Comparison of Performance Calculations
for a 22 MW Condensing Steam Turbine
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PerAero TurbineDesigns

INTRODUCTION

A 17-stage condensing steam turbine (Fig. 1) was modeled with the **Aeolus** performance analysis and compared with **AxStream™** results. The following objectives were accomplished:

1) Established a baseline calculation with **Aeolus** for the original GE 17-stage turbine configuration prior to modifying the steam path for new rerate conditions. Validated **Aeolus's** convergence capabilities and overall performance prediction by comparison with the original manufacturer rating.
2) Compared **Aeolus** and **AxStream™** results for overall turbine performance as well individual stage details such as: efficiency, power, pressure ratio, velocity ratio, reaction. Determined whether the two different loss modeling systems show any significant difference in these results.

TURBINE DESCRIPTION

A 17-stage condensing turbine was modeled. It was manufactured by GE (circa 1985) with a partial admission inlet Rateau stage and no inductions or extractions. Figure 1 shows the cross-section layout and Table 1 provides some key geometry details for the nozzles and blades. Rated output is 22 MW at the following operating conditions:

- Working Fluid = superheated steam
- Inlet Pressure =650 psig
- Inlet Temperature = 700 º F
- Exhaust Pressure = 1.5 inHgA
- Shaft Speed = 3,600 RPM

