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Computer aided selection of water tube steam boiler for heat operation using by MADM approach

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Abstract : *Many thermal power facilities use water tube steam boilers to repeat the most difficult and risky labour given by heat (steam). A boiler is a closed vessel in which water or other liquids are heated. This study aims the investigation of the best water tube steam boiler to finds out the Computer-aided selection by using the MADM approach. The selection of a good water tube boiler is getting increasingly challenging due to the significant degrees of complexity in boiler construction, configurations, and alternatives offered. The TOPSIS Method is utilised in this work to rank the available alternatives. Various types of water tube steam boilers used in the range of input parameters that the sugar mill and a thermal power plant etc. These method decisions will help the manufacturer to select a suitable water tube steam boiler according to the requirement. The developed software is analyzed by an illustrative example s for the Sugar mill industry with the same data. We find out a Computer-aided water tube steam the boiler selection model, where the user or group of experts can select a suitable water tube steam boiler with its own requirement with the help of a programming algorithm for a particular operation.*

Key Words: *Water Tube Steam Boiler, TOPSIS, MADM, Power Plant.*

1. INTRODUCTION:

There has been a tremendous increase in the demand for the automated machine in the industrial sector of power plants and with greater efficiency and high quality. Continuous monitoring and frequent inspection have to do in power plants. That is what explains the need for automation in the industries. In many industries, the steam generated by the plant instead of going to waste is used for production of power production. Boilers do have much strength which makes them the greater feature of the system. An entire world knows that a Boiler is a vessel in a closed shaped and inside the boiler water or other fluid is heated. Use of hot and steamy water in a variety of boiler-based heating operations, including cooking and cleaning, central heating water, and boiler-based electricity generation. Boilers are used to heat water, produce steam for industrial heating facilities, and produce electricity for powering steam turbines. Moreover, boilers are used to heat rooms in buildings, provide the hot water and steam that users need for their kitchens and laundry.

Who invented the first steam boiler is a topic of controversy throughout the globe, however most people would concur that George Babcock and Steven Wilcox were the forefathers of steam producing boilers. Using tubes within the firebrick-walled structure to create steam, he was the first to patent his boiler design in 1867. He also founded Babcock & Wilcox Corporation in New York City in 1891. Their first boilers made by Babcock & Wilcox Company were very small, the lumps used were coal, hand-picked, and used extremely little heat input when operating. Coal, oil, or natural gas taken from the main source of heat in a fossil fuel power plant's steam cycle boiler is burned to produce electricity. In some cases, byproduct fuels are mainly used in the sugar cane industry such as bagasse. Where sugar cane is economically available in the plant can also be used. Steam generators or boiler integral part components of steam turbines, which are used as primary movers to drive generators to produce electricity in all thermal and nuclear power plants. In the industrial sector of power plants, there has been a huge increase in the demand for automatic machines with more efficiency and high quality, continuous monitoring, and continuous inspection of plants in a power plant. There are chances of the occurrence of errors while measuring. Nowadays, modern technologies are being used in industries in place of conventional techniques. Boilers systems are multi-purpose and produce products like heat, steam and chemical gas, etc. in the cane production unit. Instead of wasting it in many industries, the steam generated by the plant is used for generation.

2. MULTIPLE ATTRIBUTE DECISION MAKING :

Making preferences judgements over the available alternative that are defined by many, frequently competing qualities is known as MADM (Multiple Attribute Decision Making). A subfield of MCDM is called MADM (Multiple Criteria Decision Making).

• The multi-criteria decision (MCDM) consists of building a global reference relationship for a set of assessment options using multiple criteria.

•Choosing the optimal course of action from a range of options after weighing each one against many, sometimes at odds criteria.

Two connected schedules make up decision-making with many criteria.

1. Multiple attribute decision making

2. Multiple Objective decisions making

Multiple attribute decision making: It is believed that multiple attribute decision-making issues have a predetermined, constrained number of choice possibilities.

Multiple Objective decisions making: The set of decision alternatives is explicitly constrained by multiple objective programming rather than being provided as decision alternatives. There may be a lot of different decision-making options available.

