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A FIFTH DIMENSION IN ENGINEERING DESIGN

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ABSTRACT

A matured engineering design is normally an efficient one. When properly excuted, it will not only help in the economical performance of its respective overall system; but also in reducing the stopping time of operation through the consequent improvement in maintenance and repair requirements.

This paper deals with a philosophical look on the concept of the matured engineering design process. It gives justification for the explanation of a matured design through the application of not only Einstein's fourth dimensional conception as a "time" parameter; but also on an additional fifth dimensional conception represented here by the "operational state" parameter. These two conceptions, however, collectively demonstrate the dynamical part of the design process or what might be termed the "designer's experience".

Consulting both the fourth and fifth dimensions, meanwhile, a graduate engineer with a caquate technical background, could easily develop his statical three-dimensional design into a state of maturity in the least possible time; thus covering his own experience gap. In so doing; numerous (nearly thirty) practical engineering design problems have been forwarded, in this treatment, in order to demonstrate the justification of adopting a fifth dimensional conception; in addition to the previously recognized fourth dimension.

I. INTRODUCTION

When confronted with a particular design problem a graduate engineer, with appropriate technical education background, usually resorts to its presentation on a scale drawing in the familiar three-dimensional manner. Should his design be practically excuted; he soon realizes that his preliminary three-dimensional conception is not sufficient to develop a reasonably matured design. It would not, in many cases, sustain continuous operation for a long period without undue failure; nor would it be free of maintenance troubles as could practically be endured.

Normally a more experienced design engineer would add up to such preliminary design his own experience and previous accumulated knowledge taking unforeseen factors into due consideration. One such item which has evolved over the years; although not clearly exposed, is the introduction, in the design procedure, of the time factor previously proposed by Einstein as a fourth dimension. Moreover, with the advent of more technological advancement, need is required to introduce still another factor; namely a fifth dimension in order to help achieve that goal. Through such approach, however, a graduate engineer would normally overcome his experience gap by simply taking into account such added dimensional conceptions "á priori" in his original design.

Consequently, it is anticipated to present a brief acount of the first three dimensional concepts together with their respective influence in promoting the initial design process. Moreover, numerous practical sample examples are then presented in order to justify the need for the introduction of not only a fourth dimension; but also a complementary fifth dimensional conception in a way to reach a matured practical engineering design .

2. ZERO AND SINGLE DIMENSIONS

The Webster Dictionary defines "a point" as a geometric element of which it is postulated that at least two exist and that two suffice to determine a line. Hence, a point can represent what might literary be termed a "zero dimension".

On the other hand, "a line" which is defined as "a geometric element generated by a moving point and that has extension only along the path of the point", might well be considered a "single dimension". Consequently, in engineering design drawing terms, a single dimension (either a straigh line of a curve) could well represent a linear measure.

3. THE TWO DIMENSIONAL CONCEPTION

The term "two dimensional" is defined by the same dictionary as "having two dimensions or lacking depth in characterization". Consequently, it can be represented, in its simplest form as for example in an engineering drawing, by only the length and breadth of the object under consideration. It thus becomes easy to obtain the area of such object; since that area is merely its length times its breadth. Hence, "a two dimension" represents more realistically, in its simplest form, an area measure rather than a linear measure as obtained from a single dimension.

3.1 Two-dimensional Graphical Presentation

It is a well known fact that a graph; being the collection of all point whose coordinates satisfy a given functional relation, (with the x-axis representing the abscissa and the y-axis representing the ordinate) may well be regarded as a two-dimensional presentation.

The following, however, give some typical examples demonstrating the wide scope of application the two-dimensional presentation as assisting the engineering design process.

3.1.1 Area

(Fig. 1) shows a certain relationship which exist between the x and y coordinates represented here by the drawn curve; in the region between points a and b. Should each of these coordinates denote a length i.e. a linear measure, then the simple integration of that curve between these two limits would render its area; since

$$A = \int_a^b y \, dx$$

Nevertheless, should the coordinates x and y demonstrate different quantities other than length; one would expect to get various presentations for such area.

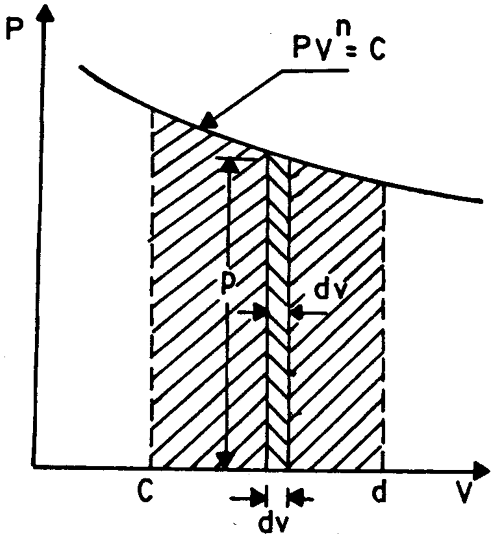
3.1.2 Workdone

(Figure (2) demonstrates one such example as given by the well known p-v diagram, normally used in heat engineering problems, where both p and v represent the y and x axis respectively. Consequently with the abscissa v representing the volume of a certain gas and with the ordinate p denoting its pressure, the shaded area, given by the integration of the (Pv^n = const.) curve in this case, would represent the work done by that gas in an engine or device; since

$$W = \int_c^d p \, dv$$

3.1.3 Quantity of Heat

Another example is the (T-s) chart used frequently in steam engineering problems; where the absolute temperature T



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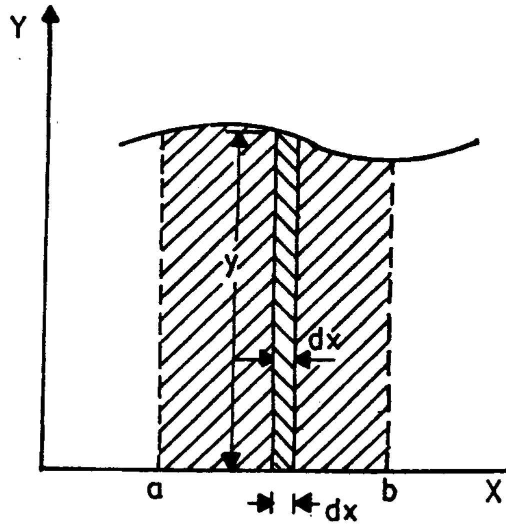

