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[54] CALCULATING DEVICE FOR ESTIMATING TURBINE STEAM RATES

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[52] **U.S. Cl.** ....**235/70 R**, 235/89 R

[51] **Int. Cl.** **G06g 1/02**, G06c 3/00

[58] **Field of Search** ....235/70 R, 70 A, 70 C, 85 R, 235/89 R, 61 B

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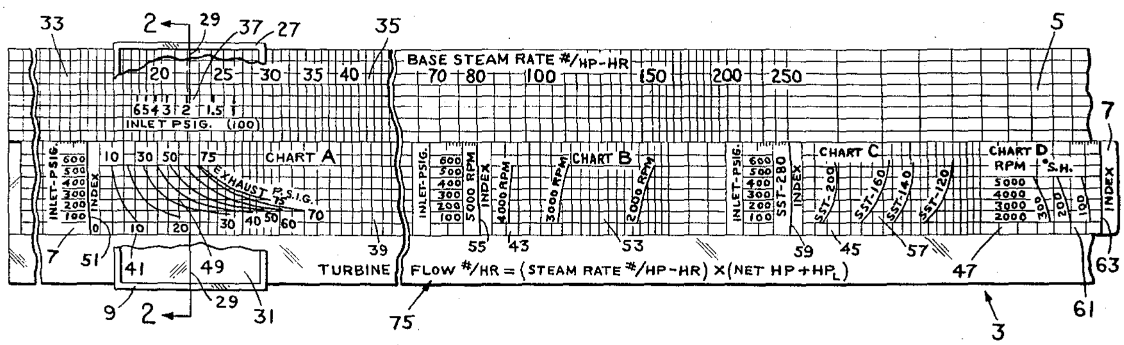
[57] **ABSTRACT**

A slide rule-type calculating device for estimating steam consumption in single curtis stage steam turbines. The device includes a casing having a steam rate scale, a slide member movable endwise in the casing and carrying a series of graphical plots indicative of steam rate variation with respect to selected operating variables, and a hair-line slide. Appropriate displacement of the slide member and hair-line slide serves to effectively combine coordinate values on said plots to yield a final steam estimate readable on the steam rate scale.