A collection of 17 MADM approaches were categorized by Hwang and Yoon (1981) based on the primary characteristics and the types of information the decision-maker provided. The decision-kind maker's of information is used to initially categories the approach in this categorization. The Dominance approach is used if no information is provided. The maxi-max technique is appropriate if the information about the environment is supplied as either pessimistic or optimistic. If information on an attribute is provided, a subcategory the key element of the data the decision maker provided is utilized to further classify the approaches. The information provided can consist of the average value for each characteristic or even attribute weights calculated using ordinal or cardinal scales.

3. METHODOLOGY :

Graphic Representation of Multiple Attribute Decision Making

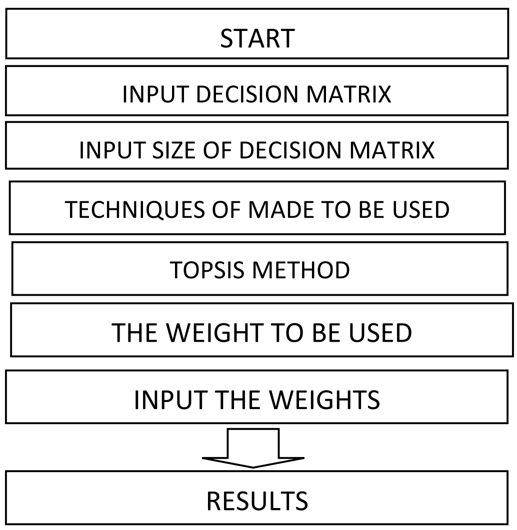

Fig. 1: Graphic Representation of Multiple Attribute Decision Making

Elimination search
When choosing a water tube boiler for a given application, none of the features that have been highlighted are crucial. There won't be many characteristics that directly influence the choosing process. By gathering information from the user and a group of experts, these important traits may be allocated to boundary values. Based on the relevant parameter threshold values, a list of water tube boilers is constructed. This may be done by identifying the database one at a time for key characteristics in order to eliminate alternatives to water tube steam boilers that have one or more relevant attribute values that are below the minimum required values.

Evaluation procedure
As a result, a little database is created that contains these satisfactory solutions, or alternatives, that fulfil the degree of ambition in all respects. Finding the most ideal or finest among these agreeable options is now the challenge. So, the selection process must rate this solution according to its worth. The initial stage in this process will be to express all the data from the database that is accessible regarding the satisfied solutions in matrix form. A choice matrix is one such matrix (P). This matrix has one potential water tube boiler assigned to each row and one attribute under consideration for each column. Hence, for the i^{th} water tube boiler, an element $p_{ji}$of the decision matrix P provides the value of the j^{th} characteristics in the row in both (non-normalized) form and units. As a result, the choice matrix is a (m*n) matrix if there are m shortlisted water tube boilers and n relevant qualities. This process of evolution is completed in three phases.

Step-1 Normalized specifications
The normalised specification matrix, N, is then built from the decision matrix, P, as the following step. In addition to providing the dimensionless magnitude, normalisation is utilised to bring the data into a certain range or scale. To calculate the normalised specification matrix, this phenomenon is employed. The magnitudes of all the characteristics of the water tube boiler will be represented in the normalised specification matrix on the standard 0–1 scale. It is a kind of value that shows where a given attribute's magnitude stands in relation to the whole range of magnitudes for all potential water tube boiler candidates.
An element n_{ij} of the normalized matrix ‘N’ can be calculated as

$$n_{ij} = p_{ij} \Big/ \sqrt{\sum_{i=1}^{m} p_{ij}^2}$$

Where pij is a component of the ‘P’ decision matrix..

Step 2 Method for Assigning Weights: -
Many Characteristics, Several Methods Problems in decision-making call for knowledge of the relative weights each characteristic carries. Typically, it is provided by a collection of weights that have been normalised to have a total of 1. In case of n set of weights is-$R^T = (r_1, r2, r3, \ldots\ldots\ldots\ldots\ldots\ldots, r_n)$

$$r_1+r_2+r_3+r_4+r_5+r_6 = 1$$

$$\sum_{j=1}^{n} R_j = 1$$

Step 3 Weighted normalized specification: -
As all qualities have varying degrees of value when choosing a water tube boiler for a certain application, the weights generated from the relative importance matrix must be applied to the normalised specification. The weighted normalised matrix ‘V’combines the relative weights with the candidate's normalised specification. It will provide accurate values for the properties.this will be obtained as follows.