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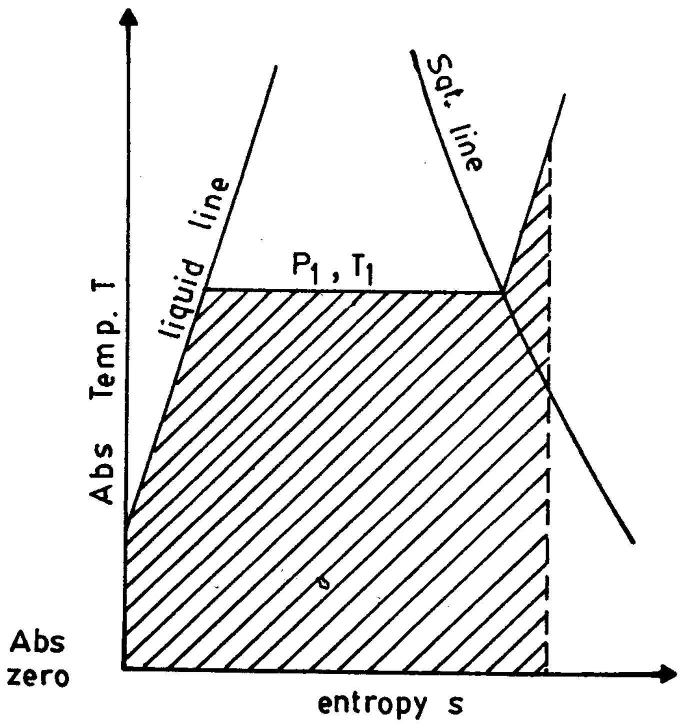

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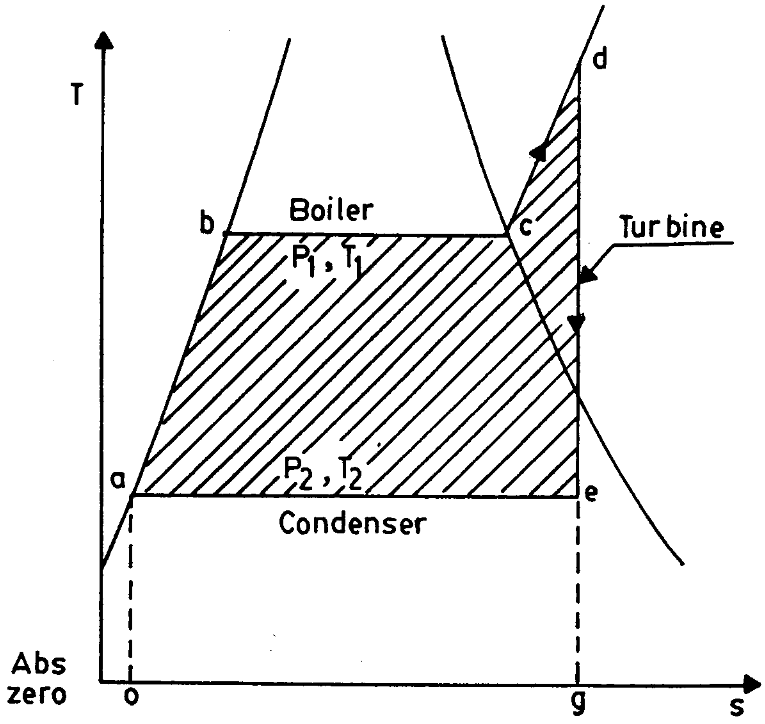

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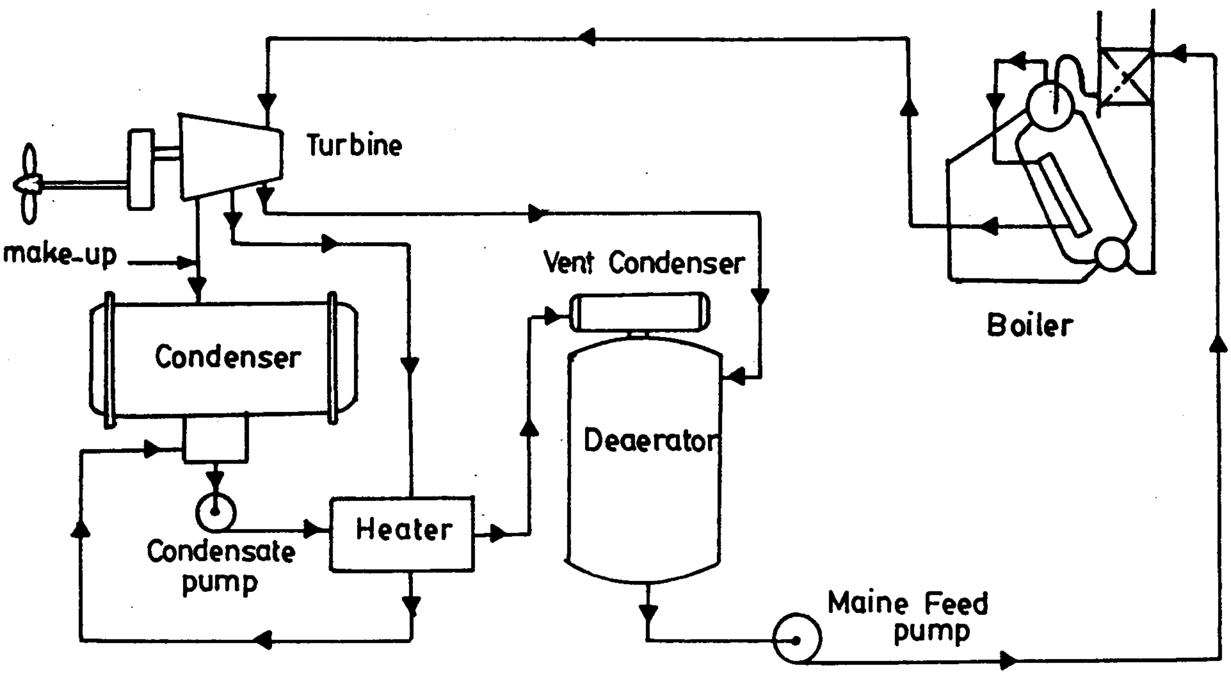

Simple Closed Feed System

(fig -5)

represent the ordinate or y-axis; while the entropy s denotes the abscissa or x-axis of the chart. In such case, however, the shaded area of the diagram shown on (Fig. 3) represents the quantity of heat being added or rejected during a certain process; since

$$Q = \int T \, ds$$

3.1.4 Heat Cycle

A complete heat cycle can also be presented two-dimensionally on either a (p-v) or a (T-s) chart or the like. A sample, however, is given for a typical Rankine steam cycle as presented on a (T-s) chart (Fig. 4) by the process followed by the events (abcde). The quantity of heat added, in this case, is demonstrated by the area (0-a-b-c-d-g) being that heat given by the boiler; while the cycle heat rejected (in the condenser) is shown by the area (0-a-e-g). Consequently, the useful heat can simply be represented by the shaded area (A-b-c-d-e) on the diagram. It thus follows that the thermal efficiency of the Rankine cycle can be easily expressed as follows:

$$thr = \frac{\text{useful heat}}{\text{heat added}} = \frac{\text{shaded area (a-b-c-e)}}{\text{area (0-a-b-c-d-g)}}$$

It should be noted, meanwhile, that not only the cycle efficiency as well as its steam rate could readily be determined by means of such two-dimensional presentation; but also two cycles could visually and easily be compared.

