15th SYMPOSIUM ON INDUSTRIAL APPLICATIONS OF GAS TURBINES

IAGT

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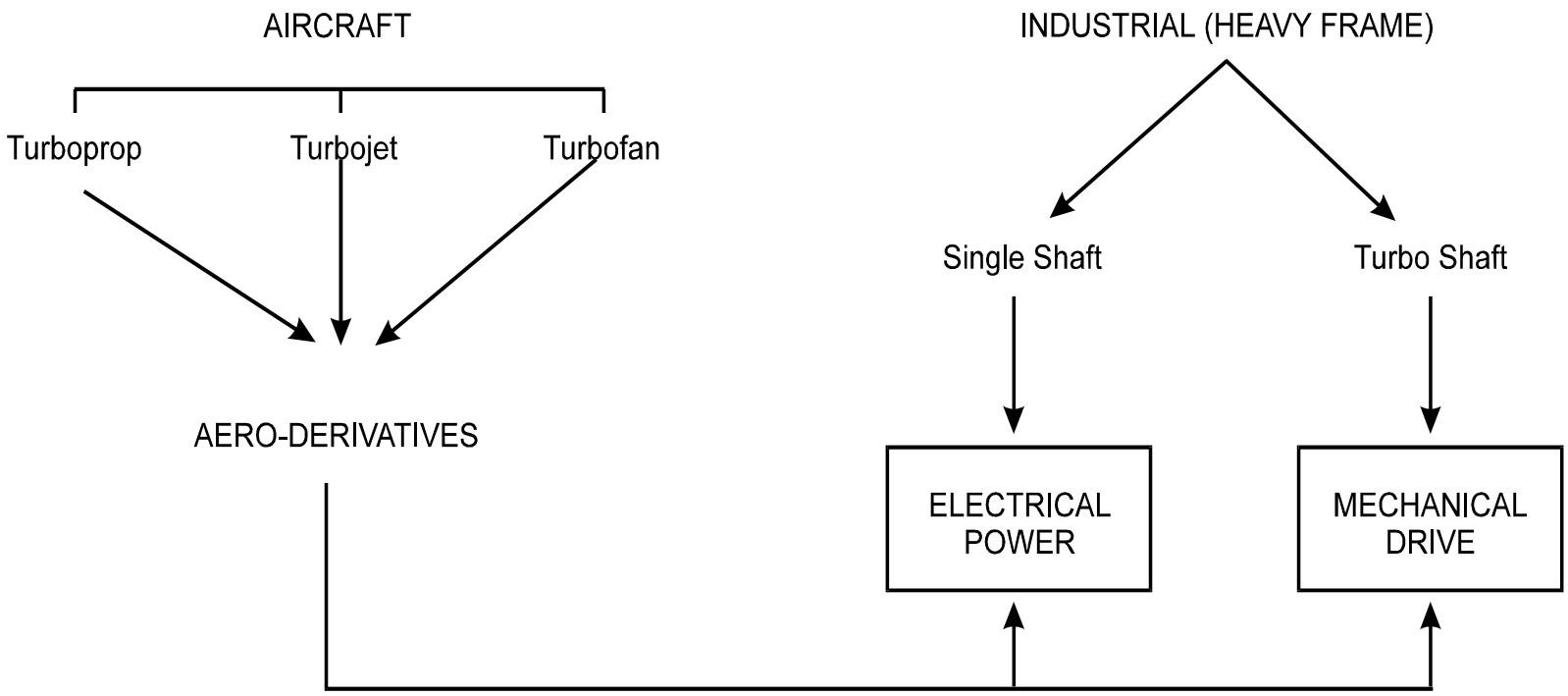
BASIC GAS TURBINE THEORY

GAS TURBINE DEVELOPMENTS

- AIRCRAFT ENGINES
- INDUSTRIAL ENGINES

GAS TURBINE TYPES



AERO ENGINES

PRIME REQUIREMENTS

- High performance (power, fuel consumption)
- Low weight
- Reliability (safety)
- Ease of maintenance
- On-condition operation

