A COOLING SYSTEM AND A METHOD FOR USING A COOLING SYSTEM

A cooling system, having a first heat exchanger (33) for heating a cooling liquid and a second heat exchanger (5), which preferably consists of an evaporator, for cooling said cooling liquid, and pump means (1) for guiding said cooling liquid through said first and second heat exchanger (3, 5). The system also comprises a pellet reactor (7) through which cooling liquid is fed, so as to remove impurities from the cooling liquid by grafting said impurities onto graft material in said pellet reactor (7). Calcium salts can be grafted onto said graft material, as a result of which the concentration factor of the cooling system can be increased significantly.
Published: — with international search report — before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
A cooling system and a method for using a cooling system

The present invention relates to a cooling system, having a first heat exchanger for heating a cooling liquid and a second heat exchanger for cooling said cooling liquid, pump means for guiding said cooling liquid through pipes and through said first and second heat exchanger, a drain for discharge of cooling liquid from the system and a supply for addition of fresh cooling liquid into the system. Preferably, said second heat exchanger consists of an evaporator. The invention also relates to a method for using such a cooling system.

A cooling system and a method for using such a cooling system as mentioned above are known in the art. These known systems have the disadvantage, that deposition of salts, in particular calciumcarbonate, is obtained on the heat exchanging surfaces at relatively low concentration factor. For, if the second heat exchanger consists of an evaporator, cooling liquid is evaporated and discarded from the system. As a consequence, the cooling liquid is concentrated. The concentration factor of the cooling liquid in the system is restricted by the calcium content, or rather the solubility product of calcium salts, mainly calcium carbonate. Increasing the concentration factor beyond the limits of the solubility product, will cause calcium salt deposition, especially on the high temperature surfaces of the process heat exchangers, causing reduced cooling capacity or clogging.

Hereafter, reference will be made to water as a cooling liquid. However, it should be understood that in stead of water other cooling liquids, known in the art and alternatively comprising additives, also can be used.

The addition of fresh water is also called make-up water. Since the second heat exchanger, for cooling the cooling liquid, usually consists of an evaporator, also a substantial amount of water is removed from the system by means of this evaporator. As a consequence, the impurities contained in the water remain in the system. Since the
evaporated amount of water is made up with further make-up water, containing further impurities, the amount of the impurities steadily increases, as indicated above. In the art, it is common practice to discharge a part of the cooling liquid containing these salts from the system and to replace this part by fresh cooling liquid.

Because of the high costs of cooling liquid, the tendency in the industry is to discharge the cooling liquid continuously or periodically. Therefore, almost constantly there will be a high concentration of impurities in the water and, consequently, said known cooling systems have to be operated at a lower concentration factor by an increased blow down.

The invention now aims at providing an improved cooling system with which the problems as indicated above will be reduced.

In particular, the present invention aims at providing a cooling system and a method for using a cooling system with which less water will have to be discharged, without increasing the scaling tendency.

The invention also aims at providing a cooling system and a method for using a cooling system with which the impurities in the cooling liquid at least partly can be removed and wherein a valuable product is obtained.

To this end, the present invention relates to a cooling system as mentioned above, which is characterized in that said system is connected to a pellet reactor having an inlet and an outlet for cooling liquid, said inlet being connected to any of the pipes of the system by means of a conduit for withdrawing liquid from the system, said outlet being connected to any of the pipes of the system by means of a conduit for feeding cooling liquid from the pellet reactor back to the system, said pellet reactor comprising a graft material for grafting impurities from the cooling liquid thereon. In this way the impurities which otherwise would deposit on the heat exchanging surfaces of the cooling system, now deposit on the graft material in the pellet reactor. As a consequence, the heat
exchanging surfaces of the cooling system remain clean and the heat exchanging capacity remains constant, while operating with a higher concentration factor.

According to another embodiment the invention is characterized in that said system is connected to a pellet reactor having an inlet and an outlet for cooling liquid, said inlet being connected to said supply for the addition of fresh cooling liquid and said outlet being connected to any of the pipes of the system for feeding fresh cooling liquid by means of a conduit from the pellet reactor into the system, said pellet reactor comprising a graft material for grafting impurities from said fresh cooling liquid thereon.

