



## INSTRUCTING THE PRINCIPLES OF GAS TURBINE

### PERFORMANCE MONITORING AND DIAGNOSTICS BY MEANS OF INTERACTIVE COMPUTER MODELS

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## Instructing The Principles Of Gas Turbine Performance Monitoring And Diagnostics By Means Of Interactive Computer Models

- **Use of Gas Turbine Computer Models in Education.**

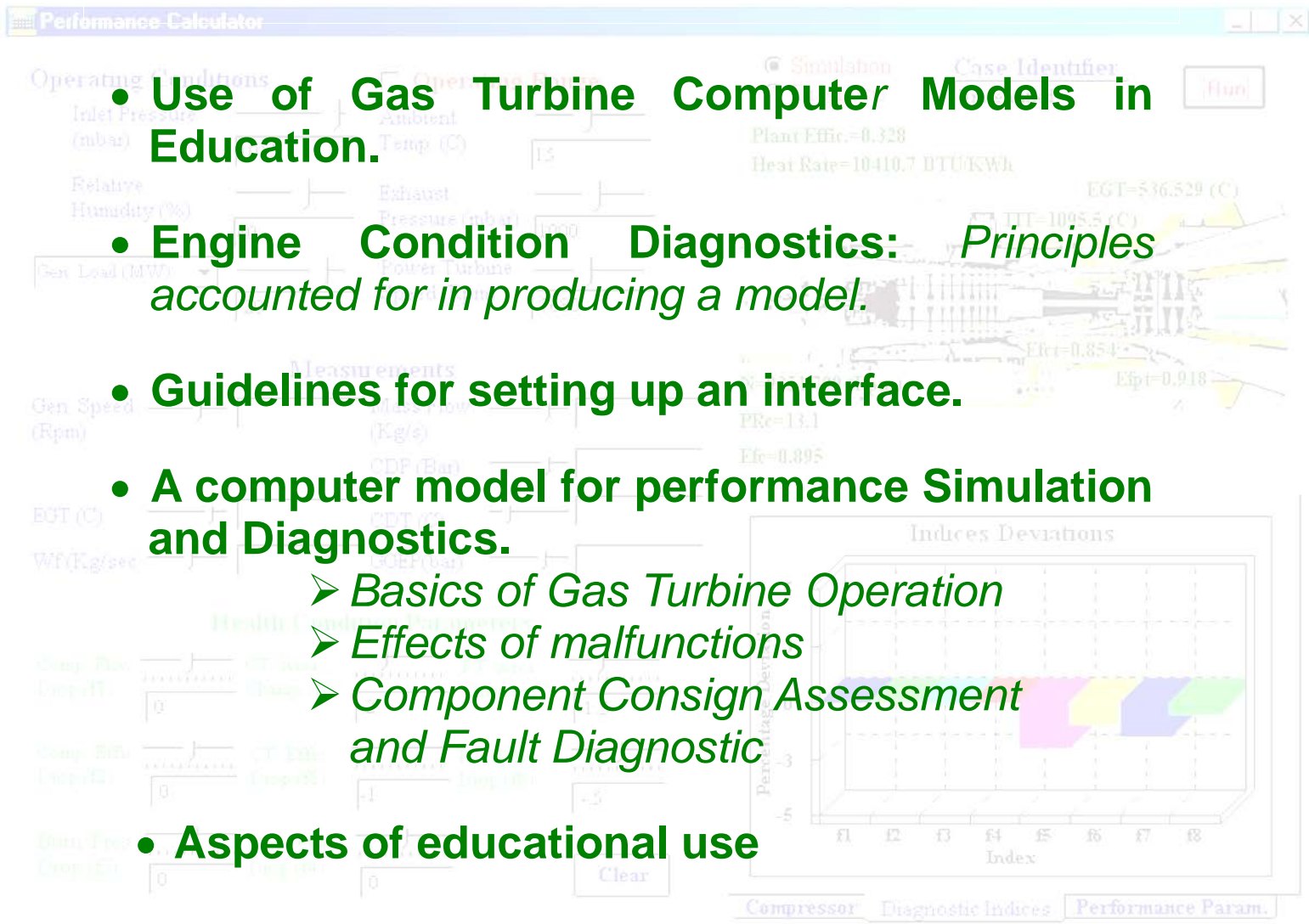
- **Engine Condition Diagnostics: Principles accounted for in producing a model.**

- **Guidelines for setting up an interface.**

- **A computer model for performance Simulation and Diagnostics.**

- Basics of Gas Turbine Operation
- Effects of malfunctions
- Component Consign Assessment and Fault Diagnostic

- **Aspects of educational use**





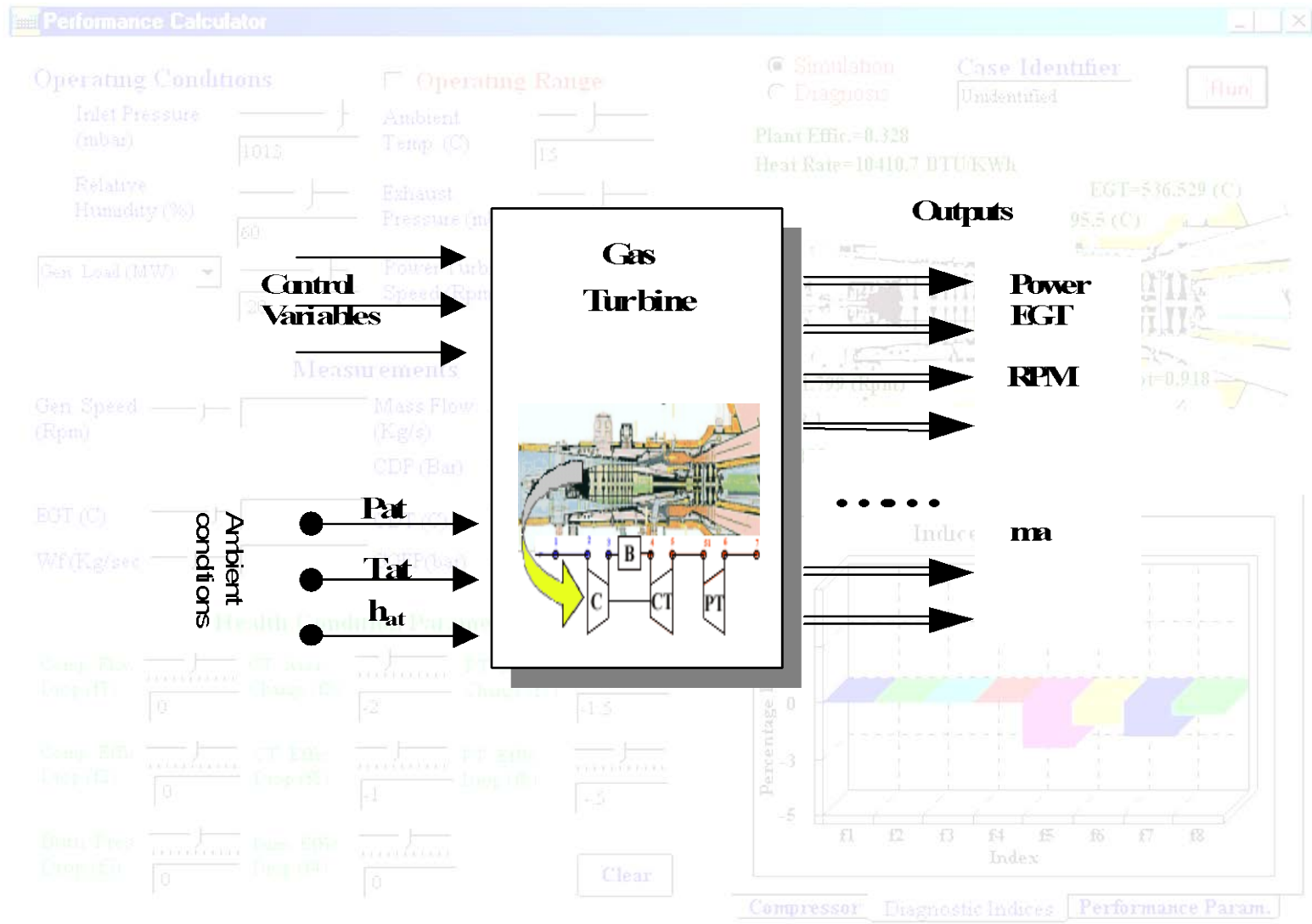
## Use of Gas Turbine Computer Models in education

The screenshot shows a software interface for a gas turbine performance calculator. It includes several sections: 'Operating Parameters' with input fields for Inlet Pressure (1013 mbar), Relative Humidity (60%), and Pressure (1000 mbar); 'Measurements' with Gen Speed (7680 Rpm), Mass Flow (Kg/s), and EGT (536.529 C); 'Health Condition Parameters' with various efficiency and pressure ratio indicators; and a '3D Indices Deviations' chart showing percentage deviation for indices 1 through 8. The chart has a vertical axis for Percentage Deviation ranging from -5 to 5. The chart shows bars for indices 1-4 in green, 5 in pink, 6 in yellow, 7 in blue, and 8 in light green. The software also displays a turbine schematic and various performance metrics like Heat Rate, IIT, EPR, and EPR.

