved and sufficient to preclude objectionable heat concentrations and stresses in some of the tubes which hitherto resulted in damage to the tubes or their connections, or even failure of the tubes.

In fact the circulation through the furnace tubes is improved to such an extent that substantially even temperatures can be maintained in them, and the starting-up time of the generator can be materially reduced without danger of damage to the installation.

After the starting-up period, and when the boiler is working under a constant normal load, the forceful injection of boiler water into the inlet headers may be terminated by closure of a valve 28 in the duct 24, to permit the furnace tubes to operate under natural circulation. Although the valve 28 is closed, however, the circulating pump 20 continues to forcefully circulate the boiler water into the convection tubes 19 in the waste gas passage 7.

If desired, still better circulation of boiler water through the furnace tubes can be obtained during the starting-up period by extending the branch ducts 25 lengthwise through the interiors of the headers, as at 30 in Figure 6, and by connecting nozzles 31 to the extensions 30 in line with the inlet end of each of the furnace tubes with the nozzles projecting a short distance thereinto. Hence, boiler water can be forcefully injected into each of the furnace tubes to greatly increase the normal circulation of water from the headers therethrough.

Figure 3 illustrates another manner of practicing this invention, and in addition affords as much protection as possible for the pump by minimizing the possibility of steam being drawn thereinto. In this embodiment of the invention the circulation pump 20 is located directly under the inlet header 12 and the inlet of the pump is connected to this header and thus with the downcomer 16 by means of a vertical pipe 33. Consequently, since the distribution header 12 always contains water it keeps the pump well supplied with water, and the pressure at the inlet of the pump therefore will be slightly higher than that obtaining in the remainder of the natural circulation system. This, of course, is desirable since it minimizes the possibility of boiler water close to the inlet of the pump flashing into steam during any sudden demand on the generator tending to abruptly lower the pressure in the system.

As in the preceding embodiment, however, the outlet of the pump is connected both with the conduit 24 leading to the inlet headers of the furnace tubes and with the conduit 23 leading to the inlet header 22 of the forced circulation convection tubes. Likewise, the valve 28 in the conduit 24 is used to control the injection of boiler water into the inlet headers of the furnace tubes.

In the embodiment of the invention illustrated in Figure 4 the pump 20 is used only for forcing boiler water into the convection tubes 19 in the waste gas passage 7, and a second pump 20′ is employed to improve the circulation of water through the furnace tubes. In this case the downcomers 16 lead to the headers through a check valve 35, and the inlet of the pump 20′ is supplied with water from one of the downcomers through a branch 36 leading therefrom and containing a shut-off valve 37. The outlet of the pump 20′, of course, is connected with the inlet headers of the furnace tubes in the same manner described previously except that the shut-off valve 28 is located close to the outlet of the pump to close off communication between it and all of the branch ducts 25.

This arrangement of shut-off valves 28 and 37 allows the pump 20′ to function for improving the circulation of water through the furnace tubes when these valves are open, or to permit only natural circulation of water through the furnace tubes when the pump is placed out of operation by closure of valves 28 and 37. It is to be understood, of course, that this manner of controlling the pump is illustrative only, and that in practice the pump 20′ may be driven by an electric motor, or the like, which can be controlled at will.

The benefits of this invention are also obtained with the modification illustrated in Figure 7 wherein the downcomers 16 for the furnace tubes are joined to the midportions of two opposite inlet headers 13 and 15. In this case each of the ducts 24 which connect with the outlet of the pump through the shut-off valve 28 has only one branch 25′ which leads through the downcomer 16 at its connection with the adjacent inlet header to extend into the interior of the header. The extremity of the branch 25′ in the header has an injector nozzle 40 pointing in opposite directions coaxially of the header so as to forcefully inject water toward the opposite ends of the header to improve the flow of water from the downcomer thereinto and the circulation of water through the furnace

tubes. The nozzles 40, of course, exert their influence in the remaining headers 12 and 14 as well, since all of the headers are communicated with one another by means of the connectors 17.

From the foregoing description taken together with the accompanying drawings it will be readily apparent to those skilled in the art that this invention provides a simple and highly effective manner of improving the circulation through the natural circulation furnace tubes of steam generator to not only protect the furnace tubes against damage but to materially and safely decrease the starting-up time of the generator.

It will also be understood that where the term "natural circulation" is employed in the specification and claims the conventional thermally induced circulation characteristic of the ordinary steam boiler is meant, and that the term "forced circulation" means the kind of circulation induced by a pump as in La Mont type boilers for instance.