INDUSTRIAL ENGINES

PRIME REQUIREMENTS

- Long life
- Reliability (economics)
- Low overall cost (purchase, operation)
- Ease of maintenance
- Long overhaul intervals

AERO DERIVATIVES

- **STARTED IN EARLY 1960's**

  - **Conversion of jet engines using separate power turbine**

RR Olympus	**(marine, electric power)**
PW J75 (FT4)	**(marine, electric power, oil pumping)**
GE J79 (LM1500)	**(gas pumping, electric power)**
RR Avon	**(gas pumping, electric power)**

AERO DERIVATIVES

Electric power - **emergency and peaking**

Pipelines - **continuous duty**

Marine - **both continuous and 'boost' usage**

Power range, approx. 4 - 30 MW

AERO DERIVATIVES

- **EARLY 70's**
  - Conversion of civil high bypass turbofans

GE LM2500	(TF39, Lockheed Galaxy)
RR RB211	(L-1011, B747)
GE LM1600	(F404, F-18)
GE LM5000	(DC-10, B747)
GE LM6000	(DC-10, B747)
RR Trent	(A330, B777)

AERO DERIVATIVES

- **FREE POWER TURBINE; MECHANICAL OR ELECTRICAL POWER**
  - **LM2500, RB211, LM5000, LM1600**
- **LP TURBINE/COMPRESSOR/GENERATOR ON SAME SHAFT**
  - **LM6000, Trent**

HEAVY INDUSTRIALS

- **PRIMARY USE, ELECTRIC POWER GENERATION**
  - Single shaft, constant speed operation
  - Can be designed to run at synchronous speed for large powers
  - Potential for operating on lower grade fuels
  - Designed for long overhaul life

HEAVY INDUSTRIALS

- **THREE MAJOR MANUFACTURERS**
  - **Alstom**
  - **GE**
  - **Siemens - Westinghouse**

HEAVY INDUSTRIALS

- **50 Hz, 3000 rpm (up to 250 MW)**
  - **e.g. Alstom GT26, GE Frame 9, Siemens V94, Westinghouse 701, ABB 13E2**
- **60 Hz, 3600 rpm (up to 175 MW)**
  - **e.g. Alstom GT24,GE Frame 7, Siemens V84, Westinghouse 501, ABB 11N2**

HEAVY INDUSTRIALS

- **SMALLER MACHINES MAY BE DESIGNED FOR 50 OR 60 Hz, USING A REDUCTION GEARBOX. RUNNING SPEED TYPICALLY 5-5500 RPM.**
  - **e.g. ABB 8, GE Frame 6, Siemens V64,**

TYPICAL EFFICIENCIES

Early aero derivatives	25%
Current aero derivatives	35-42%
Early industrials	20-25%
Current industrials	35-38%

BASE LOAD POWER

- SIMPLE CYCLE G.T. EFFICIENCY TOO LOW
- COMBINED CYCLE, G.T. WITH S.T. CAN PRODUCE EFFICIENCIES OF OVER 55 PER CENT
- EFFICIENCY OF 60 PER CENT WITHIN 5 YEARS

PIPELINE COMPRESSORS

- ESSENTIALLY CONSTANT POWER FOR LONG PERIODS
- NEED FOR VARIABLE SPEED OUTPUT, FREE POWER TURBINE
- DOMINATED BY AERO DERIVATIVE (RB211, AVON, LM2500, LM1600)
- SOME HEAVY FRAME (NUOVO PIGNONE GT10, GE FRAME 3)
- WIDE USE OF SOLAR CENTAUR, MARS, SATURN

PIPELINE COMPRESSORS

- STATIONS OFTEN AUTOMATED, IN REMOTE LOCATIONS
- MANNING REQUIREMENTS MINIMIZED
- COMBINED CYCLES SELDOM USED
- TYPICAL POWER REQUIREMENT 10-25 MW PER COMPRESSOR