- Provide a means for effectively teaching
  - Demonstrate behavior of complicated systems
  - Effective use of teaching time
- Cover an extended range of operating conditions
- Provide values of physical quantities hard or impossible to observe physically
- Abnormal operation can be studied at no cost

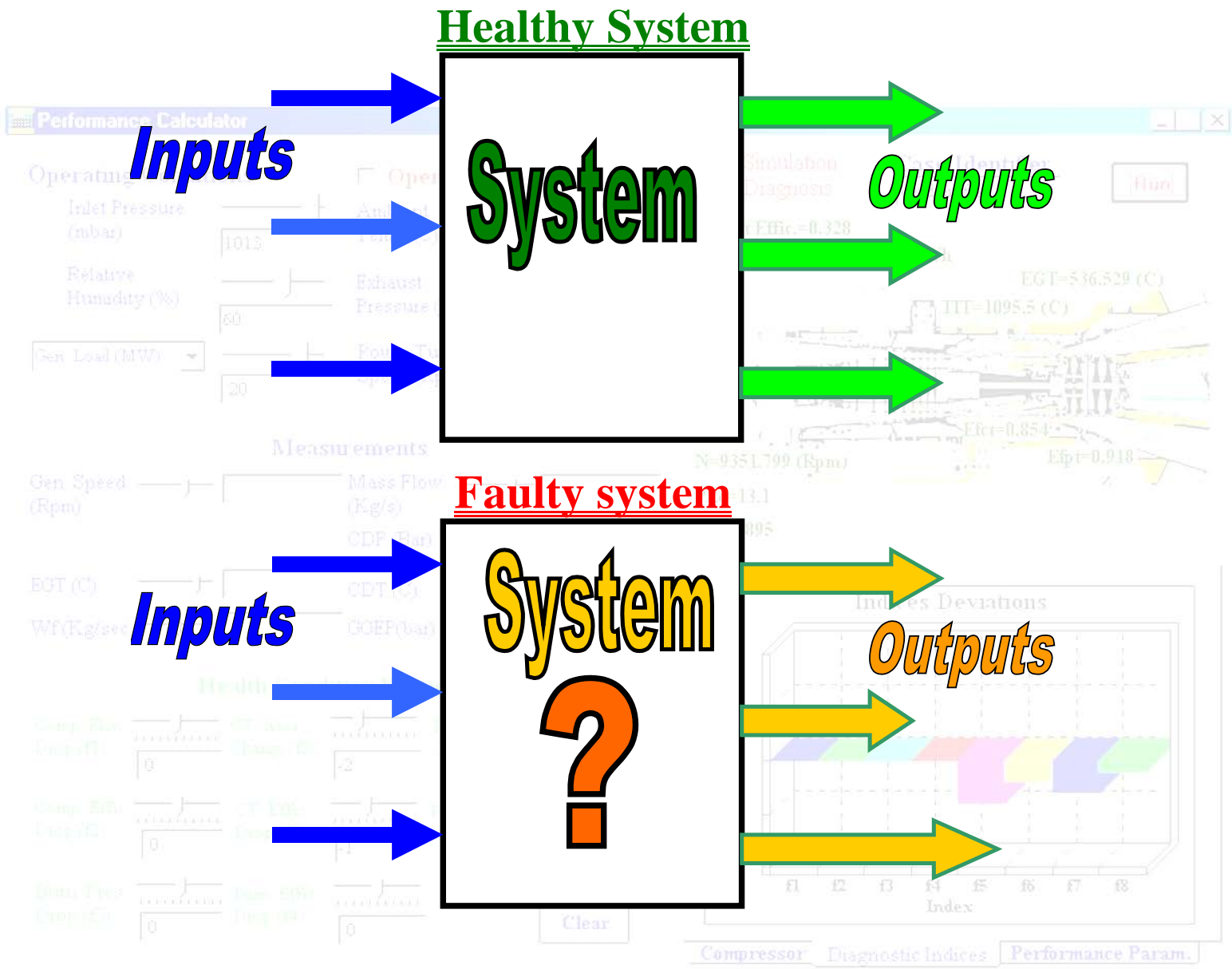


## Schematic representation of the gas turbine process



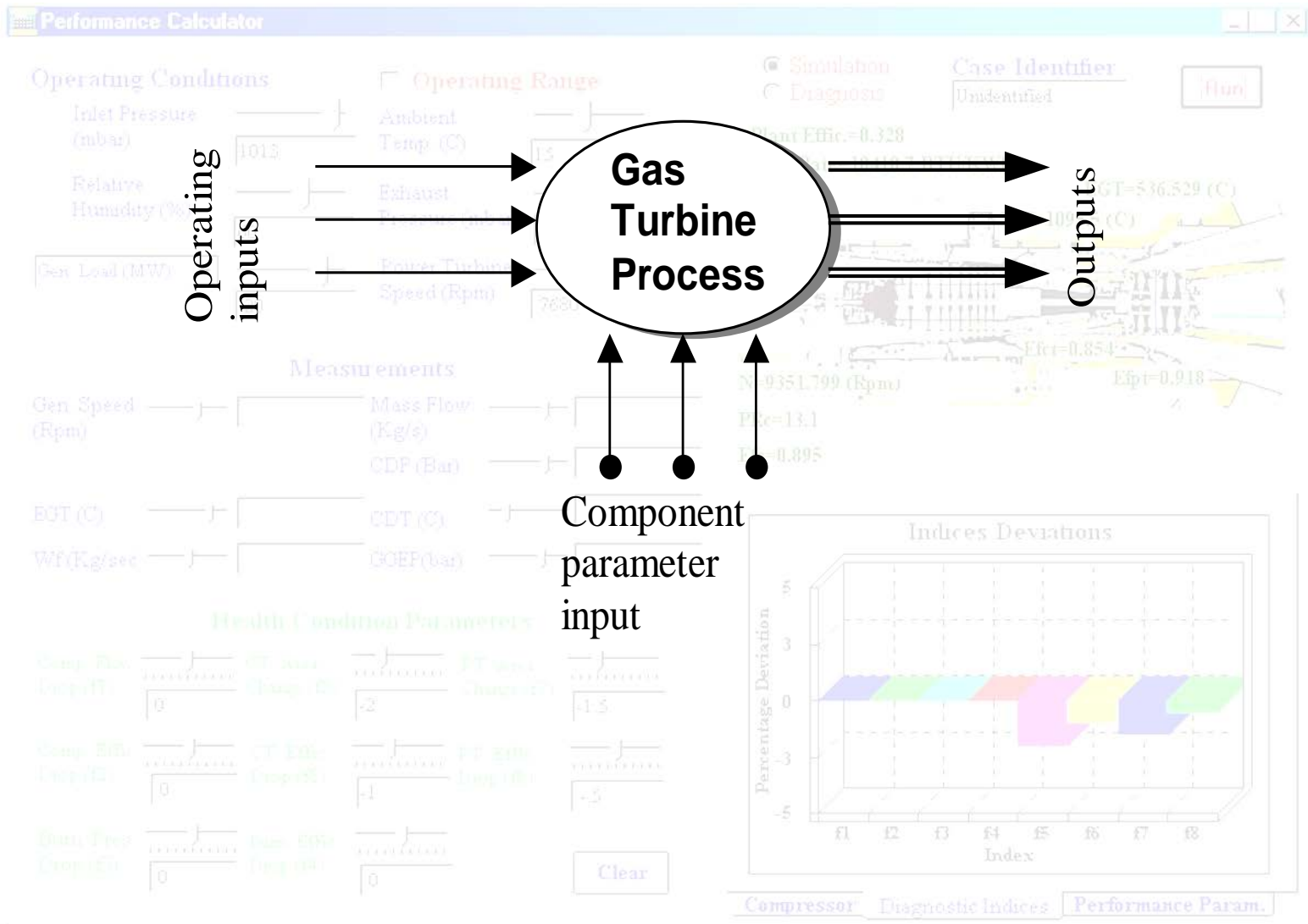


## The Principle of DIAGNOSTICS



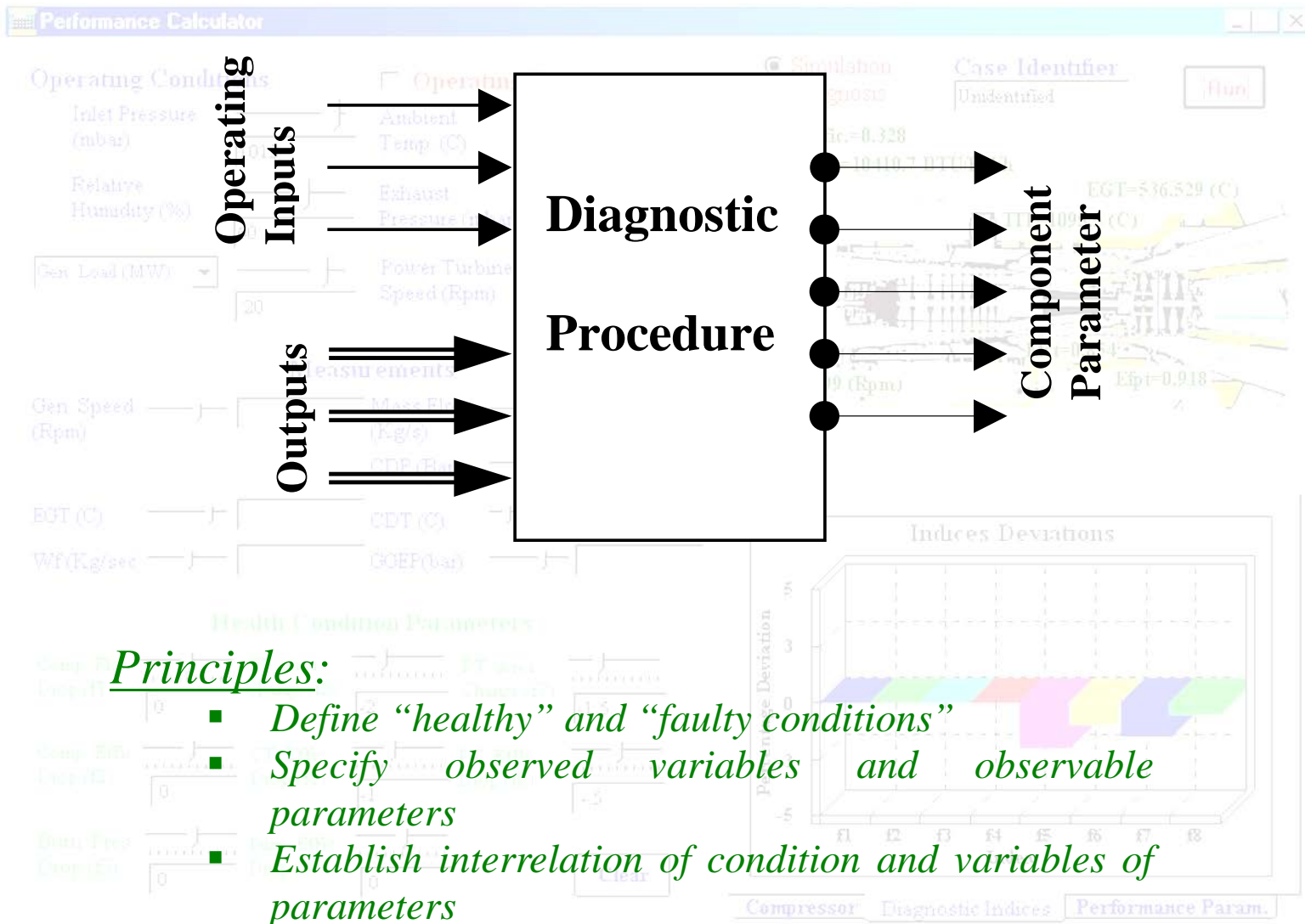


The gas turbine as an input-output system, for monitoring-diagnostic purposes





