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ENGINEERING DESIGN EVOLUTION

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Abstract

A graduate engineer, with adequate engineering background, is capable of designing an object, or part of a system or machine; and setting it three-dimensionally to scale on a drawing sheet. Nevertheless, he soon realizes that such statical three-dimensional conception is not enough to endure a practical design capable of sustained operation, within such system, without unnecessary failure.

Such lack of experience has been previously explained by us and was forwarded in the form of the fourth as well as a fifth dimensional parameters. Both parameters, however, add up to form the dynamical part of the engineering design problem; normally referred to as the designer's experience or know-how. Through their proper application in the design process; the graduate engineer is able, in our opinion, to successfully breach the gap of his practical experience in the easiest and shortest possible time.

Nevertheless, the system itself or machine undergoes a continuous process of evolutions in order to reach maturity and hence the object

under design consideration; being part of such system, has to be modified accordingly. In anticipation, and based on accumulated previous experiences, this paper sets forward a simple means by which such evolutionary process could be easily predicted" a priori", by the graduate engineer, and thus his design could be duely corrected.

Two practical sample examples have been advanced in order to demonstrate the validity as well as the simplicity of applying the proposed method.

Introduction

In a previous paper entitled " a Fifth Dimension in Engineering Design", we have advanced an explanation of the so-called designer's experience or know-how in terms of not only Einstein's fourth dimension; normally expressed as a "time" parameter but also as a complementary fifth dimension represented by the "operational state" parameter. Both the fourth and fifth dimensions, however, add up to form the dynamical part of the engineering design problem.

Nevertheless, engineering design is normally a continuous process of evolutions, performed successively by the designer, in order to reach maturity. Consequently, it is intended here to advance a simple means through which such evolutionary process could, easily and effectively, be performed. It is to noted, however, that design inventions might fit well in the evolutionary process should the idea be new and unpercidentally proposed by other designers.

The Evolutionary Process

Since, it is a known fact that nothing existing in our human world is absolutely perfect, then it must necessarily possess a certain degree of both advantages as well as disadvantages. It thus follows that any object or system, under engineering design consideration, must incorporate its own merits as well as disadvantages in achieving the goal it is intended to perform efficiently.

Moreover, and after having consulted numerous practical design problems in the engineering field, as well as tracking each to its own original basic design; it was manifested that, in each case, the evolutionary process has been conducted on a series of steps in order to reach design maturity. Meanwhile; it was also observed that the previous steps could have been contemplated on the grounds of weighing both the merits as well as the disadvantages of each design case relative to its preceding design step.

The Proposed Evolutionary Precedure

A simple means could thus, in our opinion, be proposed through which a graduate design engineer could reach design maturity in the least possible time and with least effort.

The procedure suggested, meanwhile, is as follows:

1. After stating clearly the different elements comprising each of the advantages as well as the disadvantages of the object or system under design consideration; it is recommended here to carefully weight them according to their relative merits in achieving a matured and economical design. Should they both balance then the design is basically feasible.
2. An evolution would then normally start with an effort to convert

the previously well defined disadvantage, or even a group of disadvantages, into constructive advantageous criteria through proper and adaquate engineering design proposals.

3. The resulting new design concept would naturally be a more efficient step forward. Nevertheless, it would still possess, in turn, its own advantages as well as disadvantages; which has to be weighed once more before a second evolution could be considered.
4. A second additional engineering design proposal is thus needed in order to achieve such new evolution; and the procedure is then repeated to approach the ultimate target of more matured and economical design.

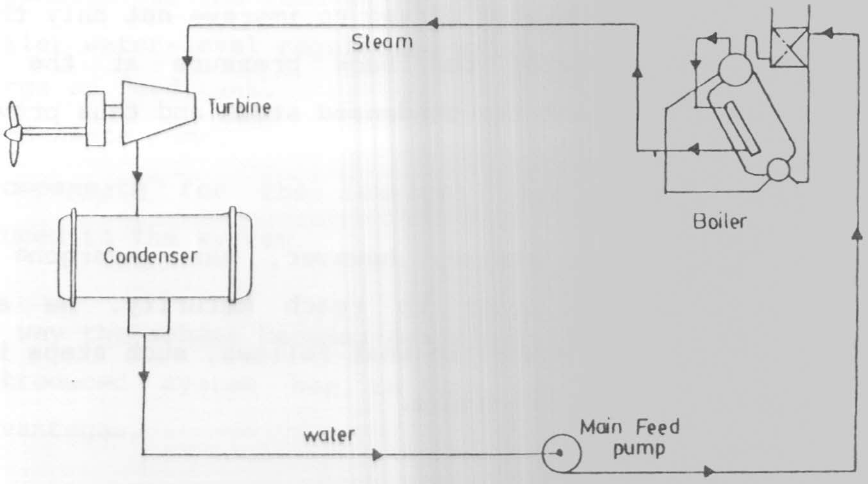
Demonstrative Design Examples

Through such means; a simple approach to the evolutionary process could, in our opinion, be easily achieved. The repeated process, however, would ultimately approach to as near a matured design as is practically feasible.