According to the invention, the supply of fresh cooling liquid and the discharge of cooling liquid from the system may take place continuously or intermittently. Furthermore, since the impurities now are deposited on the graft material in the pellet reactor, the loaded graft material can be used for various purposes. Said loaded graft material mainly consists of deposited calcium carbonate.

A further advantage of the present invention is that the amount of water which has to be discharged in accordance with the known cooling systems, now to a great extent can remain in the cooling system. For, there is no further build-up of calcium impurities in the water. Therefore, less make-up water is necessary.

As a further consequence, the costs for using the cooling system are reduced significantly. For, less water is needed for supply and less discharge costs are implied. According to the invention, the thermal efficiency of the system is not altered negatively, whereas the amount of make up water can be decreased significantly.

By means of the invention, the heat exchanging surfaces remain unaltered. Therefore, the advantages obtained with the cooling system according to the invention are significant.
A further embodiment is characterized in that said pellet reactor comprises a supply for fresh graft material at a first level and discharge for loaded graft material at a second level. Such an embodiment is especially preferred if the system is used continuously. For, in that case the loaded graft material can be removed from the system and, at the same time, fresh graft material can be added to the system.

According to a further preferred embodiment, the system is characterized in that the inlet of cooling liquid to the pellet reactor is at a position below the outlet from the pellet reactor. Especially if the inlet is near the bottom of the reactor and the outlet is near the top of the reactor, it is possible that the pellet reactor is used as a fluidized bed reactor. Since the loaded graft material is heavier than the fresh, unloaded graft material, the loaded graft material will concentrate near the bottom of the pellet reactor whereas the fresh graft material will concentrate near the top of the reactor. Then, loaded graft material can be removed continuously or batch-wise from the bottom of the pellet reactor whereas fresh graft material may be added at the top of the pellet reactor.

According to the invention, if the cooling system is operated continuously, only a part of the cooling liquid needs to be fed to the pellet reactor. After a given time, a constant concentration of calcium ions is obtained in the cooling liquid.

Since heat is evaporated continuously from the system also make-up water has to be added continuously. According to the invention, the amount of Ca\(^{2+}\) ions in the cooling liquid can be controlled very precisely. Therefore, the concentration of the Ca\(^{2+}\) ions can be controlled such, that the solubility product of these ions in the cooling liquid will not be exceeded. Then, deposition of Ca salts on the heat exchanging surfaces will not occur. The concentration of Ca\(^{2+}\) ions in the cooling liquid which is circulated in the system may be higher than in the make
up water, but it should never exceed the solubility product.

According to a further preferred embodiment of the cooling system according to the invention a pellet reactor comprises a supply for adding a CO$_3^{2-}$-providing compound to the cooling liquid to be treated. Such a compound may consist of CO$_2$ gas. When added to water, almost instantaneously CO$_3^{2-}$ will be formed. Depending on the pH value of the liquid, it is also possible that HCO$_3^-$ is formed. However, such also forms part of the present invention. The addition of this compound, for example CO$_2$, may take place immediately before entering the cooling liquid into the pellet reactor. Anyway, the addition of said compound should take place somewhere at a position in the branch line, which leads from the cooling system to the inlet to the pellet reactor, or at a position near the bottom of the pellet reactor.

According to a further embodiment the pellet reactor comprises a supply for adding a pH-regulating agent to the cooling liquid to be treated in the pellet reactor. A pH-value in the range of 7 - 10 of the cooling liquid which is treated in the pellet reactor is preferred for providing deposition of calcium compounds on the graft material.

It is especially preferred if a pH-regulating agent together with the supply of a CO$_3^{2-}$-providing compound is added to the cooling liquid which is entered into the pellet reactor. By this combination of measures, a secure deposition of calcium carbonate (CaCO$_3$) on the graft material is obtained. The pH regulating agent may be added in the branch line or somewhere near the bottom of the pellet reactor.

It is especially preferred if the graft material comprises sand.