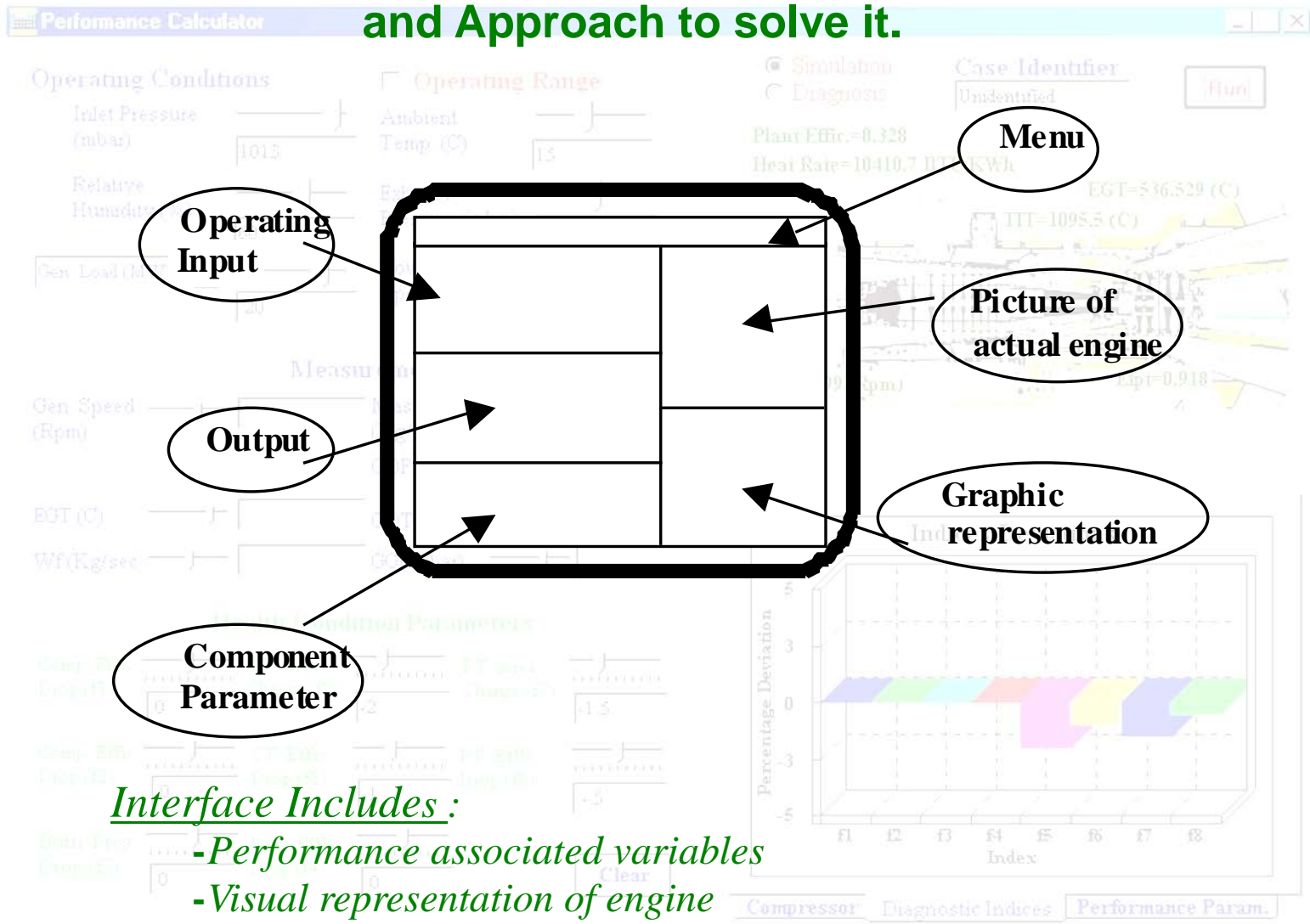
## The process of gas turbine engine condition diagnosis





## Choice of visual interface layout

**Ensure Correspondence to Physical Problem  
and Approach to solve it.**



### Interface Includes :

- Performance associated variables
- Visual representation of engine
- Graphic representation of various quantities

Programmed in widely acceptable manner





## The basic screen

# Gas-turbine performance simulation and diagnostics software TEACHES.

The screenshot displays the 'Performance Calculator' software interface. It is divided into several sections:

- Operating Conditions:** Includes sliders and input fields for Inlet Pressure (1013 mbar), Ambient Temp. (-5-48 C), Relative Humidity (60%), Exhaust Pressure (1000 mbar), EGT (517 C), and Power Turbine Speed (7680 Rpm). A checkbox for 'Operating Range' is checked.
- Measurements:** Displays real-time data for Gen. Speed (9024.7-9276.1 Rpm), Mass Flow (49.1-78.6 Kg/s), Gen. Load (8.01-21.96 MW), CDP (8.-13.6 Bar), CDT (338.8-342.4 C), and WF (77-1.53 Kg/sec).
- Health Condition Parameters:** Features sliders for various efficiency and drop parameters such as Comp. Flow Drop (f1), CT. Area Change (f5), PT. Area Change (f7), etc.
- Simulation/Case Identifier:** Shows 'Simulation' selected, 'Case Identifier' as 'Unidentified', and a 'Run' button.
- Performance Summary:** Lists Plant Effic.=0.313-0.619, Heat Rate=12472.37-9953.115 BTU/KWh, EGT=483.-483. (C), TIT=896.9-1026. (C), Eft=0.866-0.87, N=9024.682-9276.074, Eft=0.887-0.927, PRc=8.1-13.3, and Efc=0.888-0.899.
- Operating Line Graph:** A plot of Pressure Ratio vs. Mass Flow Rate (Kg/sec) showing a performance curve with a yellow line and data points.



## Input for operational parameters

Performance Calculator *Twin Shaft Gas Turbine*

Operating Conditions  Operating Range  Simulation  Diagnosis  Case Identifier: Unidentified [Run]

**Operating Conditions**  **Operating Range**

|                       |            |                           |      |
|-----------------------|------------|---------------------------|------|
| Inlet Pressure (mbar) | 1013       | Ambient Temp. (C)         | 15   |
| Relative Humidity (%) | 60         | Exhaust Pressure (mbar)   | 1000 |
| Gen. Load (MW)        | [Dropdown] | Power Turbine Speed (Rpm) | 7680 |
| Gas Gen. Speed (RPM)  | 20         |                           |      |

Gen. Load (MW) dropdown menu:  
Gen. Load (MW)  
Gas Gen. Speed (RPM)  
Gen. Load (MW)  
EGT (C)  
Wf (Kg/sec)  
TIT (C)  
CDP (Bar)

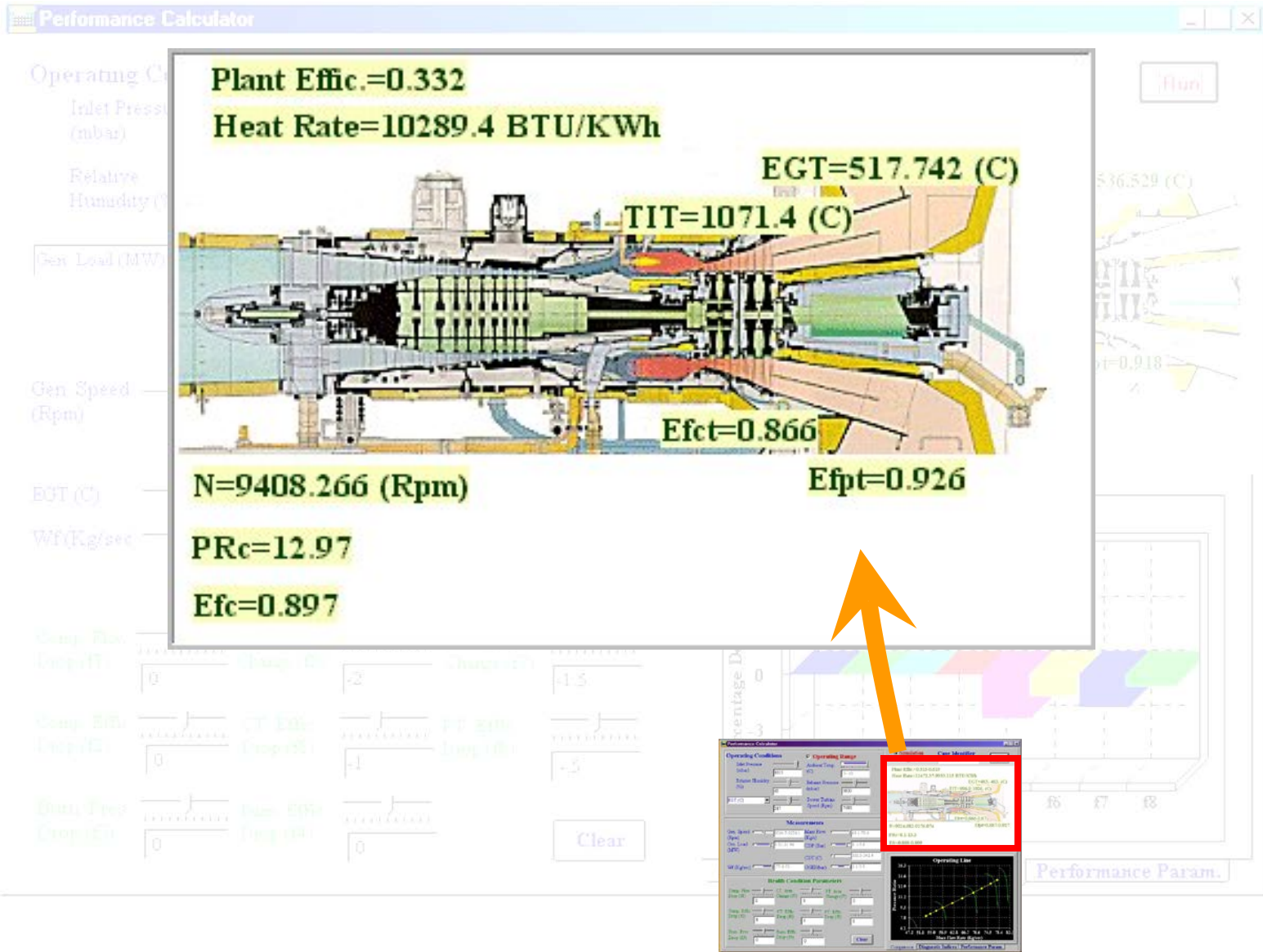
Percentage Deviation graph: Y-axis from -5 to 0, X-axis with labels F1 and F2. An orange arrow points from the graph to the Performance Calculator window.

Performance Calculator window (red box):  
Operating Conditions: Inlet Pressure, Ambient Temp., Relative Humidity, Exhaust Pressure, Power Turbine Speed.  
Measurements: Gen. Load, Gas Gen. Speed, EGT, Wf, TIT, CDP.  
Health Condition Parameters: Gen. Load, Gas Gen. Speed, EGT, Wf, TIT, CDP.  
Operating Line graph.

Compressor Diagnostic Indices Performance Param.