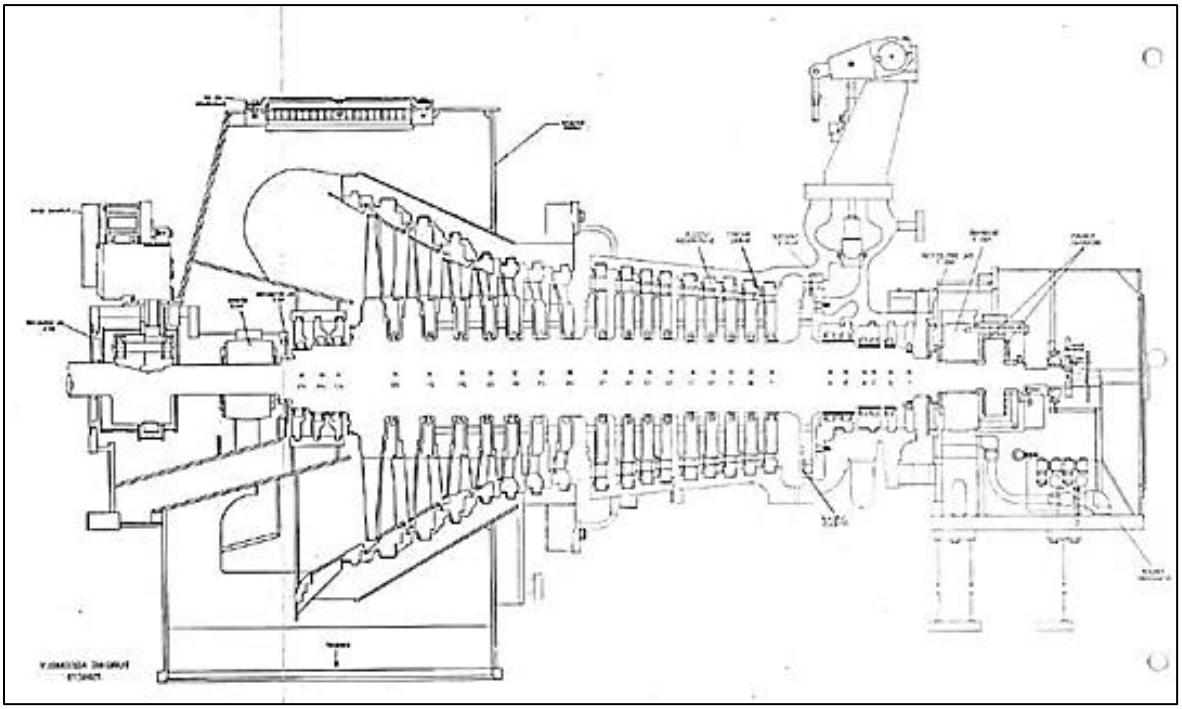

Fig. 1 - Cross-Section of GE 22 MW Steam Turbine

TABLE 1 – STEAM PATH GEOMETRY

		BASE DIA.		HEIGHT		THROAT AREA		AXIAL WIDTH	
STAGE	ADMISSION	NOZZLE	BLADE	NOZZLE	BLADE	NOZZLE	BLADE	NOZZLE	BLADE
1	0.50	35.10	35.07	1.25	1.38	14.56	26.84	1.32	1.12
2	0.75	30.00	30.54	0.81	0.81	11.70	19.69	1.91	0.78
3	0.85	30.13	31.05	0.94	0.93	0.00	0.00	1.93	0.76
4	0.88	30.88	31.56	0.99	1.06	21.02	30.49	1.93	0.76
5	0.92	31.25	32.05	1.13	1.18	22.94	41.16	1.94	0.79
6	0.94	32.00	32.52	1.31	1.36	28.34	47.64	1.94	0.79
7	0.96	32.50	33.04	1.53	1.59	35.36	57.91	1.94	0.79
8	0.98	33.00	33.56	1.72	1.78	44.57	66.62	1.94	0.79
9	1.00	33.50	34.35	2.09	2.16	55.18	81.75	1.94	0.90
10	1.00	34.00	34.55	2.34	2.40	62.89	88.24	1.93	0.86
11	1.00	37.25	37.40	2.28	2.60	66.70	129.13	2.18	1.05
12	1.00	37.25	38.15	3.16	3.18	98.48	164.47	2.18	1.17
13	1.00	37.25	37.90	4.20	4.34	137.32	210.99	2.42	1.17
14	1.00	37.25	38.31	5.75	6.12	211.00	314.93	2.42	1.40
15	1.00	37.25	38.63	8.63	8.75	327.75	447.87	2.66	1.64
16	1.00	37.25	38.44	11.88	12.73	496.91	781.33	2.79	1.99
17	1.00	37.25	37.48	16.63	17.40	1340.66	1469.95	2.91	2.06

AEOLUS PROGRAM DESCRIPTION

The **Aeolus** design system consists of both a preliminary sizing tool (or “configurator”) and a meanline performance analysis for axial turbines. Its main capabilities are summarized in Ref. 1. **Aeolus** was developed by PerAero Turbine Designs and has been successfully used to design and rerate more than 30 different turbine configurations over the past four years. **Aeolus** has proven robustness and accuracy for a wide range of of turbine types and applications including:

- subsonic/supersonic flows
- converging-diverging and drilled nozzles
- partial admission
- double flow stages
- inductions and extractions
- operation with almost any fluid

The **Aeolus** meanline analysis employs a comprehensive loss modeling system based on the methods outlined in Ref. 1. This commonality of loss systems has enabled **Aeolus** performance calculations to compare well with **AxTurb**, the throughflow solver from the **TurbAero** system that is described in Refs. 2 and 3.

RESULTS FROM PERFORMANCE CALCULATIONS

PerAero Turbine Designs had been subcontracted to support a client with their rerate evaluation of a surplus 22 MW GE steam turbine. The client, a well-known turbomachinery repair and rerate facility, had been contracted to evaluate the suitability of this unit for reapplication at different operating conditions. The rerate facility collected extensive inspection data on the surplus turbine and initially modelled the steam path using their **AxStream™** software in order to conduct a baseline analysis before starting the rerate investigation. **AxStream™** has more than 100 clients worldwide and is developed by SoftInWay, Inc., a world-renown software developer for turbomachinery.

Before beginning the rerate evaluation, a baseline performance model for the original 17-stage steam path was established using **Aeolus**. Prior experience had shown that **Aeolus** was able to accurately calculate the special features of this 17-stage turbine: partial admission, diaphragm and blade tip leakages, balance hole leakages and moisture losses. In order to reduce the time required to generate the ~850 data entries for this large model, the **Aeolus** configurator was first applied as a preprocessor to automatically create a set of default geometry data for all 17-stages.

Table 1 compares the **Aeolus** and **AxStream™** results for overall turbine performance and shows that both programs agree rather well. It should be noted that these results were obtained with **Aeolus's** default loss calculations and did not require any special adjustments or corrections.

Table 1

	AxStream™	***Aeolus***
Inlet Flow, lb/hr	210,000	210094
kW_s	21,777	22,208
η_{ts}	0.736	0.751
Inlet Loss	0.133	0.149

Figures 2 – 6 compare various performance details between the two programs. The stage efficiencies track each other reasonably well although **AxStream™** gives higher efficiencies to the front-end stages while **Aeolus** favors the back-end. These differences have apparently cancelled each other since overall turbine efficiencies are nearly identical. The power outputs of Figure 3 show the same pattern as the stage efficiencies. Stage pressure ratios, velocity ratios and reactions compared very well, as shown in Figures 4, 5 and 6, indicating that both programs are calculating very similar aero and thermo details.