Summing up, the previous sample cases demonstrate to what extent could a two dimensional presentation, in the form of a graph or diagram, help the design engineer obtain useful preliminary information greatly needed in his original design. Such information, however, may be in the form of either area, work done, quantity of heat, efficiency etc., or even the simple visual comparison with other cycles under consideration.

3.2 The Two-dimensional Potential Flow

Not only the two-dimensional conception is of direct assistance to the design engineer; but it is still helpful in simplfying the solution of certain complicated design problems he occasionally meets. Various problems in fluid engineering, for example, are being solved through that way. Mention is given here to one such problem normally met in the design of marine propellers; namely the development of a matured circulation theory upon which such design could be comprehended.

A marine propeller is normally considered as being a rather complicated engineering design problem and hence the need for the development of a specially tailored theory that could overcome the discripances involved. In the simplified solution of such a problem, however, a two-dimensional approach is being followed. Within such approach, the three-dimensional propeller blades are temporarily ignored; being replaced first by lifting lines. Consequntly, the marine propeller is thus being represented by a equivalent actuator disc and hence could be directly treated as a two-dimensional potential flow problem. It could thus be readily solved by the use of either Laplace differential equation or by Biot-Savart law or even by the electrical analogy method. The resulting propeller blade basic pitch as well as its camber could then be determined for each blade section.

Consequently, the two-dimensional approach serves as an effective tool and a preliminary step towards the final marine propeller design which has, in turn, to take in due account the third dimension; as will be explained later.

3.3 Two-dimensional System Presentation

Generally speaking, each of the devices or items considered in the engineering design under treatment is usually conceived as part of a particular system; serving either a mechanical, an electrical or even a chemical process. Such system; however, is normally expressed by means of a line drawing i.e. a two-dimensional presentation; in which the object under design consideration forms an active part.

(Fig. 5) presents a typical example of a feed system as used in a steam power plant which could serve either a land or a marine propulsion machinery. It comprises many devices such as boilers, main as well as auxiliary steam turbines and condensers, deaerators, besides many heaters and various pumps etc. Each of such items, however, could in turn be designed separately within the framework of that feed system. Nevertheless, one has to keep in mind, in their respective design, the proper and efficient functioning of each item in order to render a practical as well as an overall economical system.

It should be born in mind, meanwhile, that heat balance calculations, which are usually performed on such two-dimensional feed system, would render certain useful information needed for the preliminary engineering design of each of the parts comprising such system. Determination of such items as the quantities and rates of both steam and water, temperatures as well as pressures etc. needed in each part could readily be calculated. Moreover, economical consideration could also be taken into account through the determination of the system overall fuel consumption at the various part, full and over loads.

It should be noted, however, that other systems, used in connection with say Diesel engines, such as the cooling, the fuel oil, the lubricating oil systems etc. can also be readily treated in a similar manner.

Consequently, one could thus envisage that the two dimensional presentation of a system renders useful information much needed in the preliminary design stage of not only that system as a whole; but also each of its individual constituents.

4. THE THREE DIMENSIONAL CONCEPTION

The term three dimensional is defined by the Webster dictionary as follows: "giving the illusion of depth or varing distance used of an image or a pictorial representation". In otherwords, in addition to the length and breadth measurements, in a two-dimensional engineering drawing, the introduction of the depth measure would thus render its three dimensional presentation.

4.1 Engineering Drawing as an Engineering Language

When confronted with a specific engineering design problem; the design engineer usually starts by conceiving his preliminary ideas on the drawing sheet in a sort of plan or any other two-dimensional view presentation. Nevertheless, the introduction of an added two-dimensional view or more,to his drawing,would greatly help the designer to apprehend and visualize his design more realistically. He can also make any alterations in his original design to cope with a certain specific condition he deems appropriate with much ease; while taking other factors in due consideration. His aim being always to arrive at as nearly a perfect design as his engineering education, knowledge, as well as experience would allow him to do so. It is worth mentioning, meanwhile, that an engineering student normally finds it easy to see an actual three dimensional configuration drawing of the object under design consideration. However, with increased experience the student successively trains himself to see two or more two-dimensional views and think in terms of a three-dimensional visualization. This being the art followed by practically all engineers; and in fact it developed to be nearly considered as a language of its own through which engineers could intelligently and literary converse through the art of proper engineering drawing channels.

4.2 The Three-dimensional Presentation

It should be noted, meanwhile, that the introduction of a third dimension, in the design process, would allow the design engineer not only to express more precisely the object under consideration through the proper engineering drawings; but also to help him obtain certain useful information needed to reach a more matured design. There are certainly a great number of such design examples, nevertheless, we are going to present, in what follows, a few sample problems for demonstration.

4.2.1 The volume measure

It was indicated previously that a depth was needed, by definition, for a three-dimensional presentation; in addition to both the linear measures of length and breath of the item under design consideration. Consequently it represents, in its simplest form, a measure of volume; being merely the multiplication of the previous three measures.

Furthermore; since the two-dimensional graphical presentation was expressed in the x and y directions, hence the introduction of the z-axis (perpendicular to their plane) would presumably indicate a third dimension. It thus follows that whereas the integration $\int y dx$ was shown to express an area in the two-dimensional presentation; then the integration $\iint y \, dx \, dz$, on the other hand would generally indicate a volume measure in the three-dimensional conception.

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4.2.2 Ship hull form design

It is well known that modern ship design is determined completely by purpose and that the shaping of the underwater hull is planned so as to move the vessel through water with a minimum power wastage.