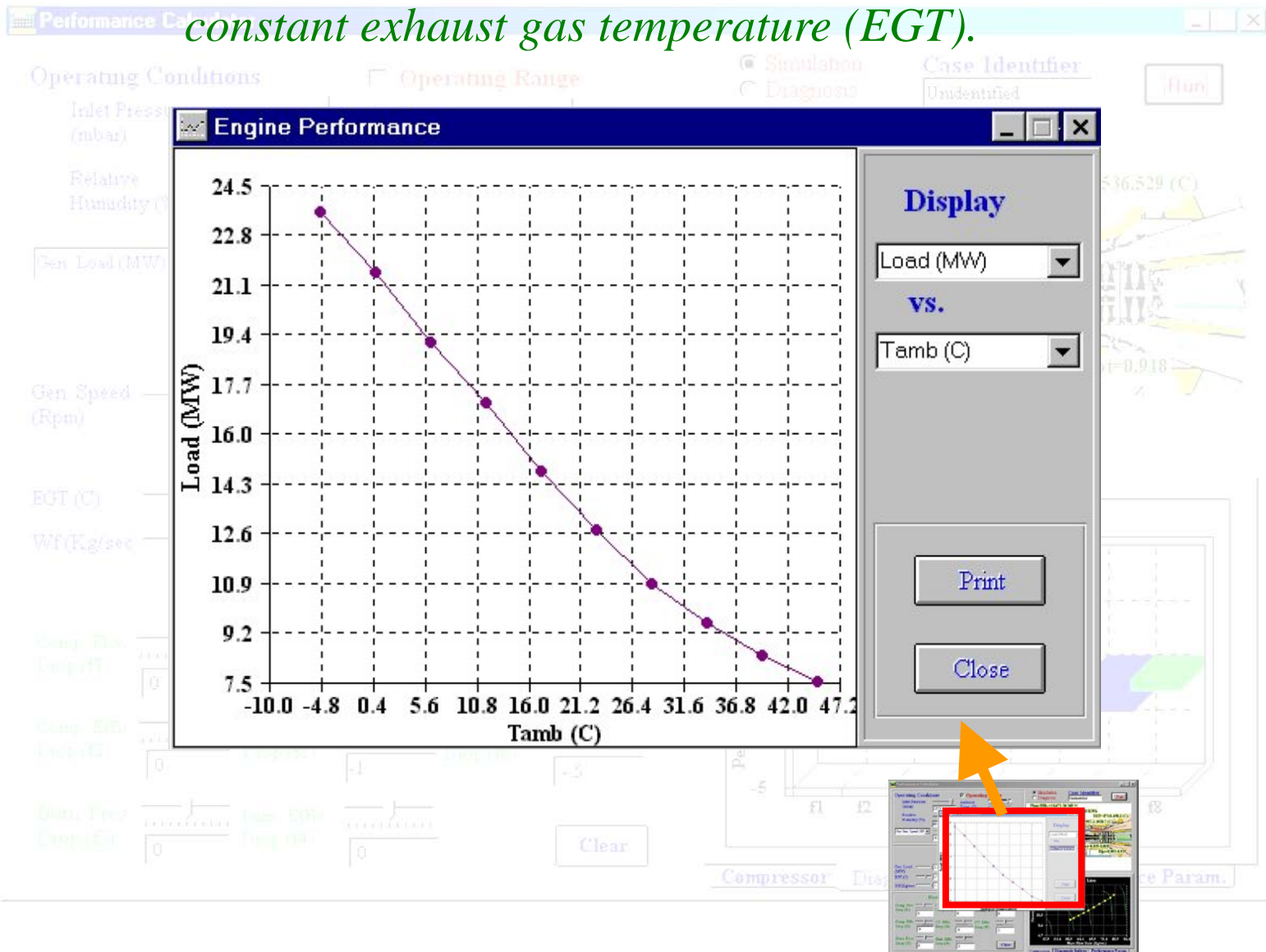
**Display of performance variables and parameters on an engine cut-out.**





## Interrelation of Performance Parameters

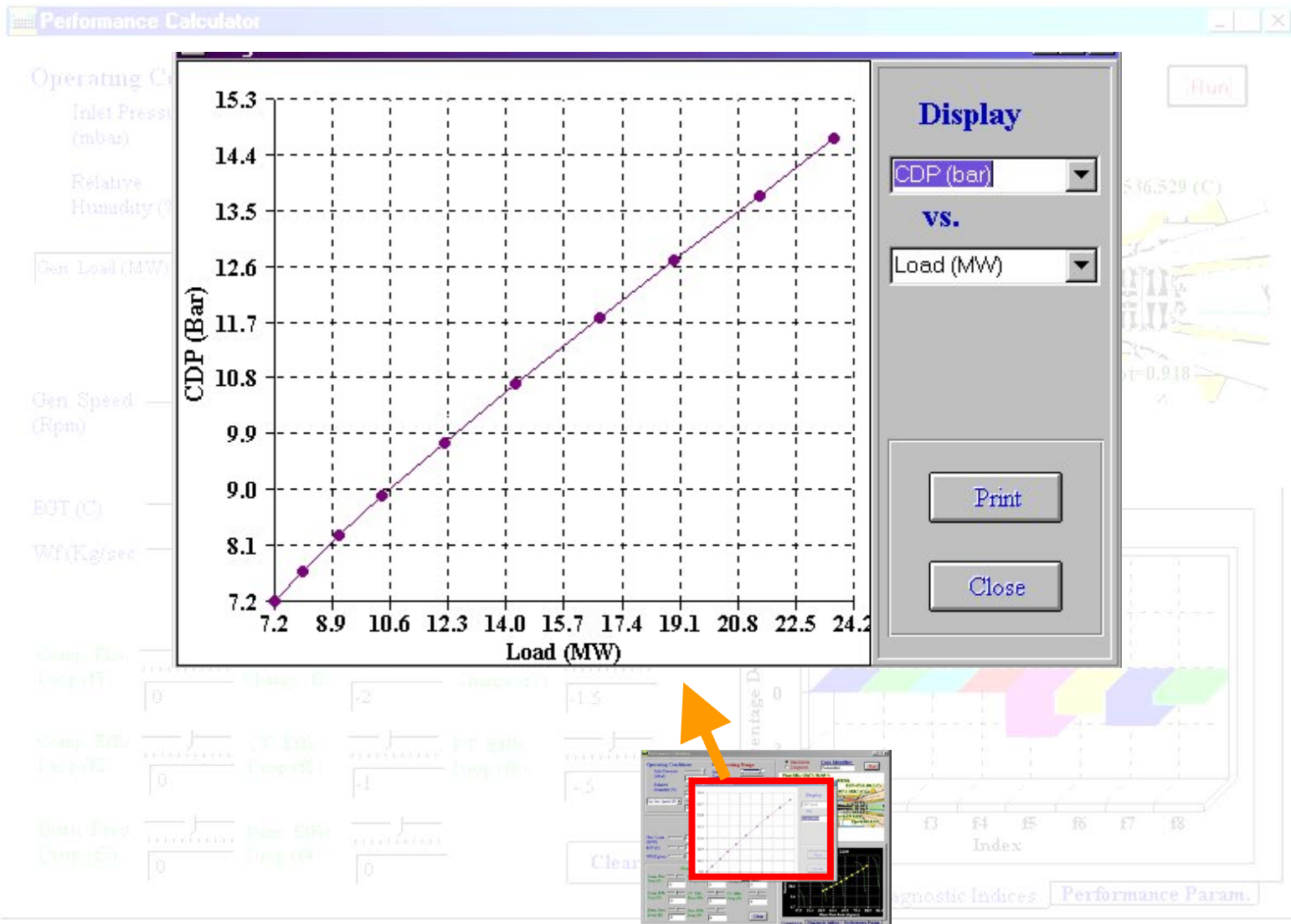
*Output power versus ambient temperature for constant exhaust gas temperature (EGT).*





## Interrelation of Performance Parameters

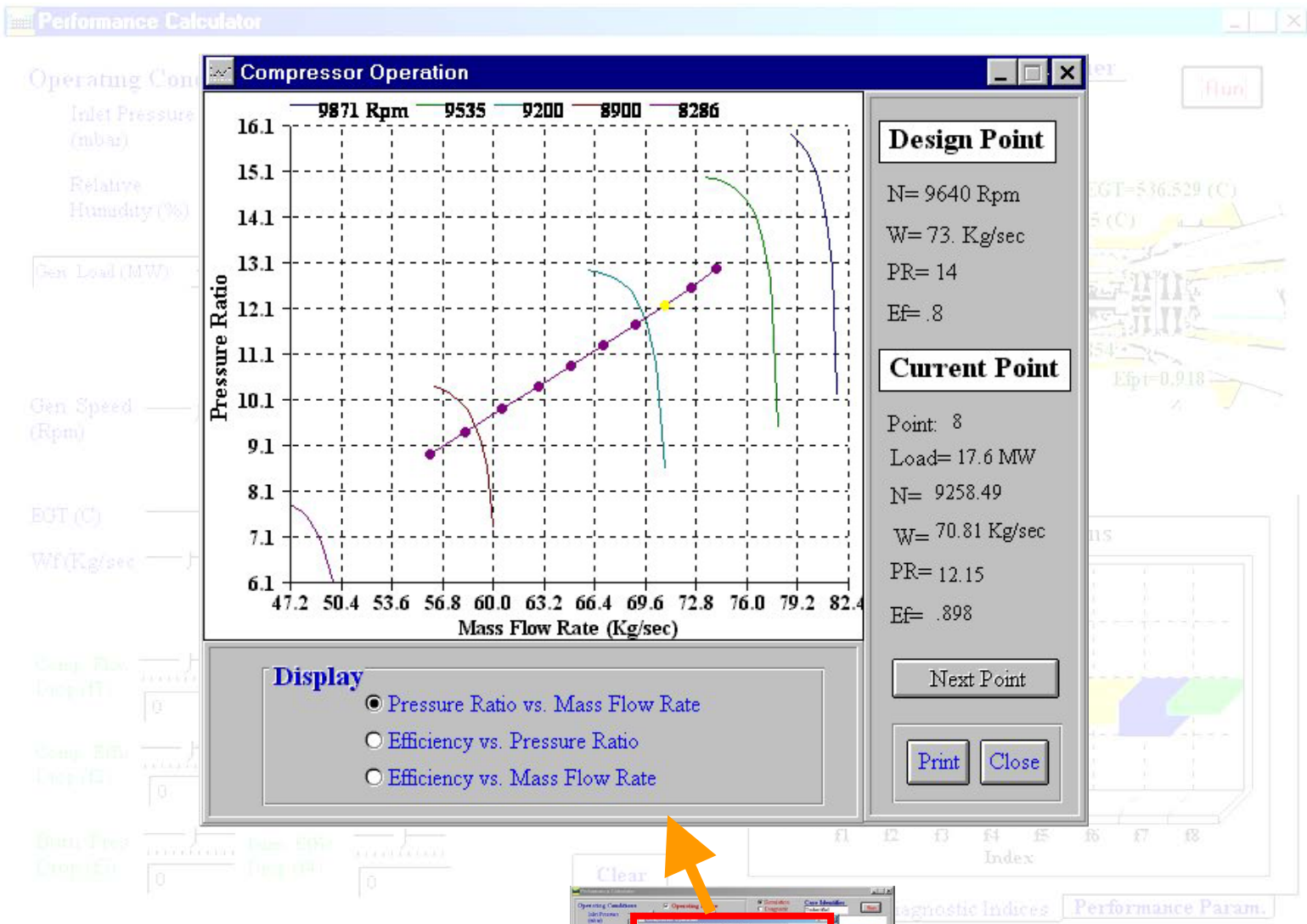
*Compressor delivery pressure and load.*