In order to clarify such evolutionary process, meanwhile, two typical examples are briefly cited here; namely the evolutionary steps followed in developing the steam feed system as well as those adopted in the case of marine boilers; in order to reach the matured designs which we contemplate at present time.

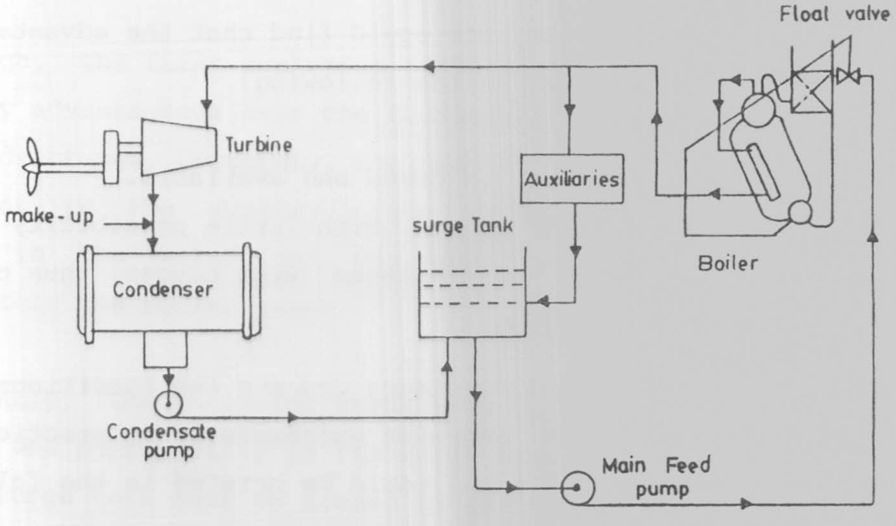
I. The Steam Feed System Evolution

In a fundamental steam feed system (Fig. 1), the steam travels from boiler to turbine hence to condenser and back to boiler. Such fundamental feed system, however, requires a pump (namely the main



Fundamental Feed System

(fig_1)



Practical Open Feed System
(fig_2)

feed pump) in order to force the water from the condenser to the high pressure boiler. It should be noted, meanwhile, that the inclusion of the condenser in the steam system serves to improve not only the cycle efficiency through decreasing the back pressure at the turbine exhaust; but also to collect the condensed steam and thus provide the boiler fresh water.

Such fundamental feed system, however, has undergone several evolutionary processes in order to reach maturity. We are thus anticipating to briefly present, in what follows, such steps in a way to demonstrate the proposed procedure.

i. First Evolution (Practical Open Feed System)

Weighing both the advantages as well as the disadvantages of the fundamental steam feed system; one would find that the advantages of such system could be summerized in the following:

- All the heat in the condenser is saved and available.
- The system is completely closed with little possibility of the boiler feed water being contaminated with oxygen; thus causing boiler tube internal corrosion.

On the other hand, the main disadvantages concern the conditions under which the fundamental cycle operates successfully in practice (the fifth dimension), which, in turn, could be briefed in the following two points:

a- Absolutely no-varying load.
b- No leakage.

Consequently, in order to render the fundamental system feasible and practical we have to add, in its design, the following items:

a. To compensate for the load variation,
  - A boiler water-level regulating valve.
  - A surge or feed tank.
  - A condensate pump.

b. To compensate for the leakage; some means for make-up feed is introduced to the system.