$$V = \begin{pmatrix} r_1 n_{1,1} & r_2 n_{1,2} & K\, r_n n_{1,n} \\ r_1 n_{2,1} & O & M \\ r_1 n_{m,1} & r_2 n_{m,2} & K\, r_n n_{m,2} \end{pmatrix} = \begin{pmatrix} v_{1,1} & v_{1,2} & K\, v_{1,n} \\ v_{2,1} & O & M \\ v_{m,1} & v_{m,2} & \Lambda v_{m,n} \end{pmatrix}$$

3.1 TOPSIS (TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION)
The benchmark water tube boilers, which are hypothetical water tube boilers and represent the best and worst conceivable characteristic results, are obtained using the weighted normalisation matrix ‘V’. TOPSIS was created by Hwang and Yoon with the idea that the best alternative (optimum) should be the closest to the positive benchmark water tube boiler and the furthest away from the negative benchmark water tube boiler (worst possible water tube boiler). The benchmarking measure makes sure that the top-ranked water tube boiler is the closest to both the positive and negative benchmark water tube boilers. Here, we determine the calculation separation measurements from the positive and

negative water tube boilers, referred to as Yi^+ and Yi^-, respectively. The disconnection from the water tube boiler with +ve benchmarks is given by

$$Y_i^+ = \left[\sum_{j=1}^{n}\left(v_{ij} - v_i^+\right)^2\right]^{1/2} \quad i = 1,2,3, \ldots \ldots \ldots \ldots \ldots \ldots . . n$$

And separation from the -ve benchmarks water tube boiler is given by

$$Y_i^- = \left[\sum_{j=1}^{n}\left(v_{ij} - v_i^-\right)^2\right]^{1/2} \quad i = 1,2,3, \ldots \ldots \ldots \ldots \ldots \ldots . . n$$

Subsequently, on the basis of the features taken into account, the relative proximity to the positive benchmark water tube boiler, C*, which serves as a gauge of the water tube boiler's fitness for the selected application, is determined. It is desirable to use a water tube boiler with the highest C*.

$$C^* = Y_i^- / (Y_i^* + Y_i^-)$$

The prospective water tube boilers are ranked according to the decreasing values of the indices C* that represent the most desirable and the least preferred practical alternative solution.

3.2 ILLUSTRATIVE EXAMPLE

Using the multiple attribute decision making (MADM) method, a water tube steam boiler is chosen for the heating operation.

We use the MADM technique to choose a water tube steam boiler for heating operations.

After doing an elimination search, we can identify a manageable number of potential candidates for water tube steam boilers and their relevant characteristics.
Candidate water tube steam boilers are listed below:-

- Thermax Water Tube Steam Boiler (75TPH) (B1)
- IJT Water Tube Steam Boiler (80 TPH) (B2)
- Thermax Water Tube Steam Boiler (90 TPH) (B3)
- Thermax Water Tube Steam Boiler (120 TPH)(B4)
- KCP Water Tube Steam Boiler (150 TPH)(B5)
- IJT Water Tube Steam Boiler (40 TPH) (B6)

Pertinent attributes are listed below:-

- Working Pressure (Kg/Cm2) (Y1)
- Boiler Capacity (TPH) (Y2)
- Total Heating Surface Area (m2) (Y3)
- Efficiency (%) (Y4)
- Working Temp. (^{0}C) (Y5)
- Feed Water Pressure (Kg/Cm2) (Y6)

Table 1: Attributes For The Short Listed Candidate Water Tube Steam Boiler

Att. → **Alter. ↓**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**
B1	42	75	2302	72	410	60
B2	45	80	4758	65	430	103
B3	87	90	3717	73	510	105
B4	90	120	4828	70	515	110

B5	110	150	8633	78	540	210
B6	45	40	2745	68	432	104

Total heating surface area and operating temperature of the smallest magnitude are preferred, and hence the reciprocal of the values in the column indicating heating surface area should be utilized to build the choice matrix 'P'. Table 3 displays the resulting decision matrix:

Table 2: Minimum Magnitude Matrix

Att. → **Alter. ↓**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**
B1	42	75	.00043	72	.0024	60
B2	45	80	.00021	65	.0023	103
B3	87	90	.00027	73	.0019	105
B4	90	120	.00021	70	.0020	110
B5	110	150	.00012	78	.0019	210
B6	45	40	.00036	68	.0023	104