## Operating points on compressor maps

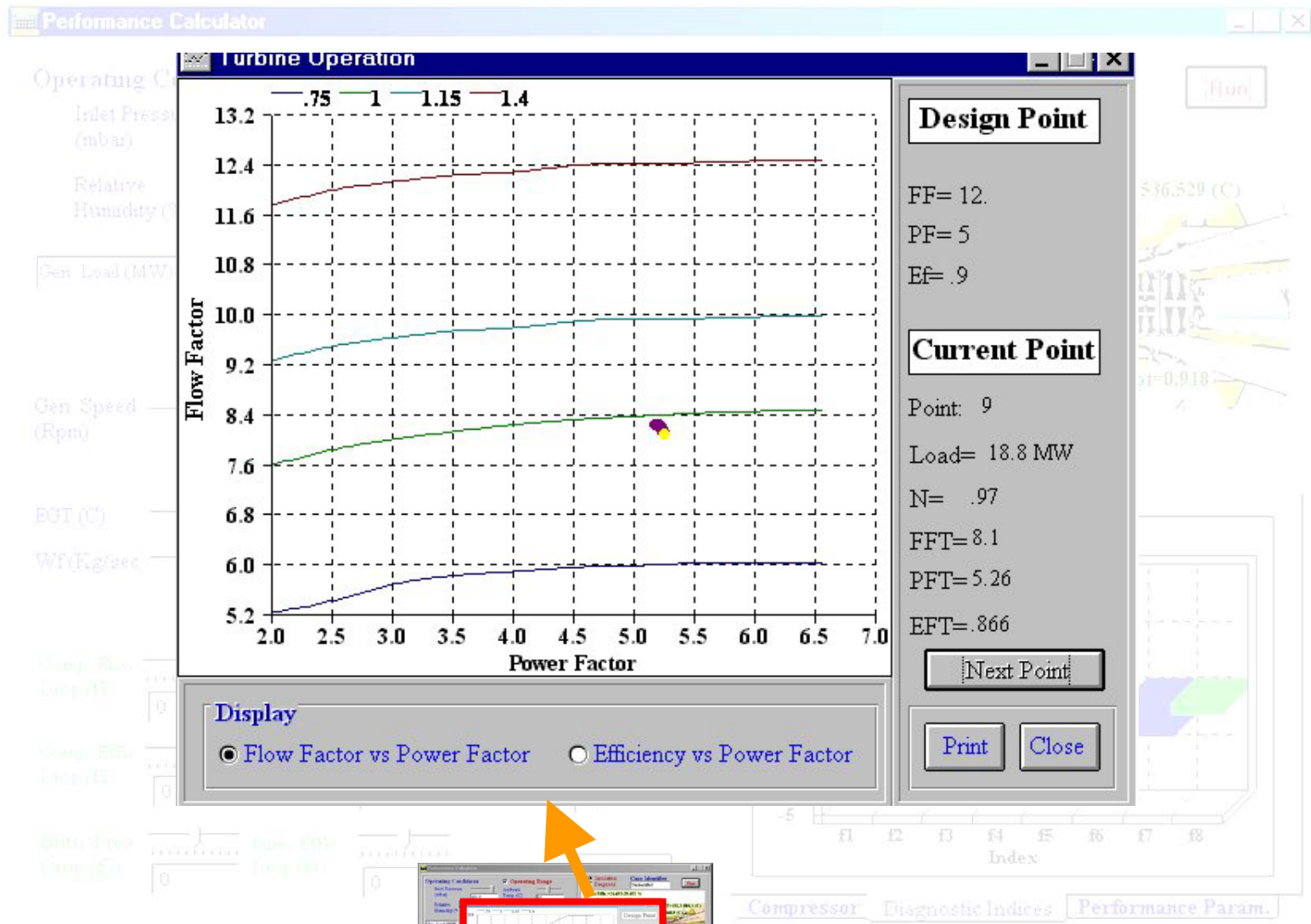
*Twin spool gas turbine: a range of power outputs.*





## Operating points on turbine map

*Twin spool gas turbine: a range of power outputs.*





## Representing Malfunctions

- Choice of main components condition parameters

- Introducing diagnostic quantities

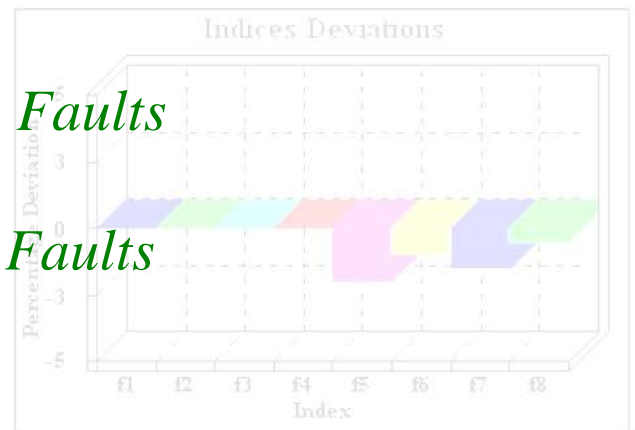
- Modification Factors

$$MF = \frac{X}{X_{act}}$$

- Use them for

→ Simulating Faults

→ Diagnostic Faults







## Introducing Component Condition Parameters

**Health Condition Parameters**

|                        |                        |                      |
|------------------------|------------------------|----------------------|
| Comp. Flow Drop (f1)   | CT. Area Change (f5)   | PT. Area Change (f7) |
| -2                     | 0                      | 0                    |
| Comp. Effic. Drop (f2) | CT. Effic. Drop (f6)   | PT. Effic. Drop (f8) |
| -0.5                   | 0                      | 0                    |
| Burn. Pres. Drop (f3)  | Burn. Effic. Drop (f4) | Clear                |
| 0                      | 0                      |                      |