5 Claims, 7 Drawing Figures



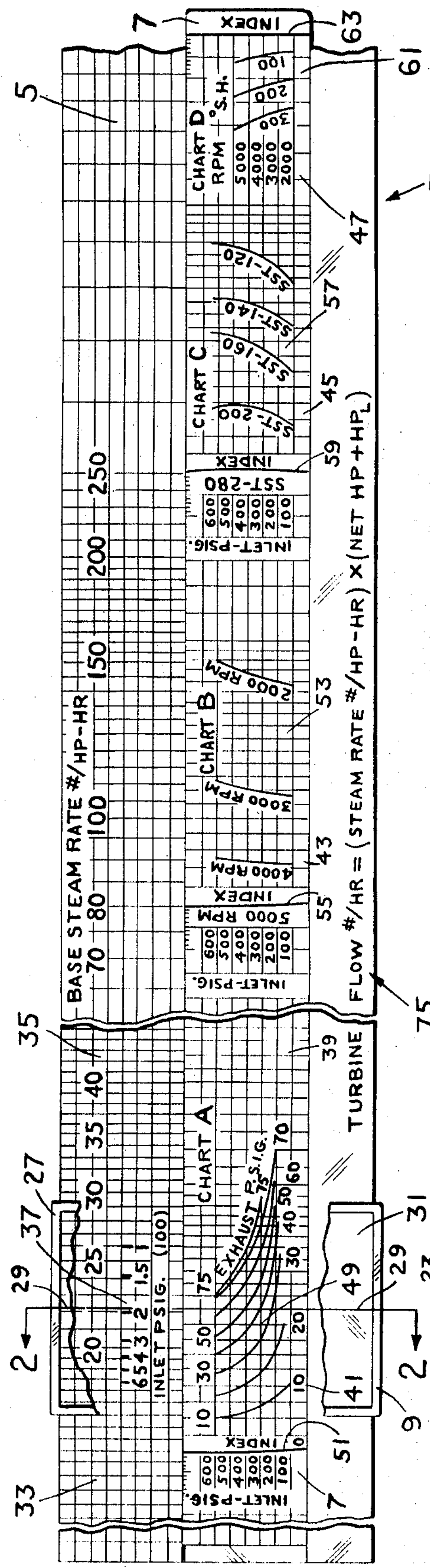


FIG. 1

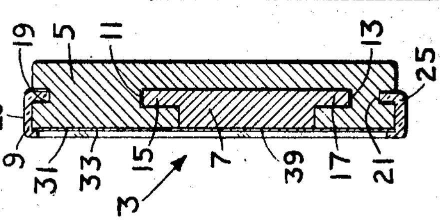


FIG. 2

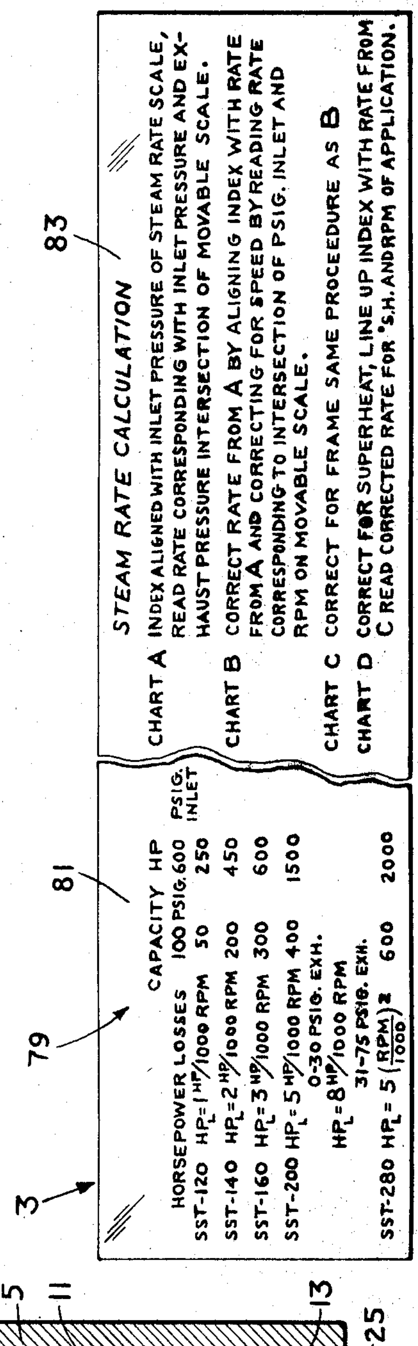


FIG. 3

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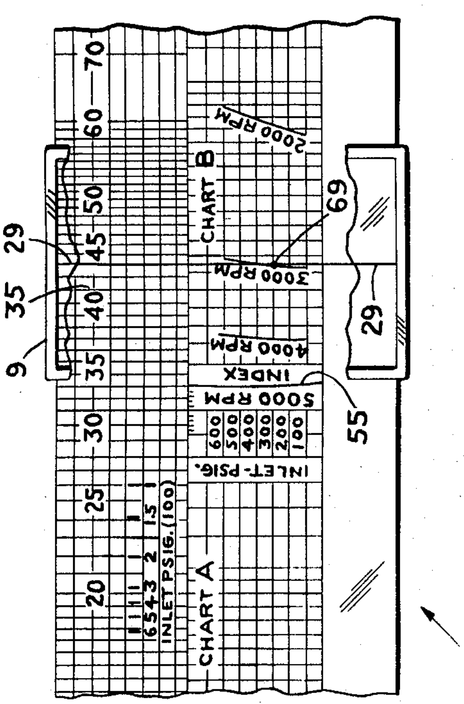