The data from the above table is used in the following approach for selecting a water tube steam boiler:

Step 1
Formation of decision matrix 'P' i.e. the matrix that will include all specified magnitudes. The columns of the matrix list the values of the characteristics of the candidate's water tube steam boiler in the rows.

$$D = \begin{bmatrix} 42 & 75 & .00043 & 72 & .0024 & 60 \\ 45 & 80 & .00021 & 65 & .0023 & 103 \\ 87 & 90 & .00027 & 73 & .0019 & 105 \\ 90 & 120 & .00021 & 70 & .0020 & 110 \\ 110 & 150 & .00012 & 78 & .0019 & 210 \\ 45 & 40 & .00036 & 68 & .0023 & 104 \end{bmatrix}$$

Step 2

The normalised specification matrix calculation. The dimensionless matrix elements are made available with the aid of this normalization

$$n_{ij} = p_{ij} \Bigg/ \sqrt{\sum_{i=1}^{m} p_{ij}^2}$$

$$N = \begin{bmatrix} .229183 & .309751 & .614286 & .413318 & .461538 & .197550 \\ .245553 & .330401 & .300000 & .373134 & .442308 & .339128 \\ .474735 & .371701 & .385714 & .419059 & .365385 & .345713 \\ .491106 & .495601 & .300000 & .401837 & .384615 & .362176 \\ .600240 & .619502 & .176429 & .447761 & .365385 & .691426 \\ .245553 & .165201 & .514286 & .390356 & .442308 & .342420 \end{bmatrix}$$

Step 3

Assign weights for each attribute such that their sum will be equal to one.

$$\sum_{j=1}^{n} R_j = 1$$

r1 + r2 + r3 + r4 + r5 + r6 = 1

r1= 0.14 r2= 0.20 r3= 0.15
r4= 0.25 r5= 0.16 r6= 0.10

Step 4

The weighted normalise specification matrix calculation. Here, we combine the qualities' relative weights with their normalised values to produce a special parameter for the potential water tube steam boiler.
Vij = NijRj

$$V = \begin{bmatrix} .032086 & .061950 & .092143 & .103329 & .073846 & .019755 \\ .034377 & .074340 & .045000 & .093284 & .070769 & .033913 \\ .066463 & .074340 & .057857 & .104765 & .058462 & .034571 \\ .068755 & .099120 & .045000 & .100459 & .061538 & .036218 \\ .084033 & .123900 & .025714 & .111940 & .058461 & .069143 \\ .034377 & .033040 & .077143 & .097589 & .070769 & .034242 \end{bmatrix}$$

The characteristics values and their relative relevance are taken care of by the weighted normalised specification matrix. In order to compare them to one another and to the benchmark water tube steam boiler, this matrix will be able to offer a suitable starting point. For this comparison and ranking purpose, a variety of graphical and non-graphical techniques might be used.

3.3 TOPSIS METHOD FOR RANKING

The selecting process's fifth phase is this one. You may get the weighted normalised characteristics for the favourable and unfavourable benchmark water tube steam boiler as:

V^+ = 0.084033 0.123900 0.092143 0.111940 0.073846 0.069143
V^- = 0.032086 0.033040 0.025714 0.093284 0.058461 0.019755

The options are divided into the positive ideal and the negative ideal solution as follows:
Y_1+ = 0.095120 Y_1^- = 0.074739
Y_2+ = 0.098122 Y_2^- = 0.042661
Y_3+ = 0.073959 Y_3^- = 0.065352

Y_4+ = 0.066603 Y_4^- = 0.080093
Y_5+ = 0.068198 Y_5^- = 0.117222
Y_6+ = 0.111355 Y_6^- = 0.055018
Relative closeness to the ideal solution obtained as:
C_1+= 0.44000C_2+= 0.303026
C_3+ = 0.469108 C_4+= 0.545979
C_5+ = 0.632197 C_6+= 0.340594
Using the TOPSIS Method, evaluate and rank each proposed water tube steam boiler.

Table 3: Evaluation and ranking of the candidate Water Tube Steam Boiler using TOPSIS Method.