The form of a ship, meamwhile, is delineated on a scale drawing known as the lines plan. This consists mainly of the following three views; namely:

- Profile (Elevation)
- Half breadth plan (Plan view)
- Body plan (sectional view)

Each of these three views, however, is a two-dimensional presentation of its own. Nevertheless, certain information could readily be obtained from their separate as well as from their combined consideration.

a. Two-dimensional information

A typical example of the information that could be obtained say from the two-dimensional body plan is the construction of the curve of area of immersed sections; which is very useful in the design of form; since

- The area under the curve represents the displacement of the ship.
- The centroid of the area coinsides with the ship's longitudinal center of buoyancy (L.C.B).
- The ratio of the area under the curve to the area of the circumscribing rectangle is the ship's prismatic

coefficient C_p.

It should be noted, however, that if the curve of immersed sections, obtained from the previous ship or from other data, may not give the position of L.C.B. desired for the new design; the previous curve can be modified and the design corrected.

b. Three-dimensional information

Furthermore, through the consideration of the lines plan, in a three-dimensional presentation, one is able to calculate the ship's volume displacement at different drafts. In addition, he can obtain beside others; the various ship's hydrostatic curves as well as such information as needed say in the ship's stability calculations at different angles of heel. With such and other information at hand; one could easily alter his original design accordingly.

Summing up, not only the two-dimensional treatment offers valuable design information, but also the three-dimensional conception adds up still needed design criteria in order to arrive at a more matured design.

4.3 Three-dimensional Flow

We have previously visualized the case of marine propeller blades in two-dimensional flow; through which both the blade basic pitch and camber distributions along the radius as well as the resulting induced velocities could be determined. It should be noted, however, that with narrow blades; the variation of these induced velocities along the blade chord may be neglected and thus the use of the two-dimensional lifting line theory could be justified.

Nevertheless, with broad blades, associated with marine propellers, this would not be the case and the propeller blade has be represented by a lifting surface rather than a lifting line; since the induced velocities vary in a chordwise direction. This amounts to treating the marine propeller in three-dimensional flow rather than in two-dimensional flow as per the lifting line theory. With the application of the three-dimensional conception, meanwhile, the curvature of flow, in the way of marine propller blades, could be calculated and hence the basic pitch and camber have to be accordingly corrected.

Summing up, in the design of marine propellers a threedimensional approach, rather than a two-dimensional one, would ultimately lead to a more practical design developing the required thrust needed to drive the ship at the specified speed.

5. THE NEED FOR EXPERINCE

Generally speeking,through adopting both the two as well as, the three-dimensional conceptions; a graduate engineer with proper engineering background is normally capable of setting intelligently, on a two-dimensional drawing sheet, any specific engineering system he is asked to design. Such system, meanwhile, usually includes several individual items or devices for which he can also, in turn, design each of its particular parts. In addition, the graduate engineer is able, through the same means, to obtain certain scientific information needed at that stage in order to reach his goal. Consequently, a scale drawing, in three-dimensional views, could then be set; from which the part under design consideration could later be practically excuted.

Nevertheless, when pursuing such design work over the years; it becomes evident to the design engineer that certain criteria has evolved during its practical performance which might affect its proper functioning; not only individually but also within its comprising system. Consequently, such relevant accumulated experience has to be duely considered by the design engineer " a priori" and hence his future designs corrected accordingly. This actually amounts to bringing about a more matured practical design which would conform and function more efficiently within its respective system.

In what follows, meanwhile, we are anticipating to set the basis for a philosophical approach upon which such so-called designer's experience could, in our opinion, best be classified. This is carried here, on two steps. The first step being the adoption of Einstein's fourth dimensional conception well known as the "time" parameter; while the other is a proposed fifth dimensional conception entitled the "operational state" parameter.

It is only through such simple approach; that the matured engineering design process could be more easily expressed and rightly appreciated by design engineers. Moreover, a graduate engineer may find in it also a ready tool to overcome his lack of experience and hence reach design maturity in the shortest time and with least effort.

6. THE FOURTH DIMENSIONAL CONCEPTION "time" PARAMETER

6.1. Definitions

The defintion given by the Wester dictionary for the term fourth dimensional is:

- Relating or having for dimensions (space-time continuum)
- Consisting of or relating to elements requiring for coordinates to determine them.

While, the definition of time is given as, "a quantum which lacks special dimensions and in which events succeed one another from past through present to future".

6.2 Application of Einstein's Hypothesis

In the presentation of his relativity theory, early this centuary, Einstein introduced a fourth dimensional conception in the form of space-time continum. It is anticipated in the present treatment, meanwhile, to apply such time parameter to the field of engineering design and forese to what extent its application help in maturing the design procedure.

Although there are practically unlimited examples, in the different fields of engineering application; we are going to select few such examples in order to demonstrate the effectiveness of using the fourth dimension in the design process. The two selected main sample topics, meanwhile, are boilers and ships respectively.

6.3 Application to Boilers

In what follows few practical examples are given in order to demonstrate the impact of applying the time parameter in helping to advance a sustained practical performance of the boiler through the proper design of its relevant parts as a result of adopting the fourth dimensional conception.

6.3.1 Boiler Tube Corrosion

Three different cases are sighted in this particular example; namely

a. Main boiler tube corrosion

In a closed steam feed system; air leakage is anticipated in those parts of the system subjected to vacuum. Moreover, there is a great possibility of the boiler feed water becoming contaminated with oxygen which would, in time, cause boiler tube corrosion. Consequently, need is required to include in the system " a priori" an air-ejector as well as a deaerator. With the proper introduction of such devices in the design of the feed system; oxygen contents could be guaranteed below a certain permissible and safe limit; thus insuring sustained uninterrupted system operation free from corrosion failure.

b. Economizer tube internal corrosion

i. When the feed water to the economizer is contaminated with oxygen; such oxygen is releases in the economizer as the heat is applied; and over an extended time of operation internal tube and header corrosion results. Consequently, deaerating feed water heaters should be installed in the system in order to remove all traces of oxygen from the feed water.

ii. Moreover, if an economizer leak is allowed to persist, even for a very short time, corrosion-erosion damage can result. It is, therefore, advantageous to design economizers with minimum joints and, in general, header tube joints are to be either fully welded to headers or even to nipples in the headers.

c. Air-preheater external corrosion

Experience indicates that external corrosion is likely to occur in boiler airheaters, after a period of time, due to one of the following reasons:
i. The overcooling of the gases of combustion below the dew point of the flue gases, when the boiler is steaming at very low loads, and those tubes nearest to the cold air inlet

are, of course, particularly susceptible to corrosion. Sulphur contents of the fuel, moisture contents of the gases and the type of firing, however, are important factors in lowering the temperature. Nevertheless, external corrosion is prevented best by designs which do not allow operation with low tube metal temperature; and there are actually several design methods by which such air heater corrosion can be controlled.

ii. Corrosion of tube plates due to soot deposits and damp atmospheric conditions when the boilers are standing. Hence, it is recommended that all boiler designs should incorporate means for by-passing the air direct to the furnace when lighting up and under very light loads.

