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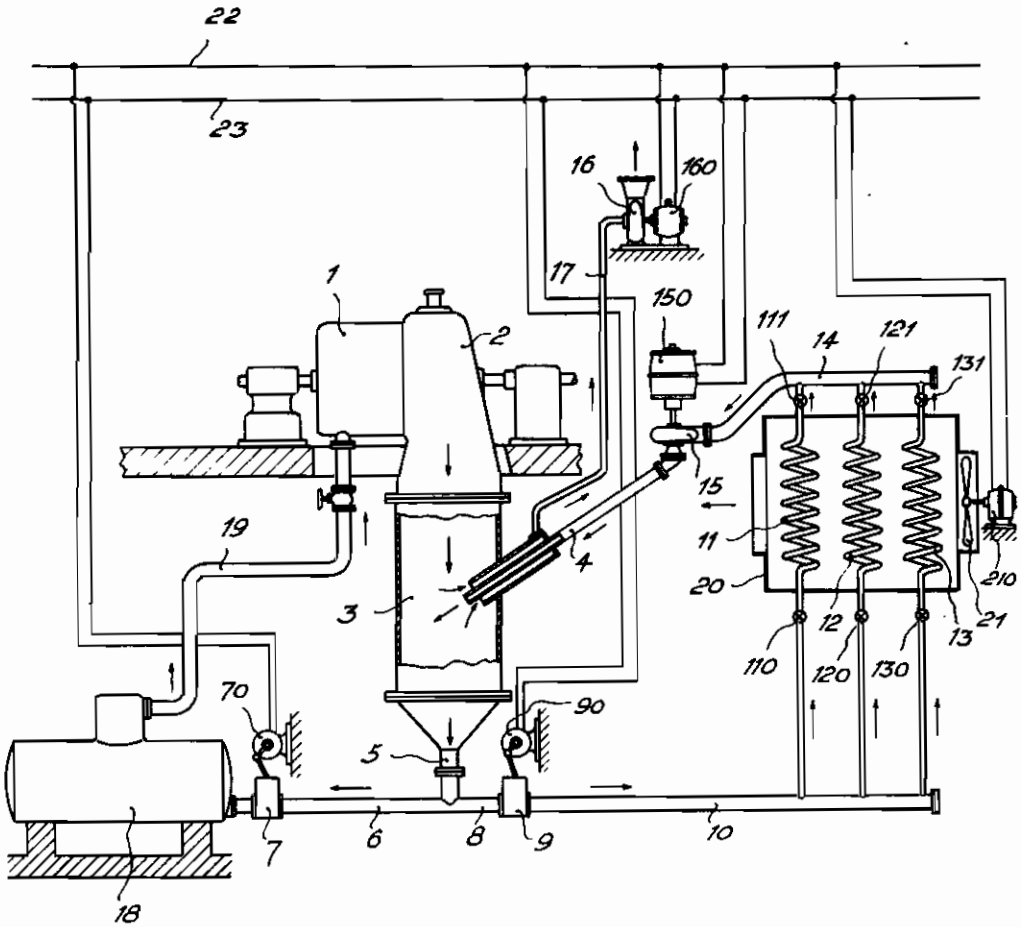

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CONDENSING SPENT STEAM

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This invention relates to the condensation of spent steam, and its purpose is to provide a condensing method which comprises the employment of cooling by air, possesses a high degree of safety of operation, and is economical, and also to provide the apparatus by means of which the new method can be successfully carried out in practice.

It is well known that the spent steam of condensing steam engines—the expression "condensing steam engines" comprising all such kinds of turbines and reciprocating piston engines, whose spent steam has to be condensed—has to be converted into water by condensation in the condenser and the heat liberated during this process has to be absorbed by means of cooling. Numerous kinds of known methods differing from each other according to whether they comprise the employment of condensers with surface cooling or of mixing condensers, and according to whether cooling is effected by means of water or by means of air, are being employed for this purpose; the operating and other properties of these methods vary widely.