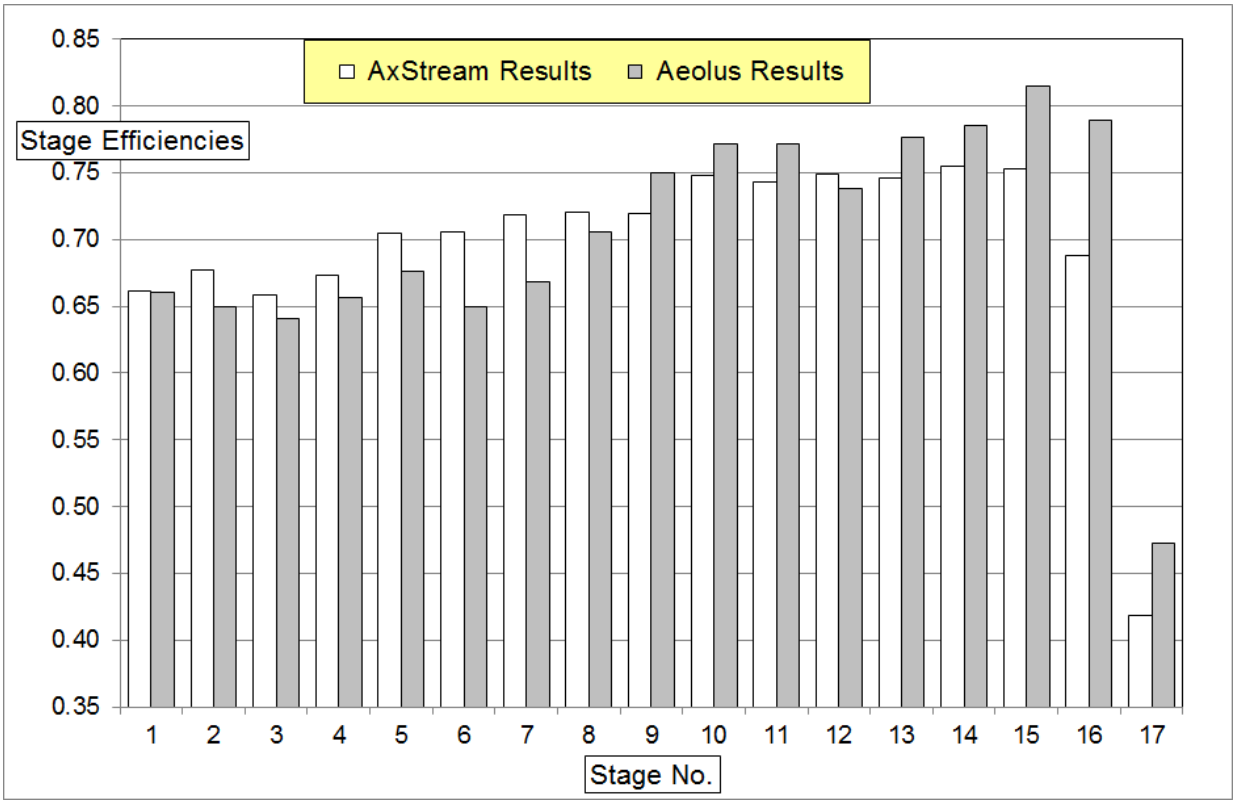

Fig. 2 – Comparison of Stage Efficiencies

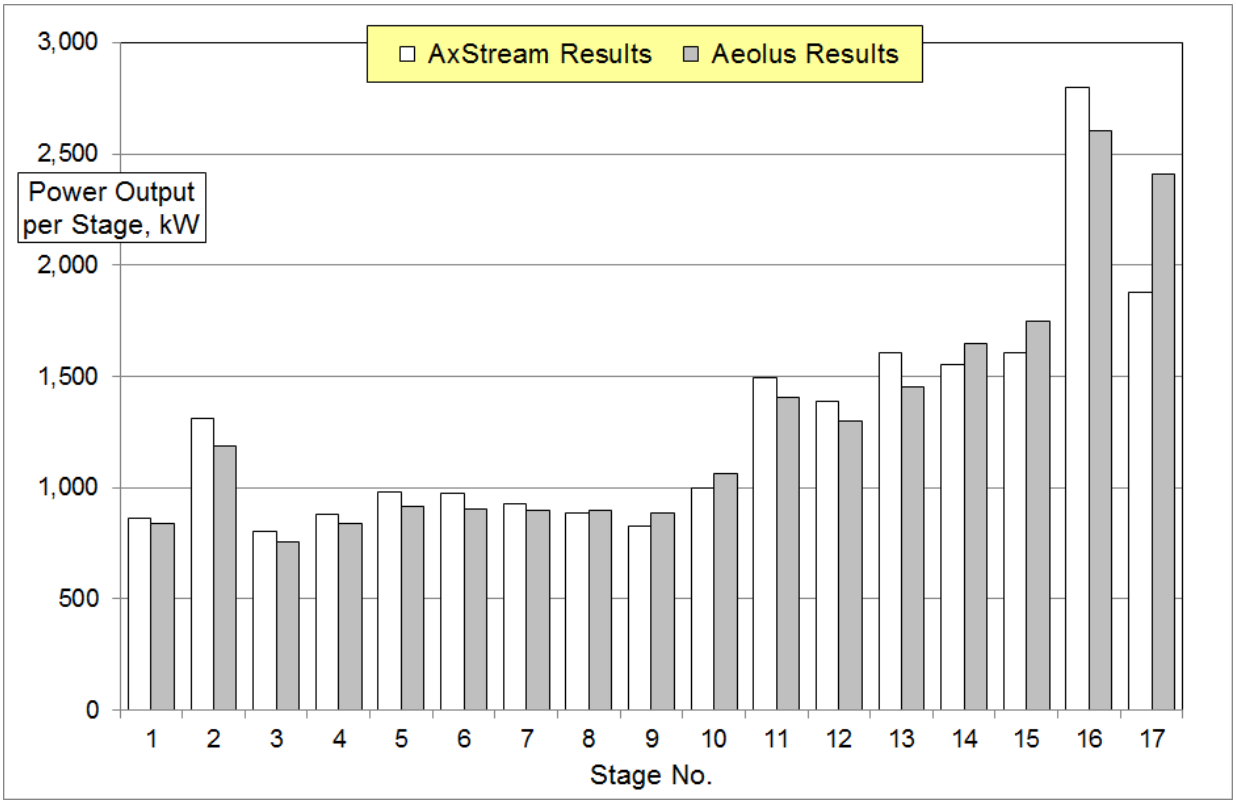

Fig. 3 – Comparison of Stage Powers

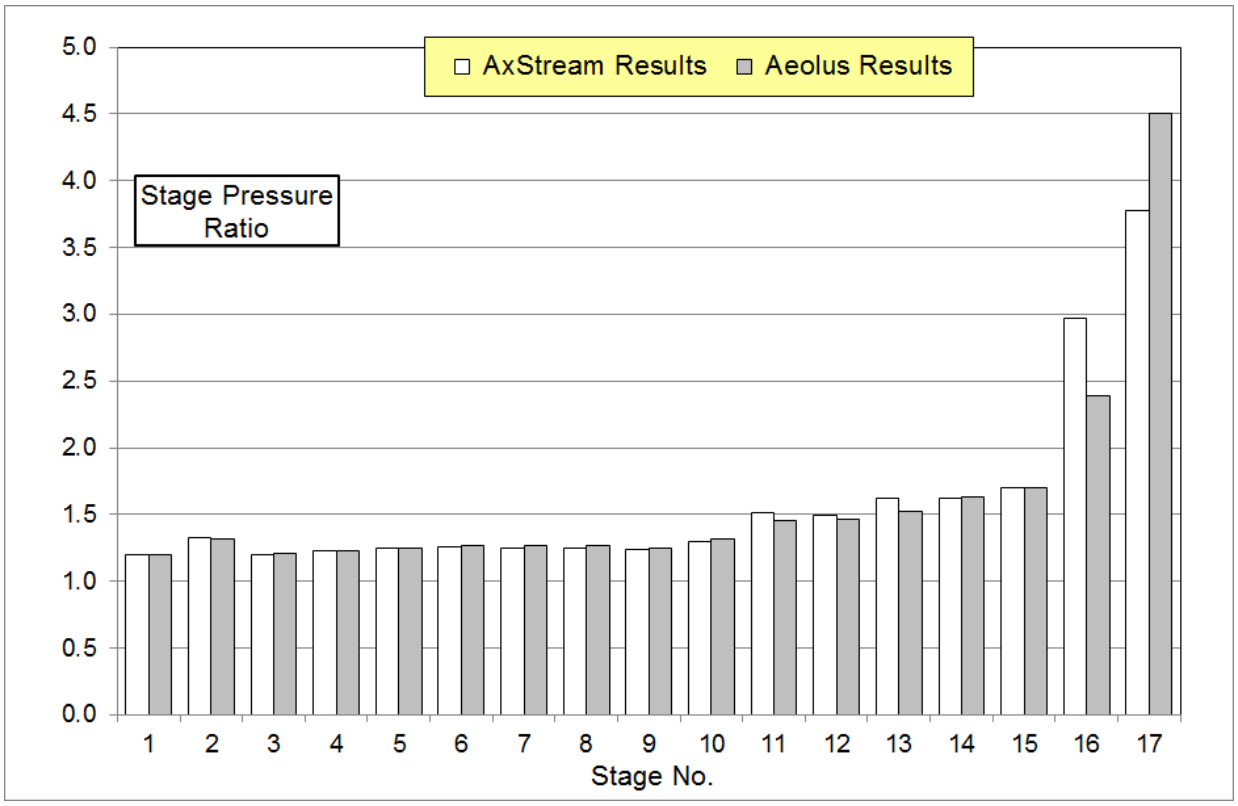

Fig. 4 – Comparison of Stage Pressure Ratio Distribution

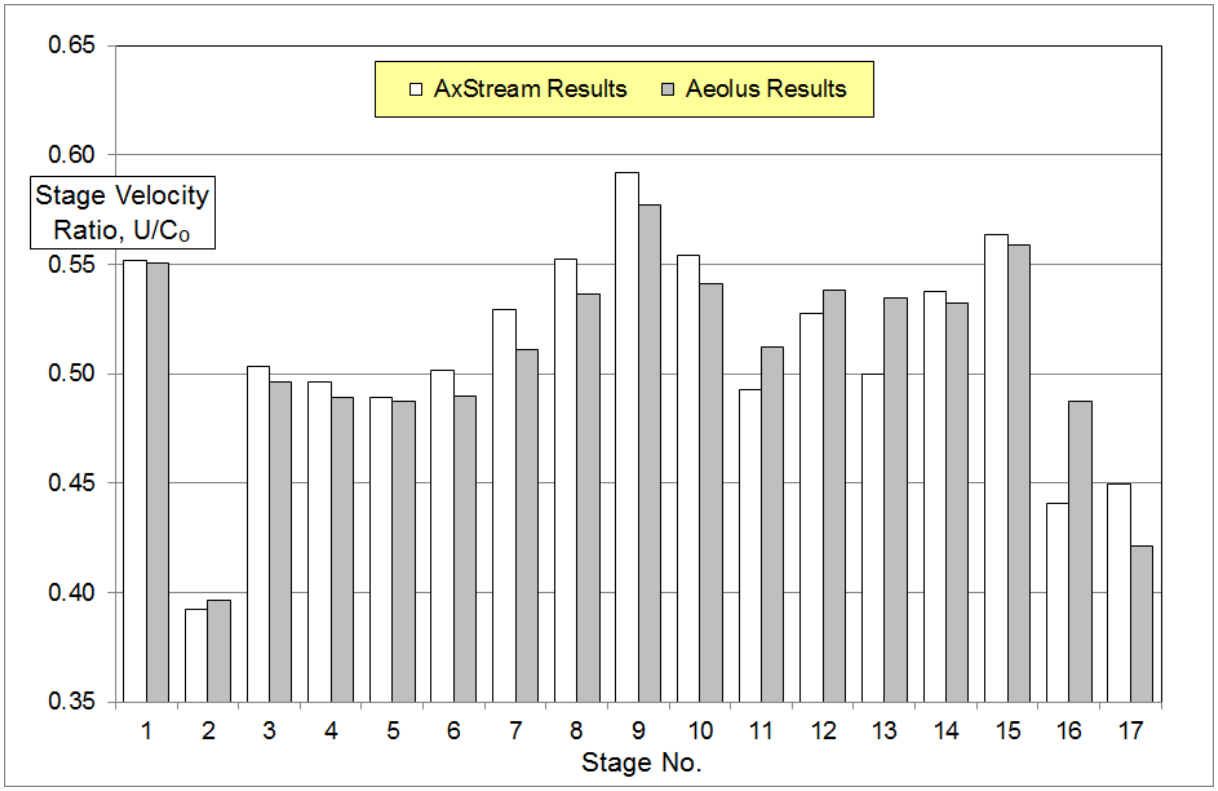

Fig. 5 – Comparison of Stage Velocity Ratios