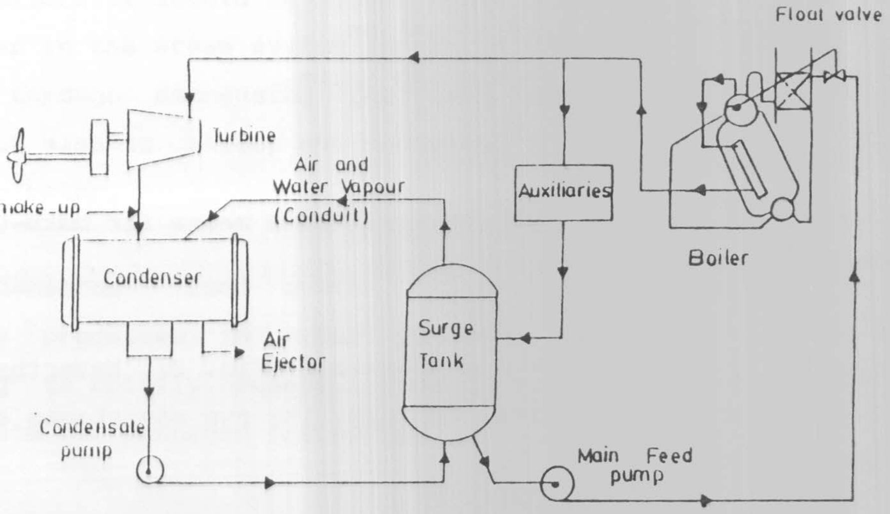
In such way the scheme becomes practical (Fig. 2). Nevertheless, the newly introduced system has, in turn, its own advantages as well as its disadvantages.

ii. Second Evolution (Closed Feed System-Deaerator below Atmospheric Pressure).

Eventhough, the first evolution (the practical open feed system) is certainly advantageous over the fundamental feed system yet it has its own disadvantages. Certainly, the open surge tank (Fig. 2) is the main weak spot in the system; since the oxygen in the air will surely dissolve in the water and the resulting corrosive solution will be carried into the boiler tubes.

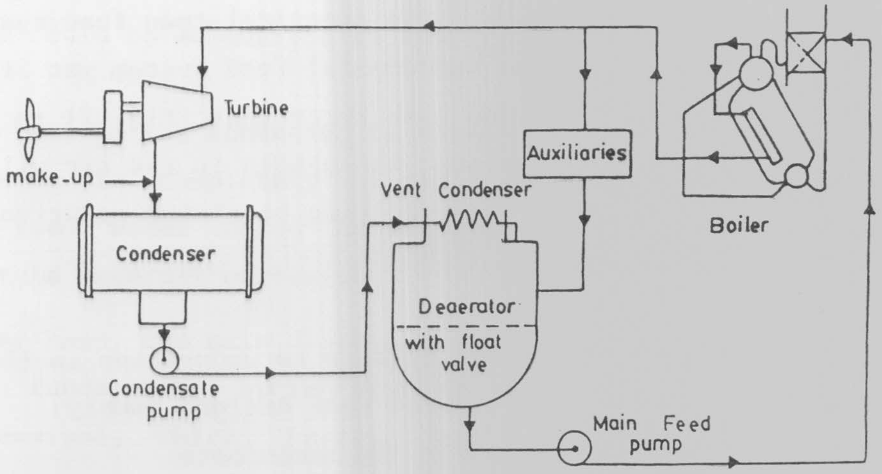
Consequently, the following steps have to be undertaken in the system (Fig. 3) and particularly in its surge tank design; namely:

- The surge tank must be closed to the atmosphere.
- The water inside the surge tank must be boiling; for better elimination of its entrained air.
- The surge tank must be vented at its top in order to get rid of any air accumulation.



Surge Tank Below Atmospheric

(fig_3)



Deaerating Tank Above Atmospheric

(fig-4)

Moreover, should the pressure inside such deaerating surge tank be set at a pressure below atmospheric; then venting must naturally be done to a still lower pressure part of the system; being in this case the condenser (Fig. 3).

iii. Third Evolution (Deaerator Above Atmospheric Pressure)

The main disadvantages of the previous evolution, meanwhile, could well be set as follows:

- Eventhough the vented air passes through the condenser and hence to its air ejector; yet all the water vapour passing to the condenser via such vent losses its latent heat to the cooling sea water.
- The resistance of the "air and vapour" flow should be kept very low. This means, in turn, that a very large pipe (conduit) or an extremely short run or both; has to be accounted for in its design; and this is often inconvenient.

Consequently, the fitting of a deaerating surge tank, above atmospheric pressure, would overcome most of the previous difficulties; besides ensuring that all the latent heat of vaporization of the boiled water is saved. In addition, the collected air in the deaerator can simply be vented to the atmosphere.

iv. Fourth Evolution (Vent Condenser)

Since for the proper deaeration of the previous system (Fig. 4) the boiling of the water inside the surage tank is needed; then valuable water is lost to the engine room in the form of fog which beside being extremely annoying is dangerous. In addition, it becomes quite impossible to obtain a perfect heat balance of the dearating unit and hence for the cycle as a whole.

