# *Improvements to the RELAP5 Turbine Model*

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# Outline

- ***Background***
- ***Improvements to turbine model***
- ***Test Results***
- ***Summary***

# Background

- ***Energy equation for turbine volume did not include dissipation due to non-ideal turbine – cannot get correct enthalpy distribution through a series of turbine components***
- ***Turbine momentum equation used normal velocity divergence term***
- ***Turbine model requires each turbine component to be proceeded by another turbine component – this requires a "dummy" turbine upstream of first active turbine***

# Background (cont.)

- *Turbine components must be numbered consecutively*
- *Second turbine junction functions as a steam extraction junction –moisture separator option desired*
- *User specified variable turbine efficiency, frictional torque, and moment of inertia desired*

# *Improvements to Turbine Model*

- ***Energy equation modified to include dissipation in turbine***
- ***Momentum equation for turbine inlet junction changed from central difference to backward difference***
- ***Numbering restriction removed – this removed requirement for "dummy" turbine upstream of active turbine***

# *Improvements to turbine model (cont.)*

- ***Removal of numbering restriction adds a geometric restriction – volume upstream or downstream of a turbine component must be singly connected in the main flow direction, i.e., only one inlet and one outlet junction on this volume – automatically satisfied if turbine component preceded by or followed by another turbine component***

- ***Moisture separator option added to turbine component***
  - ***– optional separator efficiency added to turbine input***
  - ***– old decks run as before, modified code assumes second junction is steam extraction junction***

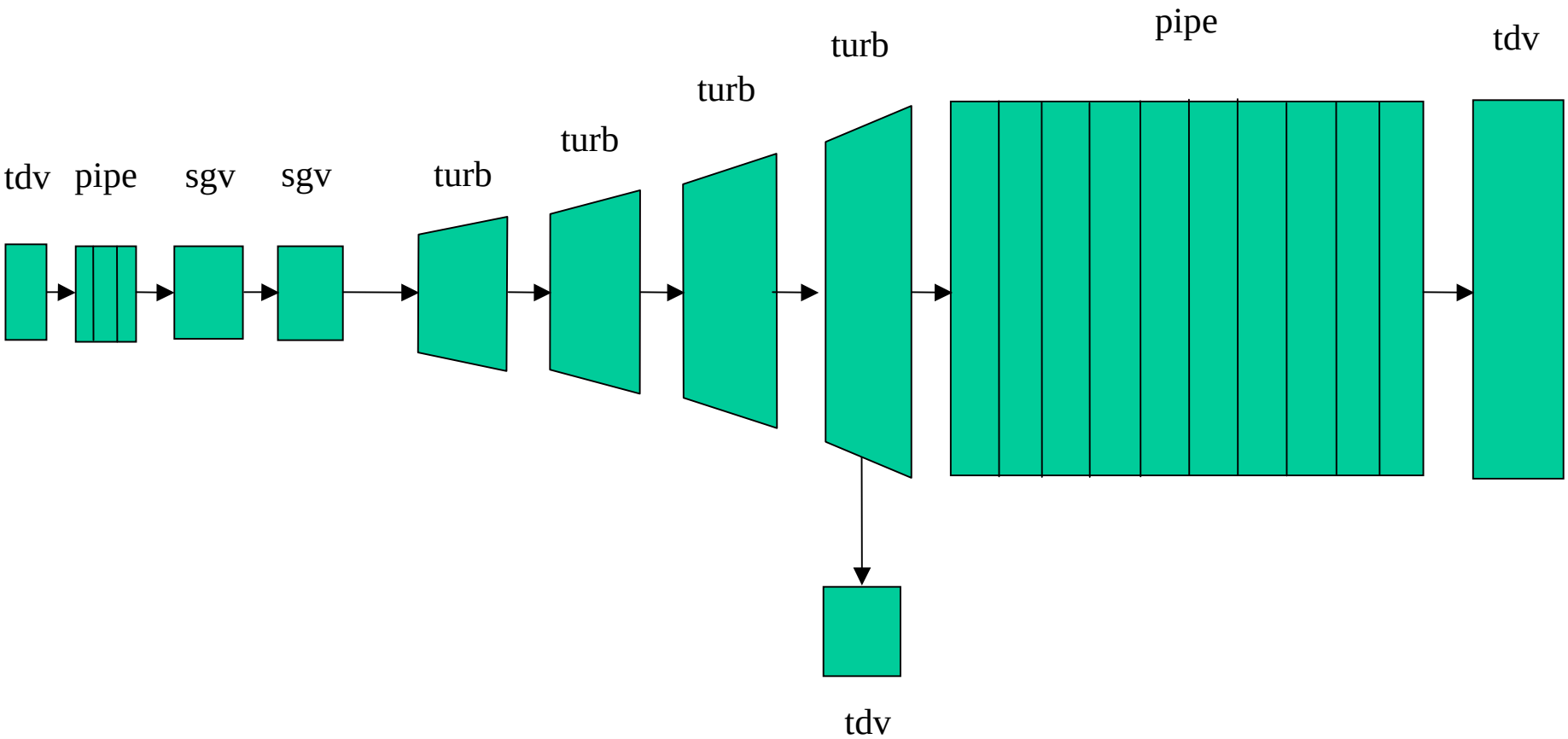
# *Improvements to turbine model (cont.)*

- ***Turbine second junction must be connected to the "cross direction", i.e. 'y' or 'z' faces***
  - ***– old decks must be modified***

# Test Case Description

- *Existing turbine test case modified - four turbine components*
- *“Dummy” turbine upstream of first active turbine converted to single volume*
- *Moisture separator junction added to last turbine component for second series of test cases*
- *Control system added to compute rate of removal of stagnation enthalpy from fluid and compare to turbine shaft power*