The cooling system according to the invention using the pellet reactor as indicated above mainly removes calcium impurities from the water. Therefore, there may be an increase of other impurities in the cooling liquid
which do not impart a problem that depositions on the heat exchanging surfaces are obtained but which may otherwise change the chemical and/or physical characteristics of the cooling liquid. Therefore, there still remains a preference to discharge part of the cooling liquid and replace it with new fresh water. However, the amount of water which has to be discharged from the cooling system is significantly lower than in cooling systems according to the state of the art.

According to a further aspect the invention relates to a method for using a cooling system, comprising the steps of providing:

- a first heat exchanger for heating a cooling liquid and a second heat exchanger, which consists of an evaporator, for cooling said cooling liquid,

- pump means for forcing said cooling liquid through pipes and through said first and second heat exchanger,

- a drain for discharging cooling liquid from the system, and

- a supply for adding fresh cooling liquid into the system. This method is characterized in that said method further comprises the steps of providing:

- a pellet reactor comprising an inlet and an outlet,

- feeding liquid into the inlet of said pellet reactor from said cooling system and returning liquid from the outlet of the pellet reactor back into the cooling system,

- removing impurities from the cooling liquid which is fed through the pellet reactor by grafting said impurities on a graft material which is provided in said pellet reactor. In this way it is prevented that impurities are deposited on the heat exchanging surfaces of the heat exchangers. Especially, deposition of impurities on the heat exchanging surfaces of the first heat exchanger is prevented.

According to another aspect, the invention re-
lates to a method for using a cooling system, comprising the steps of providing:

- a first heat exchanger for heating a cooling liquid and a second heat exchanger for cooling said cooling liquid,
- pump means for forcing said cooling liquid through pipes and through said first and second heat exchanger, wherein said pipes connect said pump and heat exchangers,
- a drain for discharging cooling liquid from the system, and
- a supply for adding fresh cooling liquid into the system. Said method is characterized in that said method further comprises the steps of providing:
- a pellet reactor comprising an inlet and an outlet,
- feeding fresh cooling liquid from said supply through said inlet into said pellet reactor, and feeding fresh cooling liquid from said outlet through conduit from said pellet reactor into the system, and
- removing impurities from the cooling liquid which is fed through the pellet reactor by grafting said impurities on a graft material which is provided in said pellet reactor.

Preferably, in said method according to said another aspect, the second heat exchanger consists of an evaporator.

It is preferred that the graft material is kept in the fluidized state by the cooling liquid. In such a way, a thorough mixing of the graft material is obtained which secures an excellent contact between the cooling liquid and the graft material.

So as to keep the graft material in the fluidized state the inlet to the pellet reactor is provided near the bottom thereof and the outlet is provided near the top of the reactor.

Since the graft material containing the deposited impurities which mainly consist of calciumcarbonate are
heavier than the fresh graft material particles, said loaded graft materials will find their way through to the bottom of the reactor, where they are preferably continuously of batch-wise removed from the reactor. Such a way of performing the method according to the invention is especially rendered possible if the graft material in the pellet reactor is kept in the fluidized state. Fresh graft material may be added at the top of the reactor.

So as to improve the deposition of calcium impurities from the cooling liquid on the graft material, a \( \text{CO}_3^{2-} \) providing compound is added to the cooling liquid to be treated in the pellet reactor. Preferably, such a compound comprises \( \text{CO}_2 \) gas which is added to the liquid.

According to a further preferred method a pH-reducing agent is added to the cooling liquid to be treated in the pellet reactor. Especially when combining these two measures, adding a \( \text{CO}_3^{2-} \) providing compound and a pH-reducing agent, a secure deposition of calcium carbonate on the graft material will almost always be obtained.

Further preferred embodiments of the invention will be easily deduced from the present description of preferred embodiments and from the description of the drawings hereafter.

Fig. 1 shows a schematic flow-sheet of a cooling system according to the invention.

Fig. 2 shows an embodiment according to another aspect of the invention.

According to Fig. 1, cooling liquid is forced by means of a pump 1 through a pipe system 2 to a first heat exchanger 3 where cooling liquid is heated.