FIG. 4B

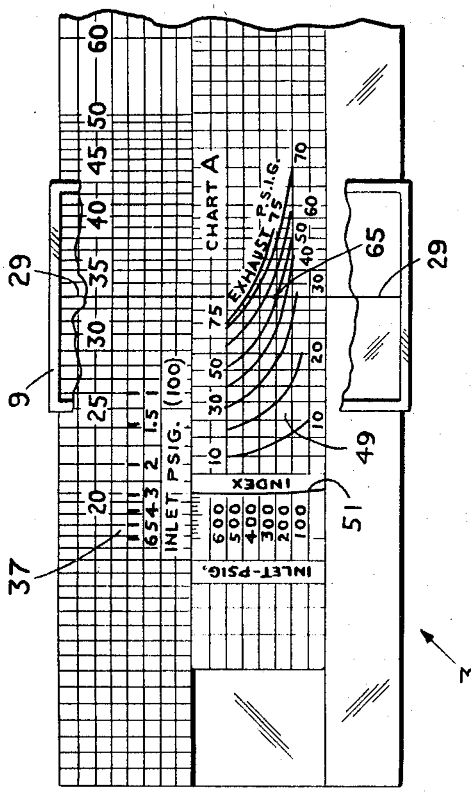

FIG. 4A

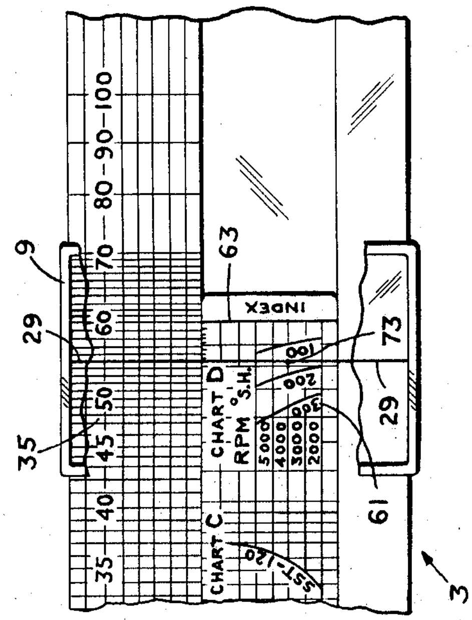

FIG. 4D

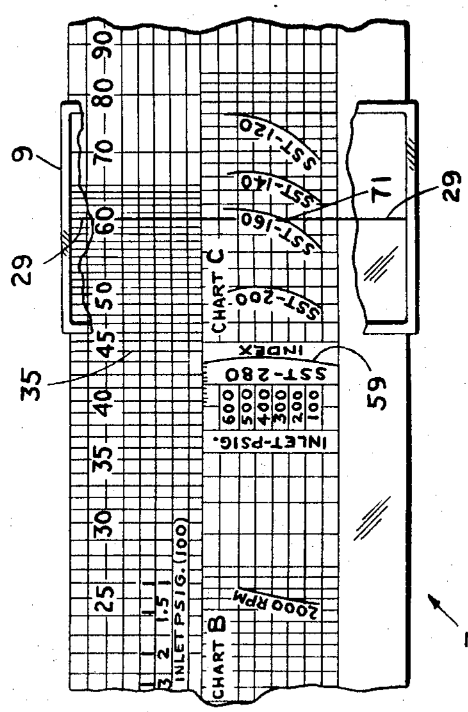

FIG. 4C

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CALCULATING DEVICE FOR ESTIMATING TURBINE STEAM RATES

BACKGROUND OF INVENTION

This invention relates generally to steam turbine technology, and more specifically relates to a calculating device for determining the steam rate of a single curtis stage steam turbine for a given set of operating conditions.

In numerous and diverse instances, engineers and others involved in making decisions with respect to investment in and/or applications of steam turbine equipment, are required to estimate steam consumption characteristics for a single curtis stage turbine operating under a specific set of conditions. A prospective purchaser of such equipment, for example, may wish to be apprised of anticipated steam consumption where a single curtis stage steam turbine of given frame size is operating with given inlet and exhaust pressures, given degree of superheating in the inlet steam, and given operating speed. In order to evaluate alternative solutions to his equipment needs, such prospective purchaser may furthermore, be particularly interested in securing estimates of steam consumption for a variety of stated operating conditions: Thus, for example, he may wish to have available data indicating approximate steam consumption for turbines of differing frame sizes operating under conditions which otherwise are held constant; or he may wish to review steam consumption data for a given frame size turbine operated at a fixed speed, as a function of inlet and/or exhaust pressures and/or degree of superheating.

According to prevalent practice in the industry, steam consumption data of the type above-specified are typically obtained through a laborious and time consuming process, involving use of a plurality of bulky graphs, charts, and formulas. Not only are the physical manipulations involved in securing data by such prior techniques unduly involved and tedious, but moreover operations on such graphs and formulas are performed only with great difficulty by individuals having little prior knowledge of the operation of steam turbines and of the influential variables or their effect upon performance.

In accordance with the foregoing, it may be regarded as an object of the present invention, to provide a calculating device for estimating steam consumption in single curtis stage steam turbines, which is in a highly portable and easily manipulated slide rule-type configuration.

It is a further object of the invention, to provide a slide rule-type steam estimator which may rapidly manipulated by a user to yield approximate steam consumption data for single curtis stage steam turbines operated under a variety of operating conditions.

It is an additional object of the present invention, to provide a slide rule-type steam estimator which may be readily utilized by individuals having little prior knowledge of steam turbine theory, and which yet enables such individuals to rapidly approximate steam consumption data for single curtis stage steam turbines.