6.3.2 Superheater Slag and Bonded Deposits

Steam boilers suffer greatly from the slagging problem particularly when using troublesome fuel oils over a long period of time. The bonding, however, is due to fusing temperature of the fuel constituents (e.g. vanadium, alkali sulphates, etc) which become sticky at these temperature; and consequently considerable slag is formed on the front portions of the superheater. Moreover, if the slag formed is not properly removed, and the boiler operation is continued, the slag deposits will then build up throughout the rest of the superheater element resulting in progressive superheater slagging.

The elimination of the bonded deposits, however, could best be achieved through the incorporation of certain design features in the orginal boiler design. such design features would normally require larger and heavier boilers. Nevertheless, such units would be more economical to operate;since their maintenance would be materially reduced.

6.3.3 Boiler Furnace Heat Stresses

Boiler furnaces are usually subject to high stresses resulting unequal expansions and could become extremely dangerous with prolonged time of boiler operation particularly with high firing rates. Consequently, in the design of the boiler furnace; a cubical configuration is considered an effective solution. Moreover, the proper consideration of the other factors which affect the furnace dimensions, in the boiler design, could help greatly in reaching that goal. Such factors as the type of boiler, operation and service condition, space and weight limitations, burner arrangement and gas flow as well as the amount and circulation in the furnace waterwalls; have to be taken in due account also in the boiler design. should such factors be properly considered in the original design, however, it would result in prolonged periods of safe operation of the boiler unit.

6.4 Application to ships

6.4.1 Ship bottom corrosion

Normally hull steel corrodes slowly in sea water. However, the problem is not one of general wasting away; but rather one of localized pitting at higher rates of corrosion. Pitting is basically an electro-chemical effect; the loss of material occuring whenever electric currents flow, for a long period of time, from metal to sea water. The two most vigorous forms of hull corrosion, meanwhile, stem either from stray electric currents or from galvanic currents. On the other hand, mill scale corrosion occurs when the relationship between certain factors is unfavourable. The surest way of avoiding scale mill corrosion is to pickle and sandblast the underwater plating before the vessel is delivered and this has to be set in the design specifications.

Neverleless, the uses of zincs and other cathodic protection materials do not necessarily protect the hull by sacrificing themselves; but by shouldering most of the burden of corrosion caused by the propeller on the bare steel in its vicinity. In effect, the attack is concentrated on replaceable doublers which are not structural members.

6.4.2 Propeller cavitation erosion

Erosion of the propeller material will occur if the cavities collapse in the proximity of the blade surface. During collapse; considerable pressure can be generated capable of such intensities, and with extended time of surface exposure, that no material can withstand the attack. Blade sections through cavitation erosion also reveal cracks penetrating into the material; thus suggesting that the basic agency promoting deterioration of the material is fatigue. Other forms of attack, however, such as corrosion and electro-chemical action are also duely related to erosion particularly with lengthy time of operation.

Although it is by far better to prevent erosion by eliminating cavitation through initial proper propeller design; yet this is not possible to achieve on all practical cases. Nevertheless, the use of high strength copper base alloys has proved to indicate high resistance to erosion and can be stated in the design specifications.

6.4.3 Stopping and backing of ships

The ship's master must have constantly in mind his experience to bring his vessel to a stop or rapidly reducing her speed; particularly in case of near collision or restricted maneuvers. Typical stopping and backing curves drawn on time basis help greatly in that respect. However, the problem of how much backing power to provide; will always arise with every new design. Nevertheless, if the astern turbine and propeller torque characteristics are known, astern thrust as well as the ship "head reach" may be estimated closely enough to assist the designer to specify capacity,in so far as stopping and "head reach" are deciding factors. It should be noted, meanwhile, that "head reach" is influenced also by factors other than the type of machinery and available astern torque; e.g. the displacement and the speed of the ship as well as the diameter of the propeller. All the previous criterions, however, have to be taken in due account, in the original ship design, in order to insure a prescribed "head reach" and time to bring it to a stop.

7. THE FIFTH DIMENSIONAL CONCEPTION "Operational State" Parameter

From the previous treatment it could be easily foreseen to what extent the application of the fourth dimensional conception, representing the time parameter, helped in maturing the engineering design procedure. Nevertheless, it did not forward still a satisfying answer to all other questions which can cover what may be termed the design engineer's experience. Consequently, it is anticipated here to submit yet another conception which, in our opinion, could cover the gap needed by the three-dimensional presentation in order to reach its practical design maturity. In order to reach such goal, meanwhile, a sizable number of typical engineering design examples have been collected at randum then sorted and classified in groups. All groups, however, seem to fit more properly under one single title; namely the "operational state parameter" which, in turn, can comprise what may be termed a fifth dimensional conception.

In what follow we are presenting the groups, comprising the operational state parameter, together with a brief account of their relevant selected examples . It is hoped that they might collectively give a still satisfactory answer to the practical maturity of the overall engineering design problem and its sustained difficient operation.

7.1 LOCATION AND SETTING EFFECTS

7.1.1 Dearerator and main feed pump

In a previous example concerning the steam feed system; the use of a deaerator was recommended. Its design, however, can easily be effected in three-dimensions after carrying out proper calculations of the system " head balance". Nevertheless, when practically excuted and being connected to the suction of the main feed pump; it might not function satisfactorily. Since the temperature of the feed water entering the pump is near the boiling point and with the sudden reduction of pressure at the pump suction; it will flash into steam and the pump will "cavitate" or "vapour lock". A margin of pressure should thus be assumed and the deaerator has to be placed at as a high point as practicable in the engine room; in order to ensure pressure at the main feed pump intake.

7.1.2 Condensate pump and condenser

In a similar reasoning, as in the previous exmaple and for the same steam feed system; since the condensate pump has a suction pressure approaching vacuum, it must be operated under submerged conditions and must be placed at the lowest point under the condenser it serves.

Consequently, the location and setting of the condensate, pump, in this example, as well as the deaerator, in the previous one, are of prime importance for their continued effective operation and have to be duely taken into consideration in the design procedure.