Sr.	**Alternatives**	**TOPSIS – Closeness to the +ve benchmark water tube steam boiler**	**Rank Based on C***
1	Thermax Water Tube Steam Boiler (75TPH) (A1)	0.440006	4
2	IJT Water Tube Steam Boiler (80 TPH)(A2)	0.303026	6
3	Thermax Water Tube Steam Boiler (90 TPH)(A3)	0.469108	3
4	Thermax Water Tube Steam Boiler (120 TPH)(A4)	0.545979	2
5	KCP Water Tube Steam Boiler (150 TPH) (A5)	0.632197	1
6	IJT Water Tube Steam Boiler (40 TPH) (A6)	0.340594	5

According to the user's needs, arrows display the best alternative. As a result, the ranking of the water tube steam boiler is based on the qualities that were chosen. The management may effectively choose the water tube steam boiler for a new water tube steam boiler based on the above ranking and other factors, as well as the boiler that will be most appropriate for the application.

4. RESULT AND DISCUSSION:

Analysis of result of water tube steam boiler selection for heat operation:

In the developed software various parameters such as boiler capacity, efficiency, total heating surface area, working pressure, working temperature and feed water pressure are the input to the program given by the user. Weights to the attributes will also be given by user according to his preferences. The compatibility of the software is examined by a solved example.

The outcome produced by the software is the same as that of the example that was solved. This shows that the arrow on Table 5 and the water tube steam boiler A5 in the MADM technique, the produced software for all the selection difficulties, respectively, provide the best alternatives. So, it is acceptable to say that the programme produced accomplishes its goal of choosing the best water tube steam boiler among several alternatives in accordance with customer requirements.

Table 3 presents the results of an analysis of the designed for water tube steam boiler selection technique based on the Multiple Attribute Decision Making (MADM) approach.

Table 4: Result and Discussion

Sr.	**Alternatives**	**TOPSIS – Closeness to the +ve benchmark water tube steam boiler**	**Rank Based on C***
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2	IJT Water Tube Steam Boiler (80 TPH)(A2)	0.303026	6
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4	Thermax Water Tube Steam Boiler (120 TPH)(A4)	0.545979	2
5	KCP Water Tube Steam Boiler (150 TPH)(A5)	0.632197	1
6	IJT Water Tube Steam Boiler (40 TPH)(A6)	0.340594	5

Selection of Water Tube Steam Boiler by MADM Approach

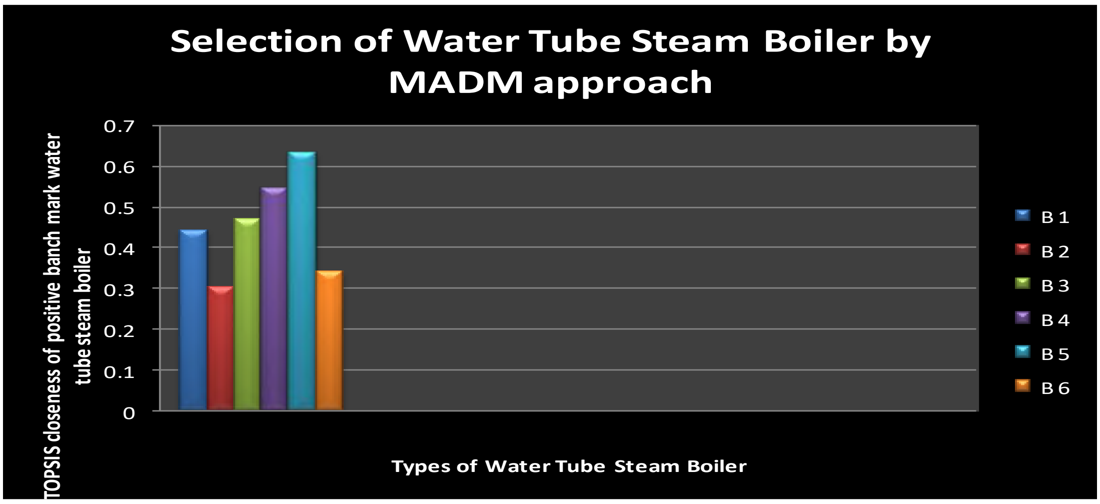

Fig.2: Graph of the Water Tube Steam Boiler

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