SUMMARY OF INVENTION

Now in accordance with the present invention, the foregoing objects, and others as will become apparent in the course of the ensuing specification, are achieved in a slide rule-type calculating device including a casing bearing a multicycle semi-logarithmic scale upon which is plotted steam rate, a slide member movable endwise in said casing and bearing on successively adjacent portions semi-logarithmic plots of four distinct families of curves reflective of steam rate variation with respect to selected turbine operating parameters, and a hair-line slide piece adapted to traverse the length of said steam rate scale and the opposed portions of said slide member. A series of index lines on the slide member are associated with each of the said family of curves. By aligning the index line of the first family of curves with an auxiliary scale on the casing calibrated in steam inlet pressure, and thereupon utilizing the hair-line slide piece to locate a point on the first family of curves corresponding to a selected pair of inlet and outlet pressures, a "base steam rate" may be established on the steam rate scale. Successive and similar operations are then conducted with the remaining three families of curves to successively adjust the base rate for operating speed, frame size, and degree of superheat present in the inlet steam, with the final estimated steam rate being directly read under the hair-line on the steam rate scale. If desired, simple operations may then be used to convert the read steam rate to throttle flows or other parameters of interest. In a preferred embodiment of the invention a reverse face of the calculating device may bear tabulated data useful in effecting the cited conversions.

BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way of example, in the drawings appended hereto, in which:

FIG. 1 is an exterior plan view of a calculating device in accordance with the present invention;

FIG. 2 is a transverse section through the FIG. 1 device, taken along the line 2—2 of said Figure;

FIG. 3 is a plan view of the reverse side of the FIG. 1 device, and illustrates the tabulated information present thereon; and

FIGS. 4A through 4D are partial plan views of the FIG. 1 device, and depict the manner in which the several elements of the calculator are successively manipulated to yield steam rate data for a representative turbine operating environment.

DESCRIPTION OF PREFERRED EMBODIMENT

In FIG. 1 an exterior plan view appears of a calculating device in accordance with the invention. This view may be considered in conjunction with FIG. 2 wherein a transverse cross section along the line 2—2 of FIG. 1 is set forth. As seen in the Figures the device 3 is of a slide rule-type configuration, and includes a rule-shaped casing 5, a slide member 7, and a hair-line slide piece 9. Casing 5 is seen to be constructed as a unit, and includes internally formed tracks 11 and 13 extending the length of casing 5 and adapted to receive runner portions 15 and 17 on slide member 7. Slide member 7 is accordingly movable endwise in casing 7 for the entire length of said casing. A pair of tracks 19 and 21 are similarly formed at the top and bottom edges of casing 5: such tracks receive runners 23 and 25 on hair-line slide piece 9, enabling the latter to traverse the length of casing 5. Slide piece 9 is of generally conventional construction and includes a frame 27 of metal or the like which is formed at its upper and lower ends into the aforementioned runners, a conventional indicating hair-line 29, and a cover glass 31.

Casing 5 is seen to carry on its upper face 33 a scale 35 upon which is plotted values of "steam rate." The term "steam rate," as is well understood to those versed in the arts of steam turbine technology, refers to the mass rate of steam flow in pounds per hour divided by the power or rate of work development of the turbine in horsepower, giving pounds per horsepower-hour. The steam rate, therefore, is the steam supplied per horsepower-hour unit of output, and is regarded as a figure of primary interest by individuals engaged in assessing turbine performance. The values of such steam rate on scale 35 are seen to extend from about 20 lb./hp-hr to 250 lb./hp-hr, as such are the values of interest for the single curtis stage steam turbines with which the present device finds principal application. Scale 35 is seen to be multicycle semi-logarithmic in nature, and the steam rates are correspondingly plotted.

An auxiliary scale 37 also appears on face 33, below the aforementioned steam rate scale. Scale 37 plots in semi-logarithmic fashion inlet steam pressure conditions for the turbine the steam rate of which is to estimated by device 3. The values thereon extend from 100 to 600 p.s.i.g., representing the practical utility range of the cited parameter. The use of auxiliary scale 37 in the present device will become clear in connection with FIGS. 4A to 4D —to be subsequently described.

Slide member **7** is seen to carry on its face a series of four graphical plots, **41**, **43**, **45**, and **47**. These plots —which are theoretically and empirically derived—are indicative of steam rate variation with respect to selected operating variables for single curtis stage turbines. Each such plot is again semi-logarithmic in nature and consists of a family of curves, a suitably calibrated vertical axis, and an associated vertical index line.