7.1.3 Boiler tube circulation

In a straight tube single drum boiler, the tube bank has to be set at a slight angle to the horizontal in order to insure better natural water circulation inside the tubes. Such arrangement would, however, help the relatively lighter density to rise up the inclined tubes and be replaced by the colder and relatively denser water comming from the drum and a circulation is thus created. Moreover, and for the same reason, two-drum bent tube boilers have their respective main tube bank set slightly inclined to the vertical. Should such tube setting not be satisfied, in the original boiler design, however, then no sufficient water is fed to each tube receiving heat with the consequent result of boiler failure.

7.1.4 Superheater location

The location of the superheater element inside the boiler has a great influence on its design as well as its performance.

A radiant superheater, set close to the furnace, should be of special alloy steel with heat resisting properties which enables it to withstand the tube temperature resulting form high heat absorption rates and from conditions of little or no steam flow as when starting up the boiler. On the other hand, with the location of the superheater coils after the main generating bank; the surface area of such "convection" type superheater is expected to be rather large. Nevertheless, a convection-radiation superheater would normally render a flatter superheater steam temperature curve; more apprpriate for the continued and safe operation of the accompanying steam turbine.

7.1.5 Superheater tube setting and support

For a radiation-convection superheater which is positioned horizontally; its tubes are usually set at a slight angle to the horizontal and on that account they are self draining. However, the *supporting of horizontal superheater* elements, in all types of water tube boilers, is a problem of considerable difficulty; since the uncooled supports have to withstand extremely high temperatures. The vertical superheater, on the other hand, could be more easily supported on the tube headers. Furthermore, with pendant type superheaters, more often used in land boilers, the major load is usually carried from the headers above the superheater tubes.

7.2 OPERATIONAL CONDITIONS

The following are some examples which demonstrate the effect of the operational condition on the engineering design procedure in order to achieve its practicability.

7.2.1 System Load variation

A fundamental closed feed system could only operate sucessfully under the condition of absolutely no varying load. If the load decreases; the feed pump will scavenge all the water out of the condenser and put too much in the boiler; thus filling it completely leaving no space for steam. There being no elastic or compressive gas; the non compressible water will burst the boiler or will flow into the turbine and destroy the blades. On the other hand, if the load increases the condenser will fill with water and the boiler will run dry and can be damaged when the water does reach it.

Consequently, in order to render such fundamental system feasible, under actual load variations, three main items have to be added to the system. A boiler water-level regulating or float valve has to be introduced to control the boiler water level. In addition, a surge or feed tank has to be incorporated in the system in order to compensate for the variation of the water in the circuit and this necessitates, in turn, the installation of a condensate pump to transfer the fluid from the condenser to the installed surge tank. With the incorporation of these devices in the circuit a practical system can be realized which could withstand the different load variations experienced by the system in actual operation.

7.2.2 System leakage

In the previous example, the fundamental feed system will only operate successfully if also no leakage is experienced in the cycle. Leakage, however, is two fold; the leakage of water and steam from the pressure side of the cycle as well as the leakage of air into its vacuum side.

The leakage of water and steam from th various joints and pipings of the system could well be compensted for by setting a make-up into the condenser or some means for adding water that is lost by leakage. On the other hand, the leakage of air into the system necessitates not only the effective use of the two-stage air ejector fitted to the condenser but also the need for a deaerating surge tank in order to get rid of the infiltrated air through its vent condenser.

7.2.3 Superheater steam-temperature control

As mentioned previously, a combination of radiant and convection superheaters can be used to maintain an almost constant superteated steam temperature for a wide range of operation, nevertheless, such arrangement is costly and necessitates large steam pressure drops. However, there are two basic methods of control being adopted in regulating steam temperature. The first is based on varying the amount of heat absorbed by the steam heating element; while the other is based on reducing the temperature of the superheated vapour passing through it.

Besides the use of a combination radiant and convection superheater in the first method; there are other means of control like the arrangement of the firing equipment, the separately fired superheaters, besides the use of dampers. On the other hand, the second method entails the use of attemperators which are either of the surface type, which includes the shell and drum types, or the direct contact or spray type attemperators. Consequently, depending on the method selected in the control of the superheater temperature regulation, the matured design of the superheater element could be accordingly contemplated.

7.2.4 Materials for superheaters

Mild steel is, in general, considered permissible for superheater tubes with steam temperatures up to 750'F; while above this temperature alloy steels are used. Moreover, in steam boilers; operating with steam temperatures as high as 950'F, the superheater tube metal temperature can be held below 1050'F where chrome-molybdenum steel can satisfactorily be used. In highly rated steam boilers, however, metal temperatures can rise above 1100'F; hence stainless steel superheater tube have to be provided. Moreover, where multi-pass superheaters are in use, the maximum metal temperature of each pass is calculated and the appropriate materials chosen; while with long continuous loops dissimilar tube materials are to be welded at transition points.

7.2.5 Economizer water hammer and thermal shocks

Rapid fluctuations in the water temperature during ship maneuvering may subject the boiler economizer to thermal shocks. For instance, the economizer will tend to steam with a momentary stoppage of the water flow. However, as the load increases the sudden introduction of feed water into the economizer may cause water hammer and high thermal stresses.

Due to such possibilities, leakage from joints and fittings must be prevented and consequently the tubes are usually welded to the headers; while soft sheet gaskets are to be used in all fittings.

7.2.6 Ships and populsion systems

Numerous examples could be sited on the effect of the operational condition in the selection and design of ships and their propulsion systems. The depth of water in certain ports in which the ship has to enter; affects its draft limitation and hence the diameter, performance as well as the number of propellers to be adopted. Moreover, the troublesome problems of both vibration and noise have their consequent impact on the design of ships as well as their respective shafting and propulsion systems.

7.2.7 Propeller wake field

We have previously considered the marine propeller in both two and three as well as in four dimensional flow. Therefore, with a proper circulation theory, the propeller could thus be designed accordingly in a free stream. Nevertheless, when working behind a ship; both the circumferential as well as the radial wake distributions have to be taken, in due account, in the calculation procedure.

The propeller blade angles have to be corrected accordingly; otherwise it will not efficiently operate behind the ship. Consequently, the introduction of a fifth dimension is necessary in order to reach a matured marine propeller design.

7.3 MAINTENANCE AND RAPAIR

Sample problems related to maintenance and repair; as affecting the design procedure in the domain of the fifth dimensional conception, are cited here and their solutions thought.