Subsequently, the heated cooling liquid is forced through a further pipe 4 to a second heat exchanger 5. Said second heat exchanger 5 consists of an evaporator. The cooling liquid is cooled down in said second heat exchanger 5 by partially evaporating said cooling liquid. Loss of cooling liquid by means of evaporation is made up by addition of fresh cooling liquid through make up 12.
Subsequently, the cooled down cooling liquid is returned to the pump 1 through pipes 6 and forced again to the first heat exchanger 3 through pipe system 2, where the cooling liquid is heated. A part of the cooling liquid through the pipe system 4 is branched off to a pellet reactor 7 through pipe system 8. The cooling liquid is supplied near the bottom 9 of the pellet reactor 7. Cooling liquid which has been treated in the pellet reactor 7 is removed near the top 10 of the pellet reactor 7 and is guided back to pipe system 11 to pipe system 6.

Cooling liquid may be removed from the system through blow down 13 if necessary. Cooling liquid which has been removed this way may be made up through make up 12.

As shown in the embodiment of figure 1, near the bottom 9 of the pellet reactor 7 a pH regulating agent is added. Preferably, sodium hydroxide is added. Sodium hydroxide has the purpose of increasing the pH-value of the cooling liquid which is added to the pellet reactor 7 near the bottom 9 and which usually has a pH value of less than 7. Also, it is shown in figure 1 that CO₂ is supplied in the pipe system 8 and therefore into the cooling liquid which is to be treated in the pellet reactor 7. By this combination of measures a secure removal of calcium in the form of calcium carbonate is obtained in the pellet reactor 7, by deposition of calcium carbonate on sand.

It is shown in figure 1 that pellets are removed from a pellet reactor 7 near the bottom 9. At this position pellets which are loaded with calcium carbonate are removed near the bottom whereas fresh, unloaded graft material is supplied at the top of the pellet reactor 7.

In use the supply of cooling liquid will ensure a fluidized state of the graft material in the pellet reactor 7. A person skilled in the art will be able to determine the flow rate of the cooling liquid through the pellet reactor so as to ensure a fluidized state of the graft material, taking into account the particle size, particle weight, diameter of the reactor, height of the reactor,
etcetera. Because of this fluidized state an equilibrium will be established in the pellet reactor 7. The graft material containing the highest amount of calcium carbonate will concentrate near the bottom whereas the graft material containing no calcium carbonate at all, will concentrate at the uppermost part of the pellet reactor 7. By removing loaded graft material near the bottom 9 from the pellet reactor 7, the total amount of graft material is decreased. This is made up by fresh graft materials which are added at the top 10 of the pellet reactor 7.

The deposition of calcium carbonate on the graft material is mainly obtained by means of crystallization of the calcium carbonate.

The calcium carbonate containing graft pellets may be removed continuously or batch-wise.

For example, the loaded graft material may be removed if it contains several times as much calcium carbonate as original graft material. For example, if the graft material consists of sand particles, the amount of calcium carbonate on the said particles may amount to several times the amount of sand.

In practice, the amount of CO₂ and NaOH which is added to the cooling liquid treated in the pellet reactor 7, will depend on the composition of the cooling liquid.

In the figure it is indicated that the CO₂ gas is injected into the cooling liquid in the pipe system 8. However, the injection may also take place at the bottom of the pellet reactor 7. The injection may be obtained by means of a venturi tube, a nozzle, a static mixer, an aeration tube or any other type of reactor. It may also be added together with the supply of sodium hydroxide or any other pH-regulating agent. Furthermore, the supply of CO₂ may take place in the pipe system 4.

The graft material may be any material which is suitable for depositing calcium carbonate. For example, said graft material may consist of sand, glass, plastics, carbon, or metal or metal oxide particles. It may also consist of inorganic material, for example non-soluble
salts.

In the embodiment as described above and as shown in the figure, the branch off is provided between the first and the second heat exchanger. However, in this respect, it should be noted that said branch off may be provided anywhere in the system.

The ratio between the liquid flow through the pellet reactor and the liquid flow through the second heat exchanger (vide Fig. 1) can be set such, that a sufficient removal of calcium is obtained. As mentioned before, the calcium concentration must be such that no deposition of calcium salts is obtained. In general a higher ratio will result in a higher removal of calcium from the liquid. A skilled man will be able to determine such a preferred ratio. The LSI index (Langelier Solubility Index) is generally used for determining whether calcium deposition may occur.