The air-cooled condensers used up to now for condensing spent steam have been substantially surface condensers, in which the spent steam to be condensed was passed into the condensing chamber, the walls of this condensing chamber itself being cooled by means of air. It was in this chamber that the steam, transmitting its heat content to the condenser walls, condensed and it was from here that the condensate was removed by means of a water pump. In addition hereto the condenser was also connected to a vacuum pump, by means of which any air which had got into the condenser was removed. In addition to necessitating the employment of very costly exhaust steam mains, one of the main drawbacks of this condensing method was that in case any defect or leakage developed at any point of the air-cooled condenser, the surface of which was necessarily very large, air from the atmosphere was liable to penetrate immediately into the condensing chamber, in the interior of which a partial vacuum has to be maintained, and to impair this vacuum. The detection, during operation, of the place where the defect has developed, was, for reasons inherent to the design, practically impossible, and even with the plant shut-down such detection was a very complicated job, involving a great loss of time. A further drawback of the method referred to was that owing to the relatively high outlet velocities at which the steam left the steam turbine supplying the steam to be condensed and to the substantial length of exhaust steam piping required with this system, the outlet loss of the said steam turbine was liable to become increased in a substantial extent.

Another known condensing method is the one in which a mixing condenser is employed, the water injected into this condenser being re-cooled by means of water in a surface cooler. In the case of this method, the chemical composition of the water injected into the condenser is equal to that of the boiler feed water. The water leaving the condenser is divided into two portions, one of which is returned into the boiler as feed water, whereas the other portion is, after it has become cooled down during its flow through the surface cooler, which is cooled by means of unpurified water, again injected into the condenser. In the case of this method, accordingly, the water injected into the mixing condenser will, as it circulates in a closed circuit, not become soiled, and will therefore not require any special purification, whilst for making-up any possible losses it it easily possible to use the water introduced for making-up boiler water losses, by slightly increasing the quantity of such make-up water introduced into the system. It is an advantage of this method that any leakage of the mixing condenser, which possesses a relatively small surface, need hardly be feared; should, however, a defect develop on the water coolers, the surface of which is fairly large, this will result in unpurified cooling water getting into the boiler. This method of condensation, comprising cooling by water, can only be employed in those localities, where the necessary large quantities of cooling water are available, this circumstance excluding the possibility of its use in many cases.

I have found that by combining the two methods described above according to the invention, it is possible to obtain a method which, whilst avoiding the necessity of a supply of cooling-water, as required by the known methods employing cooling by water, at the same time possesses the economic and operating advantages of such methods, and furthermore, if carried out according to the preferred way disclosed hereinafter, possesses a substantially increased degree of safety of operation.

In the method according to the invention, the spent steam leaving the condensing steam engine, especially the steam turbine, is passed into a mixing condenser, into which air-cooled water, the chemical composition whereof is identical or substantially identical with that of the boiler feed water, is being injected. The mixture of injected

water and of water obtained by condensing the steam in the mixing condenser is drawn off from the condenser, and one portion of the said mixture is returned as boiler feed water into the boiler, whereas the remainder is passed through air-cooled surface cooler, preferably in such a manner as to cause the water to circulate in a completely closed circuit.

In a preferred way of carrying out the method according to the invention, the water pump supplying the water to be injected is adjusted so as to ensure that the pressure of the water circulating in the air-cooled water coolers should, even at the point of lowest pressure, exceed atmospheric pressure, e. g. by about 0.05 atmospheres or more. In this case the place of any defect developing on the air-cooled water coolers necessarily possessing a large cooling surface will immediately be indicated by the water escaping at that point, and, moreover, such defects cannot result in any air getting into the condenser and, accordingly, cannot cause any deterioration of the vacuum, but will only cause a certain amount of boiler feed water being lost. This loss, however, can, in view of the fact that it is very easy to ascertain the place at which the defect has occurred, be stopped very quickly, even without having to stop the operation of the plant for this purpose.

With the method described above, it is possible, according to the invention, to obtain a substantial saving of power, if, instead of throttling-down the injecting water pressure which is higher than atmospheric to the under-atmospheric pressure of the condenser, the reduction of the said water pressure is effected by passing the water through a hydraulic turbine installed into the injecting water main, and preferably located in closest proximity to the point where the water enters the mixing condenser, or even partially or wholly incorporated into said condenser. Such arrangement makes it possible to recover the amount of power required for driving the injecting water circulating pump, with the deduction of the losses, resulting from power losses in the pump and in the hydraulic turbine, as expressed in their respective efficiencies, and the pressure losses resulting from the resistance to throughflow of the piping and of the cooler.