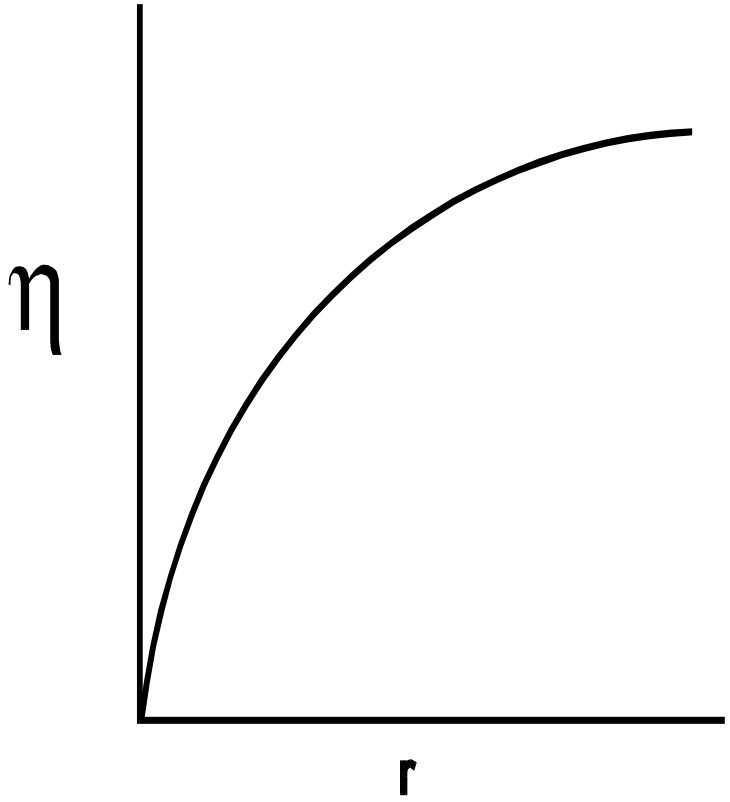
IDEAL CYCLE

- **FOR THE IDEAL CYCLE**

$$\eta = 1 - \frac{1}{r^{\varepsilon}}$$

where $\varepsilon = \dfrac{\gamma - 1}{\gamma}$

η depends only on r



IDEAL CYCLE

- **TURBINE INLET TEMP DOES NOT AFFECT EFFICIENCY BUT OUTPUT POWER IS STRONGLY DEPENDENT ON TIT**

  (For real cycle TIT does affect efficiency)