Another embodiment of a cooling system according to the invention is shown in Fig. 2. According to this embodiment the pellet reactor 7 is positioned in the supply 12 to the cooling system. The pipe system 11 from the pellet reactor 7 is connected to the supply 12 of the system. In this way, fresh cooling liquid having a diminished calcium content is added to the system. Such an embodiment can be used in open systems, wherein the second heat exchanger is an evaporator, as well as in closed systems, so as to provide the system with cooling liquid having a low calcium concentration.

In the embodiment as shown in Fig. 2, the ratio between the liquid flow through the pellet reactor and the liquid flow which is fed directly to the cooling system, without being fed through the pellet reactor, can also be determined by a skilled man on the same basis as indicated above with respect to the embodiment according to Fig. 1.

An example of a specific cooling system will now be given. However, it should be noted that this is only one example of a testing facility used to prove the efficiency of the invention and is not intended to limit the
scope of protection of the invention.

The total cooling liquid volume is 150 litres. The evaporation amounts to 10 litres per hour whereas a blow-down of 4.5 litres per hour is used. Therefore, 14.5 litres per hour of make-up water is added to the system. The amount of water in the pellet reactor and its pipe system is 150 litres in total. When in use, with an addition of 14.5 litres of fresh water each hour, the calcium hardness of the liquid initially amounts to about 752 milligrams calcium carbonate per litre. After three hours the calcium hardness has reached an amount of 270 milligrams per litre, which concentration value then is kept constant.

Therefore, it is clear that the concentration of calcium ions in the cooling liquid can be controlled precisely. For example, the concentration can be controlled such that the solubility product of calcium compounds is not exceeded. In that case, no calcium compounds will deposit on the heat exchanging surfaces of the cooling system. On the other hand, a certain calcium concentration may be maintained, so as to reduce risk of corrosion problems in the system.

As a matter of fact, the pellet reactor can also advantageously be used for removing calcium content from blow down liquid, so as to decrease the concentration of impurities in water which is blown down from the system.

Furthermore, less water has to be discharged as a blow-down, which leads to increased economics of the cooling system.
CLAIMS

1. A cooling system, having a first heat exchanger (3) for heating a cooling liquid and a second heat exchanger (5), which consists of an evaporator, for cooling said cooling liquid, pump means (1) for guiding said cooling liquid through pipes (2, 4, 6) and through said first and second heat exchanger (3, 5), a drain (13) for discharge of cooling liquid from the system and a supply (12) for addition of fresh cooling liquid into the system, characterized, in that said system is connected to a pellet reactor (7) having an inlet (9) and an outlet (10) for cooling liquid, said inlet (9) being connected to any of the pipes (2, 4, 6) of the system by means of a conduit (8) for withdrawing liquid from the system, said outlet (10) being connected to any of the pipes (2, 4, 6) of the system by means of a conduit (11) for feeding cooling liquid from the pellet reactor (7) back to the system, said pellet reactor (7) comprising a graft material for grafting impurities from the cooling liquid thereon.

2. A cooling system, having a first heat exchanger (3) for heating a cooling liquid and a second heat exchanger (5) for cooling said cooling liquid, pump means (1) for guiding said cooling liquid through pipes (2, 4, 6) and through said first and second heat exchanger (3, 5), a drain (13) for discharge of cooling liquid from the system and a supply (12) for addition of fresh cooling liquid into the system, characterized, in that said system is connected to a pellet reactor (7) having an inlet (9) and an outlet (10) for cooling liquid, said inlet (9) being connected to said supply (12) for the addition of fresh cooling liquid and said outlet (10) being connected to any of the pipes (2, 4, 6) of the system for feeding fresh cooling liquid by means of a conduit (11) from the pellet reactor (7) into the system, said pellet reactor (7) comprising a graft material for grafting impurities from said fresh cooling liquid thereon.
3. A cooling system according to claim 2, characterized, in that said second heat exchanger (5) consists of an evaporator.

4. A cooling system according to any of claims 1 to 3, characterized, in that said pellet reactor (7) comprises a supply (15) for fresh graft material at a first level and a discharge (16) for loaded graft material at a second level.