Furthermore, it is very advantageous from the point of view of safety of operation, to effect the cooling of the water to be injected into the condenser by passing it through a plurality of air cooled water cooler units connected in parallel as this will enable any defect to be repaired also during operation, without any disturbance of service or reduction of output. Notably, if that unit on which the defect has developed is shut down in order to effect such repair, the cooling capacity thus temporarily lost can easily be recovered by putting stand-by units in commission, or, possibly, by temporarily increasing the cooling air velocities of the other units, particularly as, in any case, the whole system of cooling units has to be designed for the highest air temperature occurring during the year, which temperature therefore will probably not prevail on such occasions. A further important advantage from the point of view of undisturbed operation consists in the fact that only water of boiler feed quality circulates in the closed circuit, that is to say in the pipings, in the coolers, in the water turbine, and in the condenser, and therefore troublesome internal cleaning or removal of scale will not be required in these parts of the apparatus, and no unpurified water can get into the boiler in case of any defect.

It appears from all that has been said above that the method according to the invention will enable a very high degree of safety of operation to be obtained also in the case of condensation comprising cooling by air, whilst at the same time assuring moderate first cost, low working cost and a high steam turbine efficiency, whereas with such air-cooled condensers as were employed up to now it has not been possible to assure all these advantages simultaneously.

According to what has been said above, the apparatus according to the invention consists substantially of a mixing condenser connected to a condensing steam engine, and of an air-cooler connected into the injection water circulation of the said condenser, whilst at the same time a hydraulic turbine is preferably inserted into the water main through which the water leaves the coolers, and the air-cooled water cooler is preferably composed of a plurality of units connected in parallel. Substantial advantages of an apparatus of this type are that it requires little engine-room space, that its exhaust steam piping is inexpensive and that its condenser is relatively small-sized, added to which there are obtained, moreover, all the working advantages disclosed above.

The invention will be described further in detail with reference to the accompanying drawing, in which, by way of example, a certain form of apparatus according to the invention is illustrated diagrammatically.

It appears from this drawing, that the exhaust steam passes from the steam turbine **1** through the duct **2**, of small length and large cross-section, into the mixing condenser **3**, into which the cold water for condensing the said steam is introduced through the main **4**. The liquid mixture composed of the injected water and of the water of condensation leaves the condenser through the outlet **5**, and a part of this water of boiler feed quality is conveyed by the main **6** into the boiler feed pump **7**, whilst the remainder streams through the main **8** to the circulating pump **9**, arranged preferably in the immediate vicinity of the condenser. This pump feeds the water, increasing also its pressure above the atmospheric, into the cooling water main **10**. From this main the water, after passing through the parallel-connected air-cooled coolers **11**, **12** and **13**, possessing each a cooling surface of substantial magnitude, and being cooled-down in them, passes into the collecting main **14**, from which latter it returns again, through the hydraulic turbine **15**, into the condenser **3**, from which the air is removed by the air pump **16** connected to it by means of pipe **17**. The water fed into the boiler **18** is being converted into steam, and this steam feeds the turbine **1** through the main **10**. The coolers **11**, **12**, and **13** are provided with valves or cocks **110**, **111**, **120**, **121** and **130**, **131**, and are surrounded by the casing **20**, through which the cooling air is driven by the fan **21**. In actual practice it is, of course, preferable to employ, instead of the three cooling units shown on the drawing, a greater number of cooling units, of any suitable construction, which likewise are connected in parallel with each other between the mains **10** and **14**, and each of which is also provided with a cock or a valve at each end, for disconnecting it at will from the cooling circuit. Such cooling units also may possibly possess mutually different cooling capacities.

In the example shown on the drawing, the pumps **7**, **9** and **16** and the fan **21** are shown as being driven by electric motors **70**, **90**, **160** and **210**, connected to the mains **22** and **23** to which part of the electrical power is supplied by the generator **150** driven by the water turbine **15**. The power obtained from this turbine, however, may be used to any suitable other purpose, and the drives of the pumps, fan and eventual other accessories also may be of any other suitable kind, and disposition.

Also, various other changes may be made in the details disclosed in the foregoing specification without departing from the invention or sacrificing the inherent advantages thereof. For example, the cooling device may comprise series-connected cooling units provided with by-pass mains and valves for enabling repairs during operation, such series-connected units constituting the cooling device by themselves or being interconected in parallel with other cooling units.

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