The first plot, **41**, designated "CHART A" on member **7**, thus includes a family **49** of curves, each said curve being associated with an indicated steam exhaust pressure —such as 10 p.s.i.g., 20 p.s.i.g., etc. "CHART A" also includes a vertical axis calibrated in inlet p.s.i.g., the index line **51** coinciding with such axis.

On the portion of member **7** adjoining that at which "CHART A" appears (moving to the right in the sense of the Figure), is a second plot **43**, designated "CHART B" in the Figure. Such chart again includes a family **53** of curves, each said curve now being associated with an operating speed for a given single curtis stage turbine —e.g., 2,000 r.p.m. or so forth. "CHART B" also includes a vertical axis calibrated in inlet p.s.i.g., and an index line **55** coinciding with such axis.

On the next successive portion of member **7** appears a third plot **45**, designated as "CHART C." The family **57** of curves therein are individually associated with a turbine possessing a rotating member of a given diameter, or in the parlance of the art with a turbine of a given "frame" size. In "CHART C" the various curves are designated with the terms "SST–**120**," "SST–**140**," and so forth. The quoted terminology is that of the Worthington Corporation of Harrison, New Jersey, assignee of the instant application, and refers to single stage curtis turbines with, respectively, **12** inch, **14** inch etc., rotating elements. "CHART C" like charts "A" and "B" includes a vertical axis calibrated in inlet p.s.i.g., the index line **59** coinciding with said axis.

On the final successive portion of member **7** appears a fourth plot **47** designated "CHART D." The family **61** of curves therein are individually associated with given degrees of superheating in the inlet steam, e.g., 100° superheating (S.H.) or so forth. "CHART D" includes a vertical axis calibrated in operating speed for the turbine under study (in r.p.m.), and it will be observed that the index line **63** is now at the right of the family **61** —in contrast to the location of similar lines for the other described plots.

Device **3** functions to yield estimated steam consumption for a single curtis stage turbine operating under given conditions by virtue of the fact that for each combination of steam conditions there is a particular available quantity of energy. The conversion of this available energy to available work for a given set of conditions is accomplished on device **3** by in effect establishing a base steam rate through use of "CHART A," steam rate scale **35**, and auxiliary scale **37**; and then adjusting this base rate for operating speed, frame size, and degree of superheat by combining the base rate with coordinate values gleaned from charts "B," "C," and "D."

In FIGS. **4A** through **4D** the steps involved in utilizing device **3** to estimate steam rate for an exemplary single curtis stage turbine under a set of stated operating conditions is illustrated. For purposes of this example it may thus be assumed that it is desired to estimate the steam rate for a single curtis stage turbine of frame size SST–**160**, with other operating conditions as follows: inlet pressure 300 p.s.i.g.; exhaust pressure 50 p.s.i.g.; operating speed 3,000 r.p.m., and with 200° superheating in the inlet steam.

As seen in FIG. **4A**, index line **51** on slide member **7** is initially aligned with the point on auxiliary scale **37** representative of an inlet pressure of 300 p.s.i.g. Thereupon hair-line slide piece **9** is moved until hair-line **29** overlies point **65** —representing the intersection of the 300 p.s.i.g. inlet pressure abscissa with the 50 p.s.i.g. exhaust curve. The base steam rate appears under hair-line **29** at scale **35**. Such base rate may be read if desired (approximate value 33 lb./hp-hr), but more commonly the rate is not actually "read," but rather temporarily "held" by the hair-line's then set position.

In FIG. **4B** the base steam rate is corrected for turbine operating speed. Thus the index line **55** in "CHART B" is aligned with the held position of hair-line **29** i.e., as in FIG. **4A**) and the slide piece **9** is then moved so that hair-line **29** overlies point **69** —the intersection of the **300** p.s.i.g. abscissa with the 3,000 r.p.m. curve. Again the corrected steam rate appears under hair-line **29** at scale **35**, but is not necessarily "read."

In FIG. **4C** a similar sequence of operations is used to further adjust the steam rate for the frame size of the turbine. Again after aligning index line **59** with the held position of hair-line **29** (as in FIG. **4B**), the slide piece **9** is moved so that hair-line **29** overlies the point **71** at the intersection of the 300 p.s.i.g. abscissa with the SST–**160** curve. Again, the further corrected steam rate appears under hair-line **29** at scale **35** —but is not necessarily read.