**Indices Deviations**

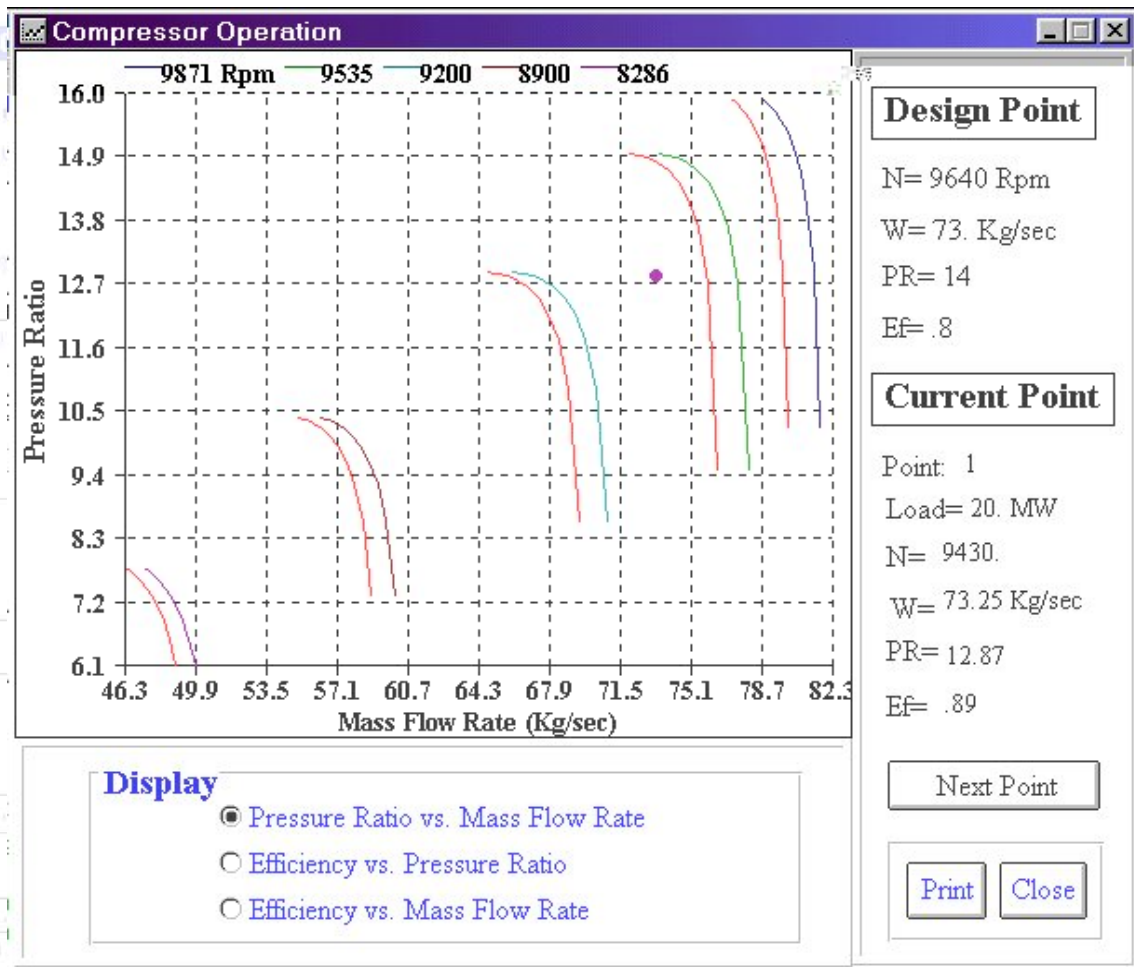
Percent Deviation

Index

f1 f2 f3 f4 f5 f6 f7 f8



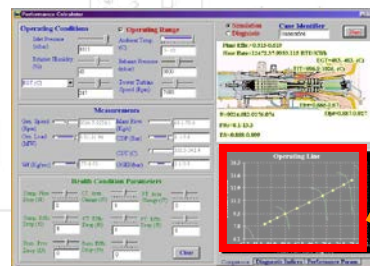
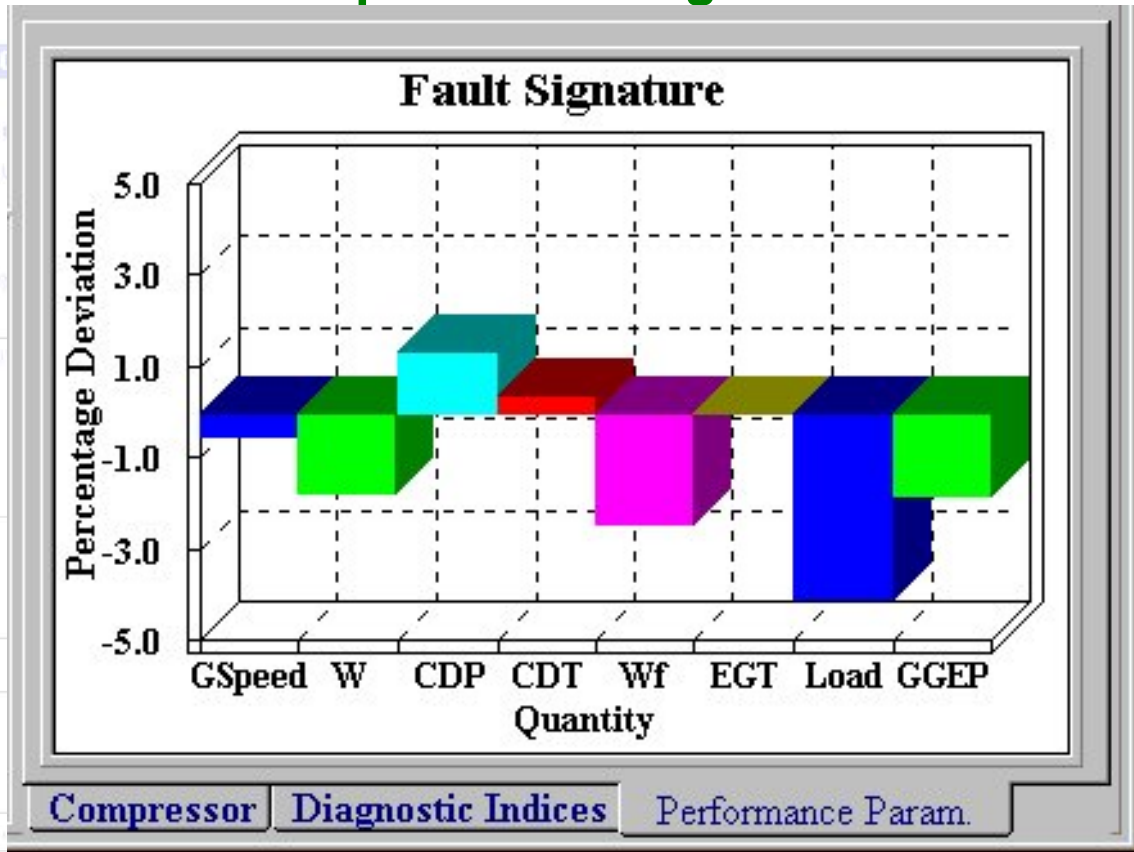
## Modification of compressor performance map for a 2% reduction in flow capacity.





## Derivation of "Fault Signatures"

### Example of fault signature





## Processing Measurement Data for Diagnosis

The screenshot displays the 'Performance Calculator' software interface. A central 'Measurements' dialog box is highlighted, showing the following data:

| Parameter        | Value         |
|------------------|---------------|
| Gen. Speed (Rpm) | 9024.7-9276.1 |
| Mass Flow (Kg/s) | 49.1-78.6     |
| Gen. Load (MW)   | 8.01-21.96    |
| CDP (Bar)        | 8.-13.6       |
| Wf (Kg/sec)      | 77-1.53       |
| CDT (C)          | 338.8-342.4   |
| GGEP (bar)       | 2.2-3.5       |

Below the measurements, the software displays 'Health Condition Parameters' for various compressor stages (C1-C8) and turbine stages (T1-T3). The parameters include Compressor Efficiency (Comp. Eff.), Turbine Efficiency (Turb. Eff.), and Turbine Inlet Temperature (TIT). The values for these parameters are shown as percentages, with a 'Clear' button at the bottom.