Consequently, such disadvantage could be overcomed through installing a "vent condenser" on the top of the desearating surge tank. Considering the vent condenser as an integral part of the surge tank assembly, however, non of the heat of the assembly is lost. In addition, this conception greatly simplifies the heat balance of the complete system.

V. Further Evolutions

Further evolutions could still be suggested, for the previous steam feed system, in order to improve its overall efficiency through the use of feed water heating along the cycle. In this way, part of the steam bypasses the condenser; thus saving its latent heat from being lost and carried away by the cooling seawater. Such feed water heating, however, could be effected on two other evolutionary steps; namely:

a) Using Exhaust Steam from Auxiliaries

The use of the exhaust steam from the auxiliaries for heating the feed water, however, has the disadvantage that should load fluctuation exist; then the only practical way is to feed the excess steam back into the main propulsion turbines. This is bad; since at various loads several feed-back points are required and hence a better evolution would be the use of steam bled directly from the turbines.

b) The Use of Bled Steam from the Turbines

One or more feed water heaters could therefore be suggested with steam being bled from different parts along the steam turbine (Fig. 5). This results, in turn, in more definite advantages; namely:

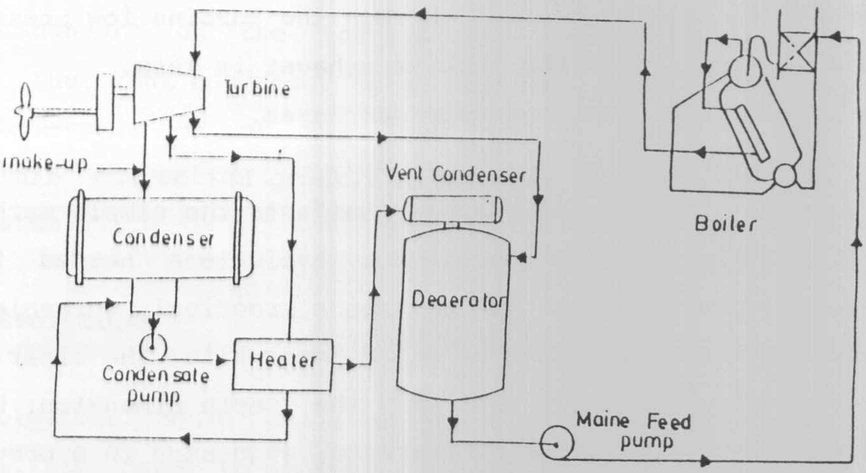
- The turbine blading design becomes more rugged; since smaller amount of steam is passing through the turbine low pressure end.
- The size and cost of the turbine exhaust is less.
- The size &cost of the condenser decreases.

Summing up, the quoted example manifests the simple method followed here in achieving the continuous evolutions needed to convert a typical fundamental feed system into a practical, workable as well as efficient system. It should be noted, meanwhile, the clear evidence of the direct application of not only the fourth dimension; but also the proposed fifth dimensional conception, suggested in a previous paper, as affecting the design procedure all along the undertaken evolutionary steps.

II **Boiler Evolution**

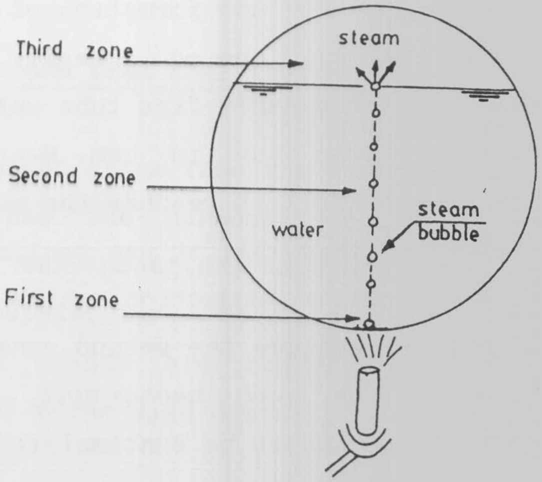
From the simple observation of the formation of a steam bubble in water, inside a heated vessel, one could easily predict why steam boilers have evolved from the early fire tube versions to the most sophisticated water tube types now in use. Eversince a bubble is formed in the vicinity of fire till it reaches the surface, passing up through the medium of water (Fig. 6), it was realized that the first zone is most important for steam production; while the third zone is needed for steam collection; whereas the second zone serves merely as a conveying medium. Based on such background, the steam boiler evolution could, in our opinion, best be contemplated.