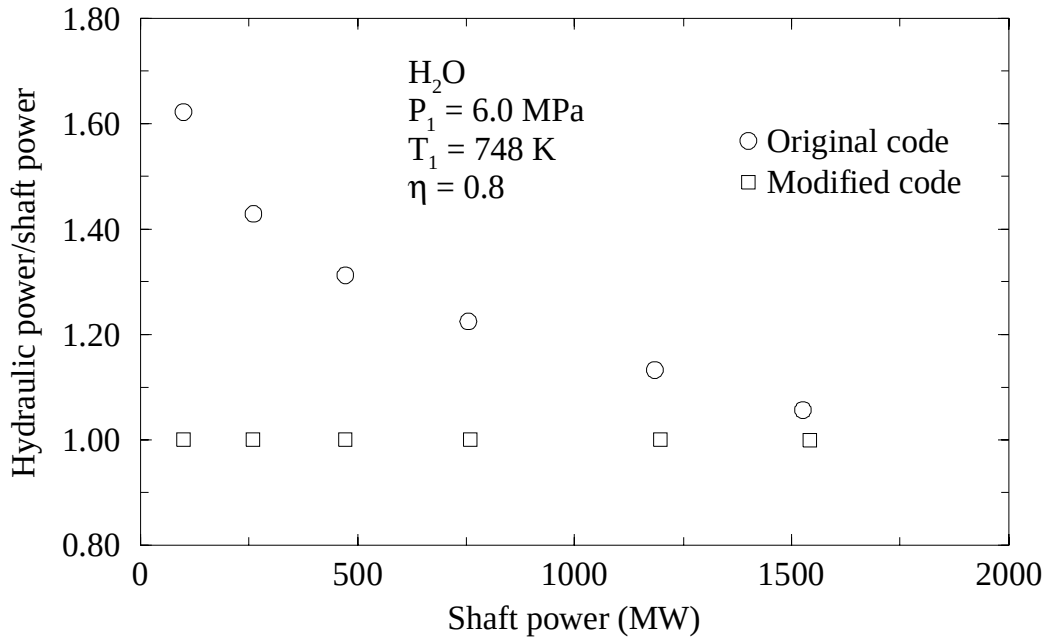
# Test Case Schematic



# Test Case Boundary Conditions

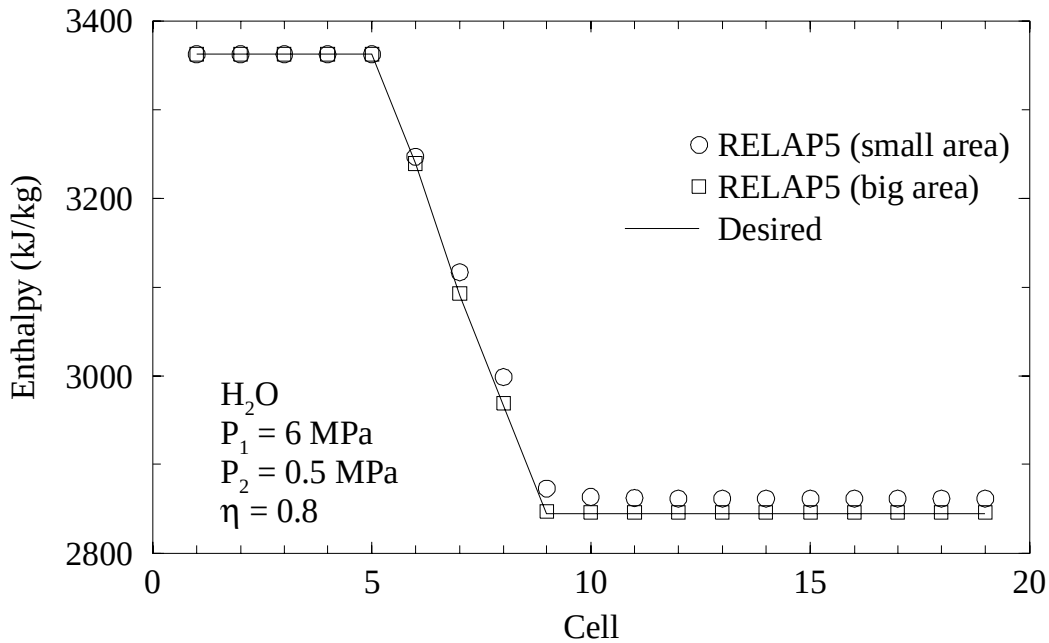
- ***Inlet TDV pressure and temperature fixed – 6.0e+06 Pa and 748 K***
- ***Outlet TDV pressure varied – 6.0e+06 to 0.5e+06 Pa***
- ***Flow rate varied from 2100 kg/sec to 3000 kg/sec***
- ***No moisture separator junction***

# Test Results
## Energy Conservation



# Test Results (cont.)

## Enthalpy Distribution



# Test Results (cont)

- *Two test runs with moisture separator*
- *Reduced inlet temperature to get two-phase in last turbine component*
- *First run with separator efficiency of 1.0e-06*
- *Ratio of hydraulic power to shaft power 0.99848, identical to case with no separator junction*
- *Second run with separator efficiency of 0.999*
- *Ratio of hydraulic power to shaft power 0.99847*
- *Flow rate of liquid out separator junction equal to amount of liquid removed by separator*

# *Summary*

- ***Energy equation for turbine volume corrected***
- ***Modified geometric constraints for turbine components***
- ***Test results verify that turbine improvements implemented correctly and producing expected results***
- ***New user specified efficiency, frictional torque, and moment of inertia options added***