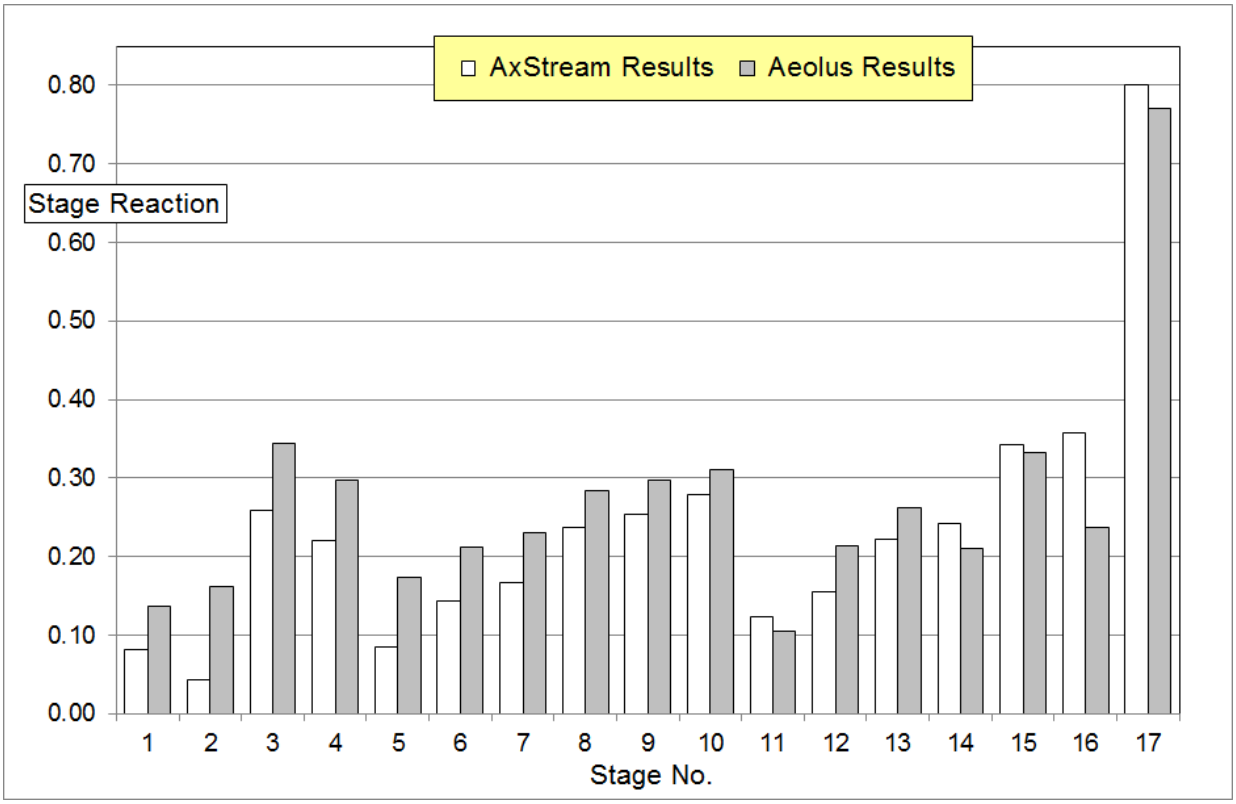

Fig. 6 – Comparison of Stage Reactions

CONCLUSIONS

A baseline performance model has been established for a 17-stage GE steam path using the ***Aeolus*** Performance program. Overall turbine performance results from ***Aeolus*** matched ***AxStream™*** calculations, that were provided to PerAero by a client, quite well. Calculation details are very similar between the two programs with only small differences that are not considered significant enough to warrant concern for a more detailed review.

REFERENCES

1. Perera, J.V., Aeolus Performance and Configuration Analysis, Aeolus_Program_Description.pdf, available at http://www.peraero.com/Pages/Software.aspx

2. Aungier, R. H., *Turbine Aerodynamics: Axial-Flow and Radial-Inflow Turbine Design and Analysis*, ASME Press, New York, 2006

3. ***TurbAero*** software system developed by Ronald Aungier and now owned by Flexware, Inc. http://www.flexwareinc.com/index.php/software/turbo-aero