As such, the steps followed were based on weighing both the advantages



Simple Closed Feed System

(fig_5)



Steam Bubble Formation

(fig _ 6)

as well as the disadvantages of the design arrived at in each evolutionary step. Whereas, the advancement in the design followed closely, as proposed here, those of converting their respective disadvantages into feasible, practical as well as more efficient design criteria.

i. First Evolution (Fire-tube Boilers)

The first from of practical application for the effective steam generation in a boiler would thus be realized by making use of the less effective second zone as a space for fire or what might be termed boiler furnace. Consequently, the heating surface of such cylindrical furnace becomes a first zone thus helping in speeding up steam and bubble formation; while the third zone is left at the top of the cylindrical vessel to collect the resulting steam.

Further evolutions, however, come in the form of an additional "combustion chamber" as well as tubes through which fire is conveyed to the chimeny; and thus both contribute more to the steam and bubble formation process. Moreover, the addition in the design of two, three or even four furnaces; together with their respective combustion chambers and fire-tubes, is yet another evolution in this respect to reach what is better known as the "Scotch" marine boiler which was extensively in use early this centuary.

Certain advantages are gained by the use of such fire-tube boilers; namely ease of maintenance and ability of using raw or even mere salt water in case of emergency. However, several disadvantages are obvious; namely the large space occupied as well as the increased thickness of the large diameter outer shell in order to cope with the ever increasing pressures needed for larger engine powers, thus resuling in more excessive boiler weights.

ii. Second Evolution (The Straight Water-tube Boiler)

In a way to obviate such disadvantages, a smaller diameter drum was thought of, in the design, instead of the larger diameter outer shell of the Scotch boiler. The smaller diameter drum, however, was used as a third zone to collect the generated steam; while horizontal straight tubes, with their much greater heating surface and inside which the water flows, were used as first zone for steam generation. Sectional headers were then introduced, as a second zone, conveying the generated steam to the drum; and thus the straight water-tube boiler evolved as a still more efficient way of generating steam.

Other evolutions to this new type of steam boiler, however, were then considered. When it was later observed that the generated steam was partially blocked inside the tubes by the incomming colder water, the tube bank was set at a slight angle to the horizontal thus ensuring better water circulation and hence speeding the process of steam bubble formation. The introduction of water-walls, in place of the bulky fire bricks, was yet another evolutionary step; while the use of superheaters presented a milestone in the further development of such boiler type towards the more efficient production of steam for still higher engine powers.

iii. Third Evolution (The Bent Water-tube Boiler)

Still another method for the effective formation of steam evolved through adopting an extra drum; namely the water or mud drum. Not only the bent water-tubes connect both drums but also the water-wall tubes as well; thus simplifying the overall boiler design. It is worth mentioning that the introduction of the outside downcommer tubes, connecting also the two drums, helped greatly the water circulation of such type of boiler.

Other evolutions which followed, however, were the introduction of the mono-wall construction as a more efficient design of water walls; besides the elimination of the heavy and bulky brick-work inside the boiler furnace. Evolutions in the heat recovery equipments, in the form of economizers and air heaters, are yet further milestones which helped to evolve such type of boiler into a more efficient and economical means of steam production. The subsequent evolution, however, of both the regenerative as well as the steam-air preheaters are also worth mentioning.

iv. Other Boiler Evolutions

Still other evolutions in steam generation and control, in the boiler design, also followed. Mention is given here to few such advancement; particularly those related to the use of reheaters, attemperators, etc. Moreover, the evolution of the topfired boiler as well as the external superheater designs of the ESD-type; not to mention the fluidized-bed boiler are yet milestones in that continuous evolutionary process.

It should be emphasized, however, that each of the former evolutionary steps was arrived at by simply weighing both the advantages as well as the disadvantages of the previous design; before converting their subsequent disadvantages into remunerative advantages. Moreover, the application of both the fourth as well as the fifth dimensional conceptions, at the different evolutionary steps of the boiler design development, is obvious in helping to achieve that end.

Conclusion

A simple method has been forewarded for the systematic evolution, of any particular engineering design under consideration, through converting its well defined disadvantages into practical and workable advantageous design proposals. It also makes use of both the fourth as well as the fifth dimensional conceptions in order to reach design maturity in the shortest possible time.

Two practical sample examples, however, have been cited in some details; demonstrating the simple and direct nature of the proposed method.

References

Bahgat, F. "A Fifth Dimension in Engineering Design" Proceedings of the Alexandria Engineering AEJ., Vol. 27 No. 2 April 1988.