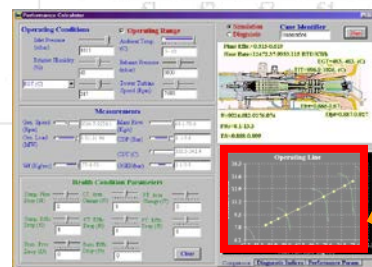
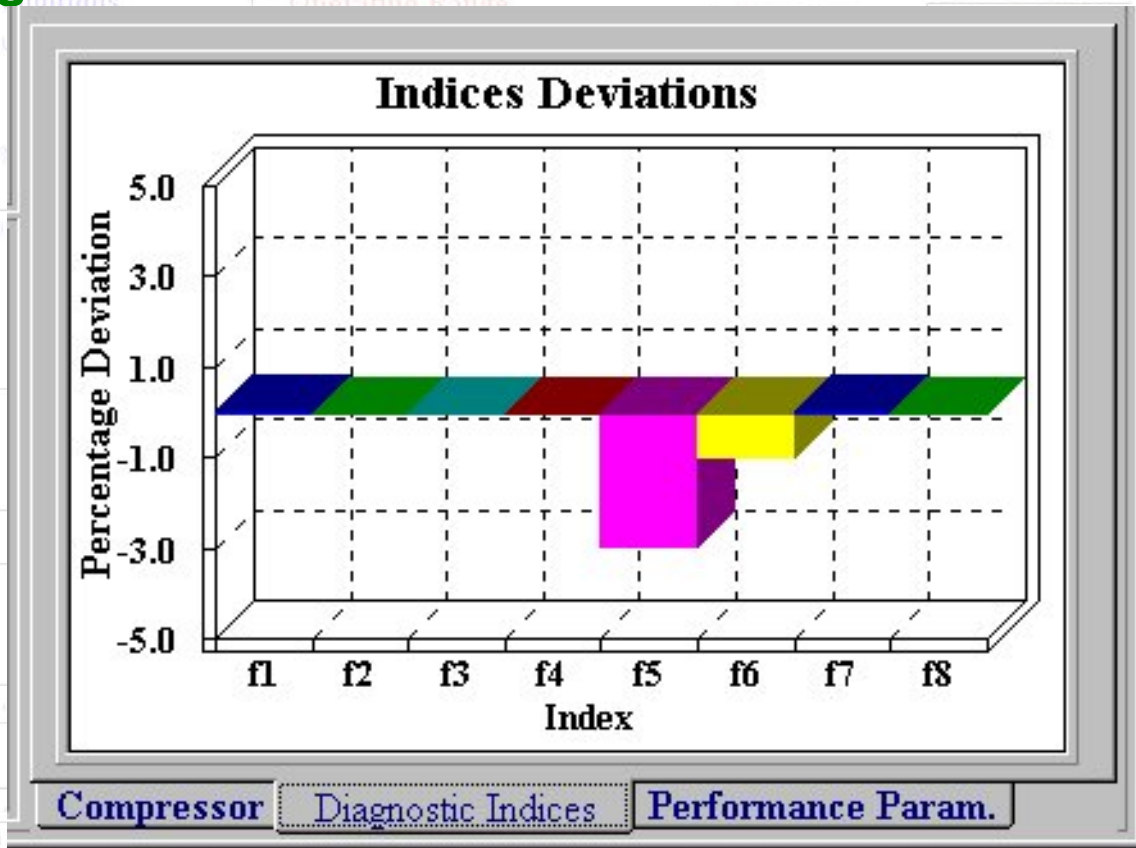
An orange arrow points from the 'Measurements' dialog box to a 3D bar chart titled 'Percentage Deviation' vs 'Index'. The chart shows the deviation of various parameters across eight compressor stages (C1 to C8). The y-axis ranges from -5% to 5%. The bars are color-coded: C1 (blue), C2 (green), C3 (red), C4 (yellow), C5 (purple), C6 (orange), C7 (light blue), and C8 (light green). The deviation values are approximately: C1: 0%, C2: 0%, C3: 0%, C4: 0%, C5: -2%, C6: -1%, C7: 0%, C8: 0%.

At the bottom of the interface, there are three tabs: 'Compressor', 'Diagnostic Indices', and 'Performance Param.'. The 'Diagnostic Indices' tab is currently selected.



## Diagnostic Information Directly Interpretable

Component modification factors, characterizing engine condition.





**Choice of combinations of available measurements and "health" parameters to be evaluated**

The screenshot displays the 'Performance Calculator' software interface. A dialog box titled 'Indices Selection' is open, allowing users to choose which parameters to monitor. The dialog is organized into several sections:

- Health Indices:**
  - Compressor:**  Flow Capacity,  Efficiency
  - Combustor:**  Pressure Loss,  Efficiency
  - Core Turbine:**  Nozzle Area,  Efficiency
  - Power Turbine:**  Nozzle Area,  Efficiency
- Measurements:**
  - CDP,  EGT,  Gas Gen Ex. Pres.
  - Fuel Flow,  CDT
  - Air Flow,  Gen. Load

At the bottom of the dialog are two buttons: 'Default Settings' and 'OK'. The background software interface shows various operating conditions and performance metrics, including Inlet Pressure (1013 mbar), Ambient Temp (15 C), Plant Effici.=0.328, and Case Identifier (Undefined).



## Further Education Aspects

- *Self sufficiency of software*

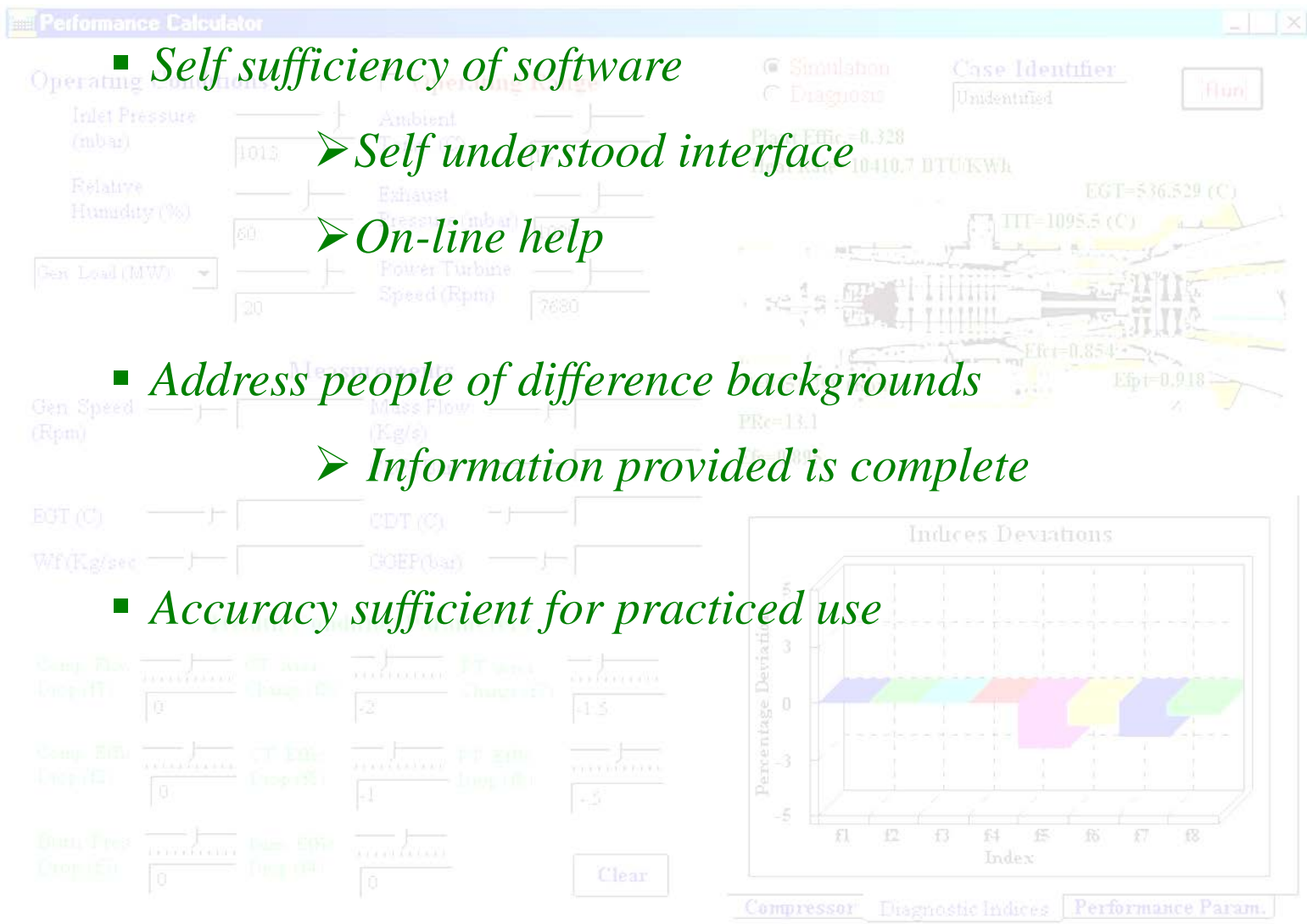
- *Self understood interface*

- *On-line help*

- *Address people of difference backgrounds*

- *Information provided is complete*

- *Accuracy sufficient for practiced use*





## Conclusion

*Gas Turbine Computer Models Offer great possibilities for education on all aspects of Gas Turbine operation, with particular usefulness when referring to operation with altered (deteriorated, faulty, damaged) components.*