REAL CYCLES

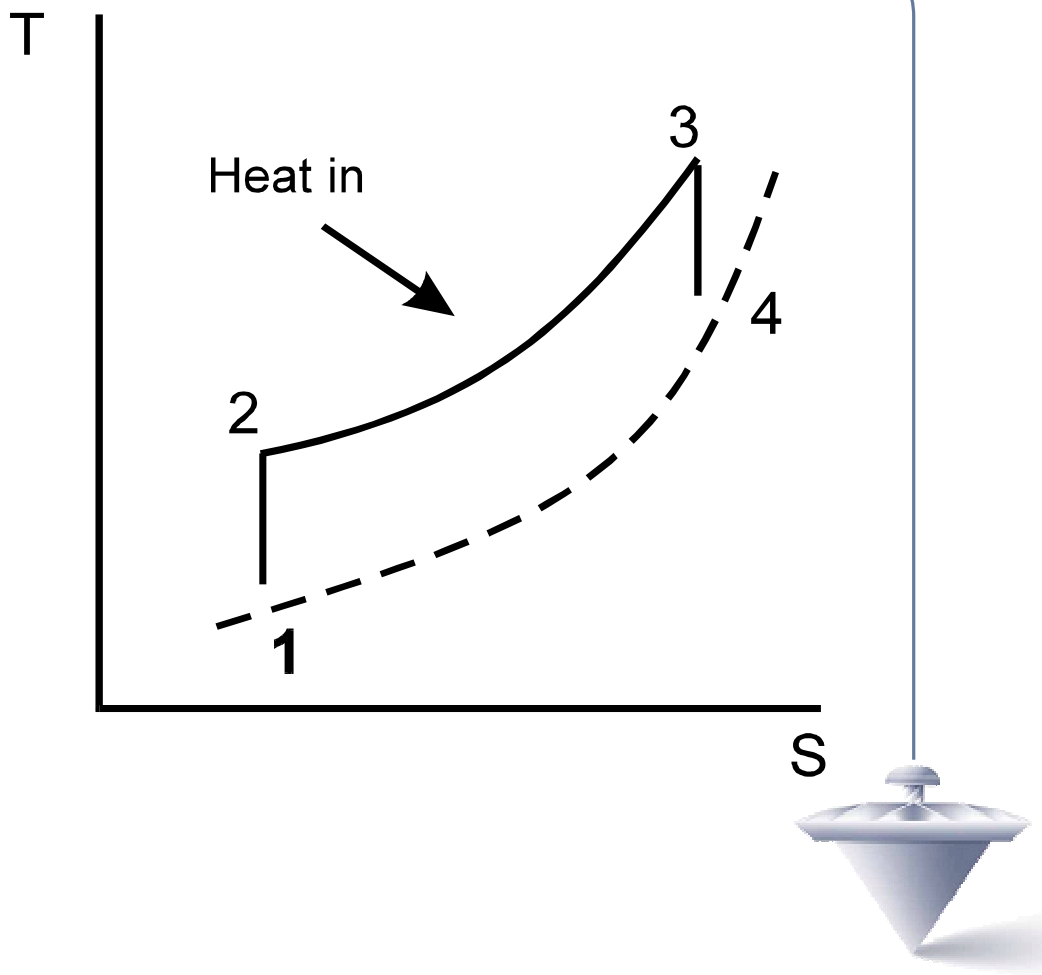
- FOR HIGH EFFICIENCY AND HIGH OUTPUT WE REQUIRE <u>BOTH</u> HIGH P.R. AND HIGH T.I.T.
- CYCLE DEVELOPMENT HAS REQUIRED CONTINUOUS INCREASE OF P.R. AND T.I.T.
- BETTER AERODYNAMICS, METALLURGY AND MANUFACTURING METHODS (cooled blades essential)

USE OF T-S DIAGRAM

HEAT ADDITION 2-3

WORK OUTPUT α AREA

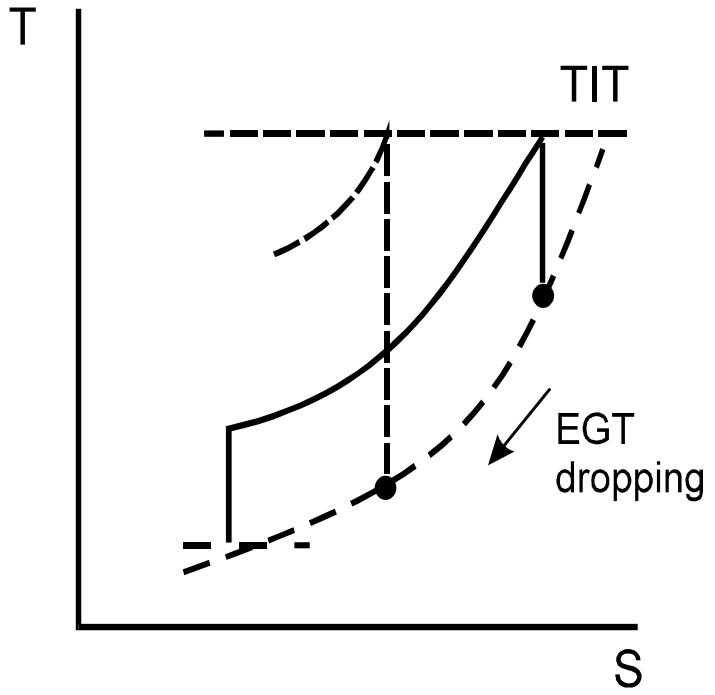
T_4 is EGT



EFFECT OF P.R. ON EGT

HIGH P.R. FOR HIGH η , GIVES LOW EGT

NOT GOOD FOR COMBINED CYCLE



REHEAT

CAN COMBINE HIGH P.R. WITH HIGH EGT USED ON ABB TYPE 24/26