



Marine Gas Turbines Performance Modelling

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1 Introduction

In the frame of present work a library of engine performance models of various types of marine gas turbines has been developed. The simulation is referred to design point as to off design point.

The user defines the set-up and its design point and then the model adapts components' performance maps and other engine specific parameters (e.g. cooling bleeds) as to make the simulated engine to have the desired performance at the design point. The operation at an off-design point is computed with the aid of the derived components' performance maps. The model has the ability to simulate the engine's performance from 7%-10% to 100%-105% of its design state.

In all cases, the engine performance model can simulate gas turbine operation with four different fuels (two types of diesel, natural gas and methane). The emitted pollutants, NO_x and CO, are predicted by the means of semi-empirical correlations.

The performance models derive for the user specified operating conditions the complete engine cycle as well as overall performance parameters.

2 Available Engine Configurations

The engine configurations that can be simulated are listed in Table 1. In Table 1 are also presented the required data for design and off design analysis.

Table 1. Available engine configurations and the required data for design and off-design point

No.	Set-up	Required data at design point	Required data at off-design point
1	One spool One shaft	<ol style="list-style-type: none"> 1. Power 2. Power shaft speed 3. Compressor's pressure ratio 4. Turbine Inlet Temperature 5. Compressor's polytropic efficiency 6. Turbine's polytropic efficiency 7. Pressure at the engine's exit 8. Ambient conditions (T_{amb}, RH, P_{amb}) 9. Fuel LHV 	<ol style="list-style-type: none"> 1. Ambient conditions (T_{amb}, RH, P_{amb}) 2. Pressure at the engine's exit 3. Power and Power shaft's speed 4. Number of off design test cases
2	One spool one shaft with recuperator	<ol style="list-style-type: none"> 1. Power 2. Power shaft speed 3. Compressor's pressure ratio 4. Turbine Inlet Temperature 5. Compressor's polytropic efficiency 6. Turbine's polytropic efficiency 7. Pressure at the engine's exit 8. Ambient conditions (T_{amb}, RH, P_{amb}) 9. Fuel LHV 10. Recuperator's effectiveness 	-//-
3	One spool Two shafts	<ol style="list-style-type: none"> 1. Power 	-//-

No.	Set-up	Required data at design point	Required data at off-design point
		2. Power shaft speed 3. Compressor's pressure ratio 4. Turbine Inlet Temperature 5. Compressor's polytropic efficiency 6. Turbine's polytropic efficiency 7. Pressure at the engine's exit 8. Ambient conditions (T_{amb} , RH, P_{amb}) 9. Fuel LHV 10. Power Turbine's polytropic efficiency	
4	One spool two shafts with recuperator	1. Power 2. Power shaft speed 3. Compressor's pressure ratio 4. Turbine Inlet Temperature 5. Compressor's polytropic efficiency 6. Turbine's polytropic efficiency 7. Pressure at the engine's exit 8. Ambient conditions (T_{amb} , RH, P_{amb}) 9. Fuel LHV 10. Power Turbine's polytropic efficiency 11. Recuperator's effectiveness	-/-
5	One spool two shafts with reheater	1. Power 2. Power shaft speed 3. Compressor's pressure ratio 4. Turbine Inlet Temperature 5. Compressor's polytropic efficiency 6. Turbine's polytropic efficiency 7. Pressure at the engine's exit 8. Ambient conditions (T_{amb} , RH, P_{amb}) 9. Fuel LHV 10. Power Turbine's polytropic efficiency	-/-
6	One spool two shafts with recuperator and reheater	1. Power 2. Power shaft speed 3. Compressor's pressure ratio 4. Turbine Inlet Temperature 5. Compressor's polytropic efficiency 6. Turbine's polytropic efficiency 7. Pressure at the engine's exit 8. Ambient conditions (T_{amb} , RH, P_{amb}) 9. Fuel LHV 10. Power Turbine's polytropic efficiency 11. Recuperator's effectiveness	-/-
7	Two spools, Two shafts	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP)	-/-

No.	Set-up	Required data at design point	Required data at off-design point
		7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Pressure at the engine's exit 11. Ambient conditions (T_{amb} , RH, P_{amb}) 12. Fuel LHV	
8	Two spools two shafts with Intercooler	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Pressure at the engine's exit 11. Ambient conditions (T_{amb} , RH, P_{amb}) 12. Fuel LHV 13. Intercooler's effectiveness 14. Coolant temperature	-/-
9	Two spools two shafts with recuperator	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Pressure at the engine's exit 11. Ambient conditions (T_{amb} , RH, P_{amb}) 12. Fuel LHV 13. Recuperator's effectiveness	-/-
10	Two spools two shafts with reheater	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Pressure at the engine's exit 11. Ambient conditions (T_{amb} , RH, P_{amb}) 12. Fuel LHV	-/-
11	Two spools two shafts	1. Power 2. Power shaft speed	-/-