7.3.1 Superheater tube failure

The superheater tube failure may be due to the following reasons:

a. The reduction of the superheater tube metal strength resulting from metal temperatures which might be within the "creep" range. This, in turn, could be insured by either the proper positioning of the superheater in a zone where the gas temperature does not cause heat transfer rates involving high superheater tube-metal temperatures; or by the adoption of adaquate steam speeds in superheater tubes.

b. The risk of inside corrosion due to wet steam entering the superheater under steaming conditions might result in tube failure. This could almost be eliminated by providing adaquate means for ensuring that the steam entering the superheater is dry. The use of effective steam driers as well as adopting moderate steam raising rates in the steam drum can help in that direction. For part load, however, means should be adopted for proper self draining of the superheater tubes particularly when the boiler is shut off.

c. At part loads or under damp atmospheric conditions; soot deposits and slag might cause outside corrosion of the superheater tubes resulting in tube failure.This demands that such surfaces be throughly dry and clean.

7.3.2 "Walk-in" superheater

As has been shown previously, the design of the superheater element, either of the horizontal or the vertical types, has its own construction and maintenance problems which vary in significance with each application. The choice, therefore, should be made from considerations of the superheater tube banks relative to the socot blower and the ease with which the superheater tubes can be replaced; particularly when these are welded to the headers.

Meanwhile, the vertical superheater has been developed in a way to have an easy access to the superheater element for both inspection and cleaning. In certain designs a space or walk-in cavity is considered, in the boiler superheater tube element, thus allowing all superheater support and soot blowers to be readily accessible for inspection and repair work.

7.3.3 Economizer by-passing

It is common practice to design marine economizers so that they can be by-passed if a leak occurs; thereby allowing the boiler to remain in service until the necessary repairs can be made. This means that the economizer must withstand entering gas temperatures without any feed water flow through the economizer tubes. Furthermore, with the economizer by-passed; a loss of efficiency is anticipated and results in an increased fuel firing rates as well as in increased draft loss. This, in turn, cause a higher forced-draft fan load which has to be taken into account during the intitial stages of the design.

7.3.4 Space allowed for repair

It is to be noted that; while performing the design procedure for any item, say in an engine room, that ample space be allowed for the persons undergoing inspection or repair in order to easily and effectively perform such work. Such space, meanwhile, should be clearly indicated on the scale drawing of the item under design consideration; so that during installation work that space would be left free for maintenance and repair.

The following, however, are samples of spaces to be provided for:

- Boiler superheater tube element for inspection and change.
- Turbine casing.
- Condenser tube removal and repair.
- Space in engine room around pumps and equipment.

7.4 SAFETY

For a ship to float in water is not in itself enough. The vessel must be able to remain afloat under all possible conditions which are likely to be met in service. Nevertheless, a ship may be said to be seaworthy when it is, in all respects, fit to carry the cargo in good condition, as far as protection from the sea is concerned, and deliver it at the port of destination. The term "seaworthiness", meanwhile, is a very comprehensive one, embracing the main elements of ship design; and in ship operation in strength, stability, freeboard, machinery, sterring gear etc.

In what follows we are going to present few such examples which affect the sefety of the ship and hence influence her design.

7.4.1 Stability

7.4.2 Damaged Condition

A most all ships are built under the rules of a classification society and must comply with her statuary regulations. The primary object of such statuary regulations, however, is to promote safety of life at sea.

When the side of a ship below the waterline is pierced, as by collsion, grounding, etc., water pours into the compartment bounded by the bulkhead adjacent to the region of damage and the buoyancy of the ship over the length between bulkheads is cancelled. Moreover, the effects of damage, which destroys the water tightness of a ship's hull, are often progressive. It is thus essential to have a standard of subdivision such that there is a reasonable chance that the ship will remain afloat under such an emergency. The degree of sudivision into water tight compartments, varies according to the nature of the ship's service and its length on the load waterline. Moreover, the international regulations for damaged stability are exacting. They require that if two adjacent compartments are floaded the ship will not only stay afloat; but the angle of heel is limited to a maximum of 7 degrees. Accordingly, all such safety regulations have to be taken in due consideration in the original ship design.

7.4.3 Ship Strength

Obviously, sufficiency of strength is one very important quality necessary for the safety of the ship on a sea voyage. If the structure is not robust enough, for the seas it will meet and the loads impressed upon it, it will fail in its primary function. Normally, the ship's hull will have sufficient strength by the disposition of the material of the structure to withstand all the stresses that may be encountered in service and remain in condition of seaworthiness.

The thickness of the steel plating as well as the scantlings of the main structure, necessary to give the required strength of the ship, are prescribed by the rules of the classification societies. Moreover, these societies are also authorized to assign to a vessel a maximum permissible draft which, in turn, is determined by considerations in addition to that of strength.

7.5 ECONOMICAL ASPECTS

Economics is always an important aspect of engineering and a potentially valuable tool at every level of design and operation.

In what follows we are putting foreward some examples at randum which would manifest such design trend.

7.5.1 Economical ship design

The commerical ship can be properly defined as a capital investment that earns its returns as a society useful instrument of water transport.

The definition of an economical ship, meanwhile, is not the same for all partners in designing, building and operating a ship. The shipyard, at one hand, consider it as consuming least costs, effort and time but nothing else, while, the shipowner understands it as having minimum combination of building and operating costs aiming at maximizing his profit. The ship designer; being more scientific, visualize the economical ship as that whose hull lines create least resistance at a specified speed and size; also that having the biggest possible stewage and can operate safely in all sea and wheather conditions. Whereas, the aims of the ship designer are generally meeting those of the shipowner from the stratigical point of view; the ship builder can only apply his own objectives after satisfying those of the shipowner. Nevertheless, the application of engineering economics to ship design is basically the conversion of the marine transport requirement into a range of feasible ship oil systems; have to be designed as to match the high thermal and mechanical loads at high mean effective pressures.

7.5.3 De-rated marine diesels

The general world economical crisis has lead the owners of ships, and eventually power plants, to look for energy saving. Thus shipowners have decided to run their ships at a reduced speed which means at loads lower than their continuous service rating. Meanwhile, de-rated versions are today offered on almost all modes of slow and medium speed diesel propulsion plants. De-rating the engine, however, is to improve its expected maintenance history lighter mechanical and thermal loads; also to obtain higher propeller efficiency and thus lower fuel consumption. If the engine could be arranged to realize the full permissible combustion pressure, even at reduced load, this would materially improve the specific fuel consumption; and the most direct means of achieving this would be to adjust the compression ratio. Such adjustment while the engine is running, however, will involve mechanical problems extremely difficult to solve in practice.