5. A cooling system according to any of claims 1 to 4, characterized, in that the inlet (9) of the pellet reactor (7) is at a position below the outlet (10) of said pellet reactor (7).

6. A cooling system according to claim 5, characterized, in that the inlet (9) is near the bottom of the reactor (7) and the outlet (10) is near the top of the reactor (7).

7. A cooling system according to any of claims 1-6, characterized, in that said system comprises a supply (17) for adding a CO$_3^{2-}$ providing compound to the cooling liquid to be treated in the pellet reactor (7), preferably gaseous CO$_2$.

8. A cooling system according to any of claims 1-7, characterized, in that said system comprises a supply (14) for adding a pH-regulating agent to the cooling liquid to be treated in the pellet reactor (7).

9. A method for using a cooling system, comprising the steps of providing:
   - a first heat exchanger (3) for heating a cooling liquid and a second heat exchanger (5), which consists of an evaporator, for cooling said cooling liquid,
   - pump means (1) for forcing said cooling liquid through pipes (2, 4, 6) and through said first and second heat exchanger,
   - a drain (13) for discharging cooling liquid from the system, and
   - a supply (12) for adding fresh cooling liquid into the system, characterized, in that said method further comprises the steps of providing:
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- a pellet reactor (7) comprising an inlet (9) and an outlet (10),

- feeding liquid into the inlet (9) of said pellet reactor (7) from said cooling system and returning liquid from the outlet (10) of the pellet reactor (7) back into the cooling system, and

- removing impurities from the cooling liquid which is fed through the pellet reactor (7) by grafting said impurities on a graft material which is provided in said pellet reactor (7).

10. A method for using a cooling system, comprising the steps of providing:

- a first heat exchanger (3) for heating a cooling liquid and a second heat exchanger (5), which preferably consists of an evaporator, for cooling said cooling liquid,

- pump means (1) for forcing said cooling liquid through pipes (2, 4, 6) and through said first and second heat exchanger, wherein said pipes (2, 4, 6) connect said pump (1) and heat exchangers (3, 5),

- a drain (13) for discharging cooling liquid from the system, and

- a supply (12) for adding fresh cooling liquid into the system, characterized, in that said method further comprises the steps of providing:

- a pellet reactor (7) comprising an inlet (9) and an outlet (10),

- feeding fresh cooling liquid from said supply (12) through said inlet (9) into said pellet reactor (7), and feeding fresh cooling liquid from said outlet (10) through conduit (11) from said pellet reactor (7) into the system, and

- removing impurities from the cooling liquid which is fed through the pellet reactor (7) by grafting said impurities on a graft material which is provided in said pellet reactor (7).

11. A method according to claim 9 or 10, characterized, in keeping said graft material in a fluidized
state by the cooling liquid.

12. A method according to any of claims 9 - 11, characterized, in providing the inlet (9) near the bottom of the pellet reactor (7) and providing the outlet (10) near the top of the pellet reactor (7).

13. A method according to any of claims 9-12, characterized, in adding fresh graft material through a supply (15) near the top of the pellet reactor (7) and discharging loaded graft material through a discharge (16) near the bottom of the pellet reactor (7).

14. A method according to any of claims 9-13, characterized, in adding a CO$_3^{2-}$ providing compound through a supply (17) to the cooling liquid to be treated in the pellet reactor (7).

15. A method according to any of claims 9-12, characterized, in adding a pH-reducing agent through a supply (14) to the cooling liquid to be treated in the pellet reactor (7).

16. Use of loaded graft material obtained by means of a method according to any of claims 9 - 15, in building constructions, in civil engineering, as fertilizer, in cultivation or in agriculture.
Fig. 2
**INTERNATIONAL SEARCH REPORT**

A. CLASSIFICATION OF SUBJECT MATTER

| IPC | F28D13/00 | C02F5/02 |

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

| IPC | F28D | C02F | F01P |

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of box C. Patent family members are listed in annex.

Date of actual completion of the international search: 30 January 2004

Date of mailing of the international search report: 09/02/2004

Name and mailing address of the ISA

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