Finally in FIG. **4D** a correction is similarly introduced for degree of superheating in the inlet steam. Thus in this case the right-hand index line **63** is aligned with hair-line **29** as set in FIG. **4C** and the slide member **7** is displaced so as to overlie point **73** representing the intersection of the 3,000 r.p.m. abscissa with the curve in family **61** representing 200° of superheating. The fully corrected steam rate is now read on scale **35** —in this exemplary instance as an approximate value of 55 lb./hp-hr.

Frequently, personnel utilizing the calculating device **3** will prefer to convert the steam rates yielded at scale **35** to "throttle flows" in lb./hr. for the turbine operation in question. To assist in such conversion the present calculating device includes both formulas and appropriate tabular information. Thus it is seen that the formula **75** for effecting the cited conversion is set forth directly on face **33** of casing **5**.

It will be noted in formula **75** that the multiplying factor for converting to turbine throttle flow is the arithmetical sum of the net horsepower (HP) and horsepower losses (HP_L). The factor HP_L, representing frictional losses, is seen in FIG. **2** to be conveniently tabulated on the reverse face **79** of casing **5**. The reverse face **79** also includes a brief tabulation **81** of approximate horsepower capabilities of the several frame size turbines treated by device **3** —for two specific inlet pressure levels. Finally, the reverse face **79** sets forth in area **83** a succinct set of directions enabling an interested individual to readily operate the present calculating device without further specialized training or instruction.

While the present invention has been particularly set forth in terms of a specific embodiment thereof, it will be understood in view of the instant disclosure, that numerous variations upon the invention are now enabled to those skilled in the art, which variations will, in propriety, yet reside within the true province of the present teaching. Accordingly the present invention is to be broadly construed, and limited only by the scope and spirit of the claims now appended hereto.

I claim:

1. A slide rule-type calculating device for estimating steam consumption in single curtis stage turbines, comprising:

a casing bearing a scale representative of steam rates;

a slide member movable endwise in said casing and carrying indicia opposed to said scale and displaceable with respect thereto by movement of said member, said indicia taking the form of a series of graphical plots indicative of steam rate variation with respect to selected operating variables for said turbine; and

a hair-line slide piece mounted to traverse the length of said steam rate scale and the opposed indicia on said slide member;

the respective positions of said scales and plots being such that steam consumption in said turbine may be estimated by successively opposing members of said series of plots to said steam rate scale and utilizing said slide piece to relate the coordinates on said plots representative of operating conditions for said turbine to said opposed scale, said successive operations thereby serving to combine said coordinates and yield said desired value on said scale.

2. A device in accordance with claim 1, wherein said plots are four in number and are indicative respectively of steam rate variation with respect to steam inlet and exhaust pressure, frame size of said turbine, operating speed of said turbine, and degree of superheating in the inlet steam to said turbine.

3. A slide rule-type calculating device for estimating steam rates in single curtis stage turbines, comprising:

a. a casing bearing a multicycle semi-logarithmic scale upon which is plotted steam rate, and an auxiliary scale representing inlet steam pressure to said turbine;

b. a slide member movable endwise in said casing and carrying indicia opposed to said scale and displaceable with respect thereto by movement of said member, said indicia taking the form on successive adjacent portions of said member of semi-logarithmic plots of distinct families or curves reflective of approximate steam rate variation with respect to specified turbine operating parameters, the first of said families reflecting said variation with respect to inlet and outlet steam pressures to said turbine, an index line being associated with each said family of curves; and

c. a hair-line slide piece mounted to traverse the length of said steam rate scale and the opposed indicia on said slide member;

the respective positions of said scales and plots being such that steam rates in said turbine may be established by aligning the index line associated with the first family of curves with the inlet steam pressure for said turbine on said auxiliary scale and then moving said hair-line slide to locate the inlet and outlet pressures on said first family of curves to establish a base steam rate, and thereupon successively displacing said slide member and said hair-line slide to align the remaining index lines with the successively adjusted base steam values to correct said base value for the parameters plotted in said remaining families of curves and thereby yield said final desired estimate.

4. A device in accordance with claim 3 wherein said plots are four in number, the last three plots being indicative respectively of steam rate variation with respect to frame size of said turbine, operating speed of said turbine, and degree of superheating in the inlet steam to said turbine.

5. A device in accordance with claim 4, further including on the reverse face of said casing tabularized data for effecting conversion from said read steam rate to throttle flow rates.

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