To overcome this difficulty, two means have been adopted; namely using variable injection timing and the use of a turbo-charger by-pass. Through using either of these designs; the economical de-rating of the diesel engine could be achieved.

7.5.4 Boiler preheater

The selection of the heat recovery equipment, to be incorporated in the design of a steam boiler, is normally influenced by the boiler operating conditions as well as by the efiiciency required by the boiler unit. However, the decision for the use of air heaters must be based not only on engineering factors; but also on economical aspects.

At one hand, the principle engineering factors are: available space, characteristics of the fuel used and the desired temperature of the preheated air as well as the exit flue gas. On the other hand, however, the major economical factors are; the original cost of the air heater, the operating cost of fuel and fan power, as well as the maintenance costs. Consequently, with the consideration of the proviously mentioned factors; the matured design of the preheater element could be realized.

8. STATICAL AND DYNAMICAL CONSIDERATIONS

We have previously considered the first three dimensions; Whereas the first dimension represents a linear measure; the second and third dimensions, however, represent an area and volume measure respectively. It could thus be easily fore-seen that all these three dimensions demonstrate statical parameters which could be duely presented on a scale drawing for the article under design consideration. A graduate engineer with adaquate background, meanwhile, is capable of undergoing such task. Nevertheless, his design could not be considered matured; since if excuted it might not function properly and efficiently, for an extended period of time, without undue failure; and the design thus considered is lacking what might be termed the designer's experience.

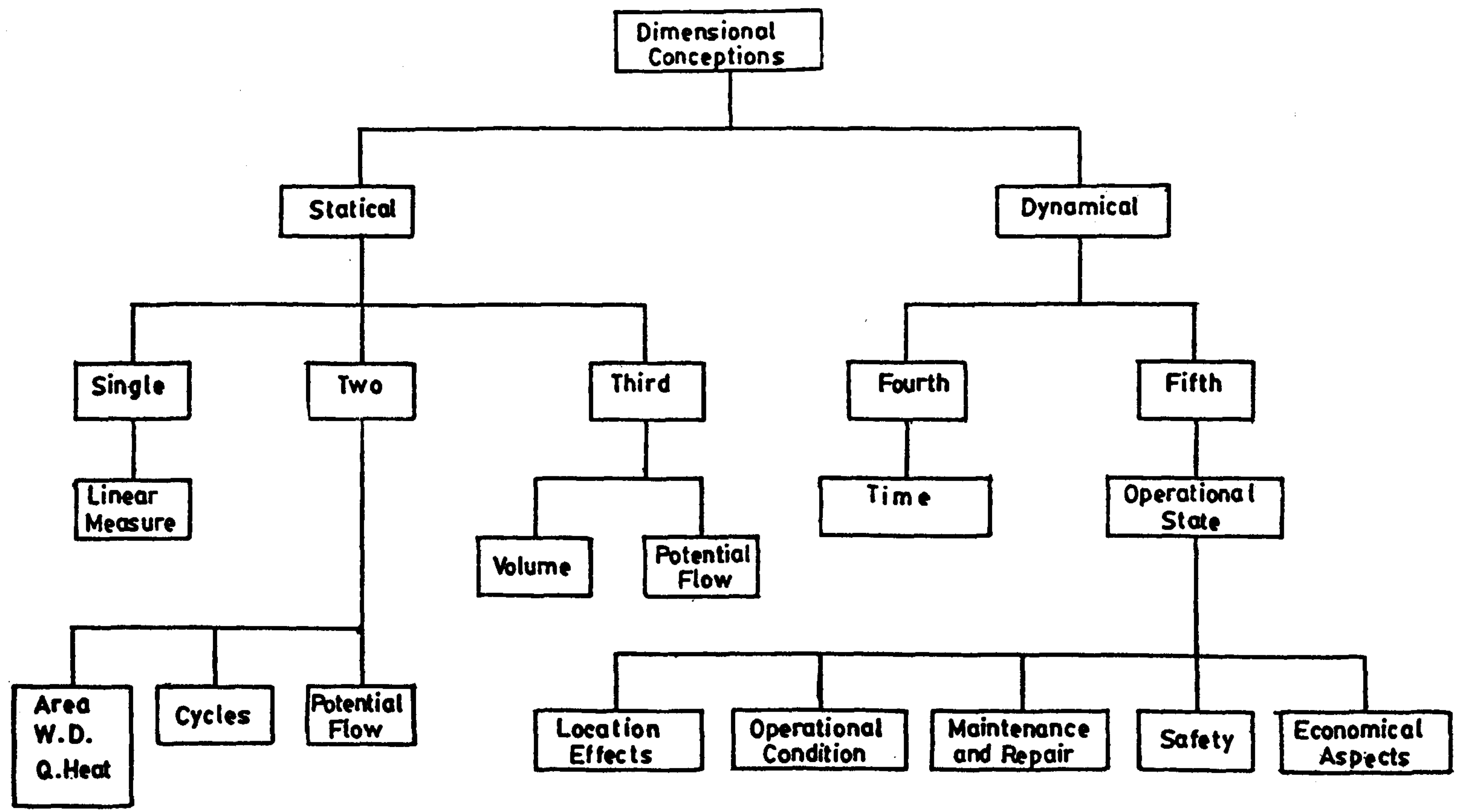
In fact the graduate engineer, at such stage, lacks the practical experience; simply expressed as the dynamical performance of the object he is designing. In our previous treatment, however, we have advanced a justified explanation to such dynamical consideration; in the form of both the fourth and fifth dimensional conceptions representing the time as well as the operational state parameters respectively.

Eventhough, the application of Einstein's fourth dimension offers valuable needed information towards that goal; yet alone it does not give a full explanation of the dynamical consideration. In our opinion, meanwhile, the introduction of the fifth dimension, proposed here, offers an explanation of the remaining link for reaching the maturity of the engineering design process.

9. CONCLUSION

In this treatment, and in what concerns the engineering design procedure, we have advanced numerous practical design problems, together with their respective solutions, in order to demonstrate the justification of adopting not only the known fourth dimension; but also a proposed fifth dimensional conception. In as such, they both add up to represent the dynamical part of the engineering design process. They also explain the definiciency of such design; normally attributed to the lack in the designer's experience.

Whereas Einstein's fourth dimension represents a "time" parameter, the fifth dimensional conception is referred here as the "operational state" parameter. Moreover, the last conception comprises several groups; each of which has been demonstrated by various relevant and practical design examples.



The Five Dimensions