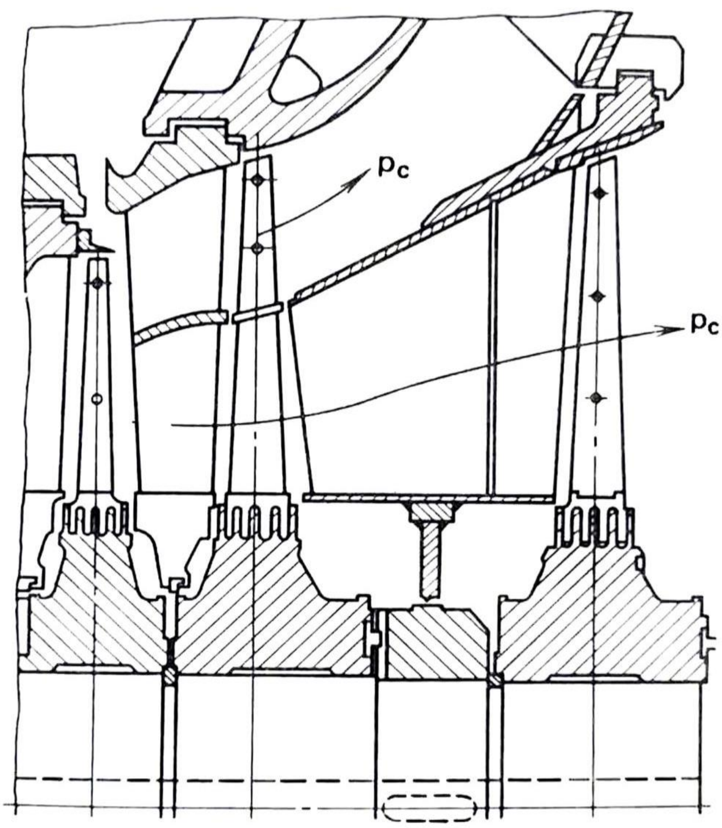
Upgradation of 200 MW Turbine to 210 MW

Preface: Heavy Electrical Equipment Plant (HEEP) of BHEL located at Haridwar acquired technology for the manufacture of 100MW and 200MW Turbine, Condenser and Generator sets (TG sets) from M/S Leningrad Metal Works (LMW) at Leningrad (St. Petersburg) USSR. LMW had designed the 200 MW turbine as Reheat turbine with sub-critical parameters for Temperate and Sub-arctic climate zones of Russia and Siberia in year 1958. The heat rate of Turboset was 1950 Kcal/Kwh. (An efficiency level of 44.1 %). Russians were very proud of their achievement. LMW transferred the design to HEEP after carrying out minor cosmetic changes to meet tropical climate conditions of India.

1. Basic parameters of reheat type turbine as adopted by LMW are given below:
   - 1.1. Main Steam Pressure 13.4 MPa.
   - 1.2. Initial steam Temperature 565 ^{o}C.
   - 1.3. Reheat Temperature was chosen as 565 ^{o}C.
   - 1.4. Condenser design was optimized for 10 ^{o}C. The quantity of cooling water chosen was 25000 cubic meter per hour condensing surface area was selected to achieve condenser pressure of 0.035 Ata. (25 mm Hg C). This is very deep vacuum. It is optimum for design of last stage exhaust area considerations.
2. However, in India most of the Thermal Plants are located near coal mines in hot tropical conditions with cooling waters in range of 24-36^{o}C. Superheater/ Reheater for Indian Conditions was chosen 538/538 ^{o}C instead of 565/565^{o}C. In view of this, LMW enhanced the turbine's valve wide open (VWO) swallowing capacity to 670 t/hr. from 600 t/hr. for their standard parameters. Except this minor change in Turbine, Condenser design was **not changed despite** the fact Indian Cooling water temperature were substantially higher.
3. A large number of efficiency calculations are required to enable customer to know the performance of TG sets at various load factors as well as "off design" parameters. In turbine industry these efficiency calculations are called Heat Balance Diagram HBD. Due to variety of reasons all this mammoth work was done using 5-digit log table as Digital Calculators had not become available. There is a saying that every black cloud has a silver lining. While I and my colleague were doing these monotonous tiring calculations, the data seeped into our psyche. I realized that the back pressure of turbine can be reduced by introducing a much bigger condenser and increasing quantity of cooling water to 30000 cubic meter per hour. This will not only improve the

heat rate but generate extra five percent output and market the set as 210 MW instead of 200 MW at a minimal extra cost. BHEL supplied nearly 50 sets of 210 MW TG sets. In other words, 500 MW came out of thin air.

4. Before I go to the other aspects of implementing this idea, let me talk about a very crucial factor in design of last stage of any turbine. It is the velocity (axial component) at which steam exits the last stage to condenser. It is a direct dead loss. Turbine industry in those days adopted 300 m/sec as the optimum economic value taking into account the availability of large size rotor forgings and length of last stage. LMW had perfected a blade design with length of 765 mm installed at mean diameter of 2100 mm and thus total exhaust area becomes 5square meters. The volumetric steam flow for 200 MW at 25 mm Hg C is 4200cubic meter per sec. Thus, the turbine required exhaust area of 14.2 sqmt. Since use of 765 mm blade (longest available at LMW in 1958), the total exhaust area in double flow mode becomes 10 sqmt. To overcome this handicap of technological limitations of USSR, LMW opted for Baumann Stage in which one third of volumetric flow is discharged to condenser directly from the penultimate and balance two thirds from last stage. It is an ingenious technique per se, but it not very efficient one. Please refer picture one. :



Hence LMW engineers did not have any rational to increase the condenser pressure.

5. On the other hand for hot humid climate conditions, the condenser pressure was working out be 0.12 Ata (90 mm Hg C) at cooling water temperature of 33°C and volumetric flow of 1400 cubic meter and exit velocity (axial component) of 100 m/sec. Since this corresponds to sub-sonic levels. There was a definite scope to improve the design of condenser to the extent feasible within physical boundaries of cut-out provided for condenser. Since the velocity was expected to be sub-sonic, partial recovery of kinetic energy was anticipated in the aerodynamically designed divergent diffusers leading steam from turbine to condenser.
6. Heat Exchanger Engineering division at HEEP informed that it is possible to increase the quantity of cooling water through the condenser tubes and increase the condensing surface area by increasing the length of tubes. After adopting these measures, it will be possible to get condenser pressure of 0.12Ata (90 mm Hg C). My HBD calculations established that rated output can be increased to 210 MW from 200 MW indicated by LMW.
   6.1. Apart from additional output, it improved heat rate by 30 Kcal/Kwhr. This is huge saving of fuel consumed.
7. I contacted Late Mr. B. J. Vohra head of Turboalternator engineering division. TG team worked out that 210 MW is possible by marginally increasing Hydrogen pressure and quantity of distilled cooling water through the stator bars.
8. In view of these findings, HEEP decided to upgrade 200MW Turbosets to 210MW. An additional 5 % power without any significant changes in the design of Turbine as well as Alternator.
9. A 210 MW set costs nearly nnnn crores per set. HEEP supplied about 50 sets in last 40 years. Thus, HEEP earned extra 2*nnnn crores by implementing the outcome of hard work. I feel so happy about this achievement.

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