What we claim as our invention is:

1. The method for improving the circulation in steam generators of the water tube type having radiation tubes connected in a circulatory system arranged for natural thermally induced circulation, and having convection tubes located in a zone remote from the radiation tubes and connected in a circulatory system arranged for mechanically forced circulation, characterized by the steps of: diverting part of the boiler water flowing toward the convection tubes, from said forced circulation system during the starting-up period of the generator; and discharging such diverted water into the natural circulation system for the radiation tubes in a manner to effect positive circulation of boiler fluid in the natural circulation system in the same direction that the fluid travels when only natural thermally induced circulation obtains therein.

2. In the operation of a steam generator having radiation tubes connected in a circulatory system arranged for natural thermally induced circulation of boiler fluid, and having convection tubes located in a zone remote from the radiation tubes and connected in a circulatory system arranged for mechanically forced circulation of boiler fluid by means of a pump, the characterizing step of diverting some of the pump discharge into the natural circulation system in a manner to augment the natural thermally induced circulation therein and thus assure sufficient circulation of boiler fluid through said natural circulation system as to prevent overheating of its radiation tubes.

3. In a steam generator having a combustion chamber and a waste gas passage leading from said combustion chamber: radiation tubes in said combustion chamber; means providing for natural thermally induced circulation of boiler fluid through the radiation tubes in the combustion chamber; convection tubes in said waste gas passage; means including a circulating pump providing for mechanically forced circulation of boiler fluid through said convection tubes; and means connected between the radiation tubes in the combustion chamber and the outlet of the pump to provide for diversion of some of the boiler fluid issuing from the pump into the radiation tubes of the combustion chamber for augmenting the natural thermally induced circulation of boiler fluid through said radiation tubes and thereby preventing overheating of said tubes.

4. In a steam boiler of the type having radiation tubes positioned to be subjected to radiant heat from the heat source of the boiler and connected in a natural circulation system in which boiler fluid normally circulates solely by thermal induction, and other tubes remote from said radiation tubes and positioned to be heated by convection by the hot gases flowing from the heat source of the boiler and arranged for forced circulation of boiler fluid therethrough by means of a pump: duct means connected between the outlet of said pump and the natural circulation system for the radiation tubes; and a valve in said duct means for controlling the flow of boiler fluid from the pump into the natural circulation system for the radiation tubes, the connection of the duct means with the natural circulation system being so disposed that the fluid thus pumped into the natural circulation system augments the natural thermally induced circulation of boiler fluid therein.

5. A steam generator of the type having furnace tubes positioned to be subjected to radiant heat joined to inlet headers and connected in a circulation system for natural thermally induced circulation of boiler fluid therethrough, and having other tubes outside the furnace positioned to be convectively heated by hot gases leaving the furnace connected in a circulatory system for forced circulation of boiler fluid therethrough by means of a pump: characterized by the fact that said pump is beneath one of the inlet headers for the furnace tubes and has its inlet connected thereto; and further by the fact that the pump outlet is connectable with the furnace tubes through a valved duct to enable boiler water to be forced into said furnace tubes by the pump during the starting-up period of the generator, and to enable the furnace tubes to be operated by natural circulation at other times.

6. In a steam generator of the type having a bank of furnace tubes and an inlet header joined to the lower ends of said tubes to supply boiler fluid thereto: means providing a natural boiler water circulation system for said furnace tubes; a pump; means connecting the inlet of the pump with a supply of boiler fluid; a duct extending lengthwise inside said inlet header; injector nozzles connected to said duct, one for each of the furnace tubes, and projecting into the lower ends of the tubes; and a conduit connecting said duct with the outlet of the pump so that boiler fluid discharging from the pump can be forcefully ejected from said nozzles into the lower ends of the furnace tubes to promote the circulation of boiler fluid from the inlet header therethrough.

7. The steam generator set forth in claim 6 wherein the generator is provided with convection tubes outside the furnace through which boiler fluid is forcefully circulated by the pump; and further characterized by the provision of a shut-off valve in said conduit, which when closed, effects operation of the furnace tubes by natural circulation only.

8. In a steam generator: a steam dome; a bank of furnace tubes, said tubes having their upper ends communicated with the steam space in said dome; an inlet header with which the lower ends of said tubes communicate; a downcomer communicated with the water space in said dome and connected to the medial portion of said inlet header to supply boiler water to said tubes for natural circulation of such water therethrough; a pump having its inlet connected with the water space in said dome; a conduit having one end connected with the outlet of the pump and its other end projecting through the downcomer at its connection to the inlet header with its extremity disposed inside the inlet header; and nozzle means on said extremity of the conduit arranged to forcefully inject water from the pump outlet in opposite directions in said inlet header to improve the flow of water into the header from the downcomer and consequently to augment the natural circulation of boiler water through the furnace tubes.

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