No.	Set-up	Required data at design point	Required data at off-design point
	with Intercooler and recuperator	3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Pressure at the engine's exit 11. Ambient conditions (Tamb, RH, Pamb) 12. Fuel LHV 13. Intercooler's effectiveness 14. Recuperator's effectiveness 15. Coolant temperature	
12	Two spools two shafts with Intercooler and reheater	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Pressure at the engine's exit 11. Ambient conditions (Tamb, RH, Pamb) 12. Fuel LHV 13. Intercooler's effectiveness 14. Coolant temperature	-/-
13	Two spools two shafts with recuperator and reheater	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Pressure at the engine's exit 11. Ambient conditions (Tamb, RH, Pamb) 12. Fuel LHV 13. Recuperator's effectiveness	-/-
14	Two spools two shafts with Intercooler, recuperator and reheater	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP)	-/-

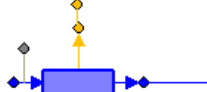
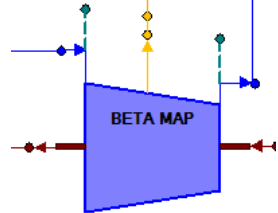
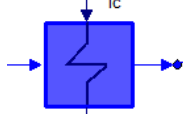
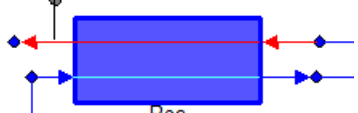
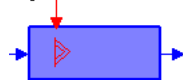
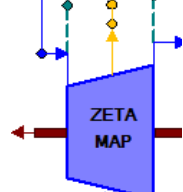






No.	Set-up	Required data at design point	Required data at off-design point
		8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Pressure at the engine's exit 11. Ambient conditions (Tamb, RH, Pamb) 12. Fuel LHV 13. Intercooler's effectiveness 14. Recuperator's effectiveness 15. Coolant temperature	
15	Two spools, Three shafts	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Power turbine's polytropic efficiency 11. Pressure at the engine's exit 12. Ambient conditions (Tamb, RH, Pamb) 13. Fuel LHV	-/-
16	Two spools three shafts with Intercooler	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Power turbine's polytropic efficiency 11. Pressure at the engine's exit 12. Ambient conditions (Tamb, RH, Pamb) 13. Fuel LHV 14. Intercooler's effectiveness 15. Coolant temperature	-/-
17	Two spools three shafts with recuperator	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Power turbine's polytropic efficiency 11. Pressure at the engine's exit	-/-

No.	Set-up	Required data at design point	Required data at off-design point
		12. Ambient conditions (T_{amb} , RH, P_{amb}) 13. Fuel LHV 14. Recuperator's effectiveness	
18	Two spools three shafts with reheater	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Power turbine's polytropic efficiency 11. Pressure at the engine's exit 12. Ambient conditions (T_{amb} , RH, P_{amb}) 13. Fuel LHV	-/-
19	Two spools three shafts with Intercooler and recuperator	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Power turbine's polytropic efficiency 11. Pressure at the engine's exit 12. Ambient conditions (T_{amb} , RH, P_{amb}) 13. Fuel LHV 14. Intercooler's effectiveness 15. Coolant temperature 16. Recuperator's effectiveness	-/-
20	Two spools three shafts with Intercooler and reheater	1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Power turbine's polytropic efficiency 11. Pressure at the engine's exit 12. Ambient conditions (T_{amb} , RH, P_{amb}) 13. Fuel LHV 14. Intercooler's effectiveness 15. Coolant temperature	-/-

No.	Set-up	Required data at design point	Required data at off-design point
21	Two spools three shafts with recuperator and reheater	<ol style="list-style-type: none"> 1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Power turbine's polytropic efficiency 11. Pressure at the engine's exit 12. Ambient conditions (T_{amb}, RH, P_{amb}) 13. Fuel LHV 14. Recuperator's effectiveness 	-/-
22	Two spools three shafts with Intercooler, recuperator and reheater	<ol style="list-style-type: none"> 1. Power 2. Power shaft speed 3. Compressor's pressure ratio (LP) 4. Compressor's pressure ratio (HP) 5. Turbine Inlet Temperature 6. Compressor's polytropic efficiency (LP) 7. Compressor's polytropic efficiency (HP) 8. Turbine's polytropic efficiency (LP) 9. Turbine's polytropic efficiency (HP) 10. Power turbine's polytropic efficiency 11. Pressure at the engine's exit 12. Ambient conditions (T_{amb}, RH, P_{amb}) 13. Fuel LHV 14. Intercooler's effectiveness 15. Coolant temperature 16. Recuperator's effectiveness 	-/-
23	Power turbine	<ol style="list-style-type: none"> 1. Power 2. Power shaft speed 3. Turbine Inlet Temperature 4. Turbine Inlet Pressure 5. Air to Fuel ratio 6. Power turbine's efficiency 7. Pressure at the engine's exit 	<ol style="list-style-type: none"> 1. Ambient conditions (T_{amb}, RH, P_{amb}) 2. Pressure and Temperature at inlet 3. fuel to air ratio at inlet 4. Power and Power shaft's speed



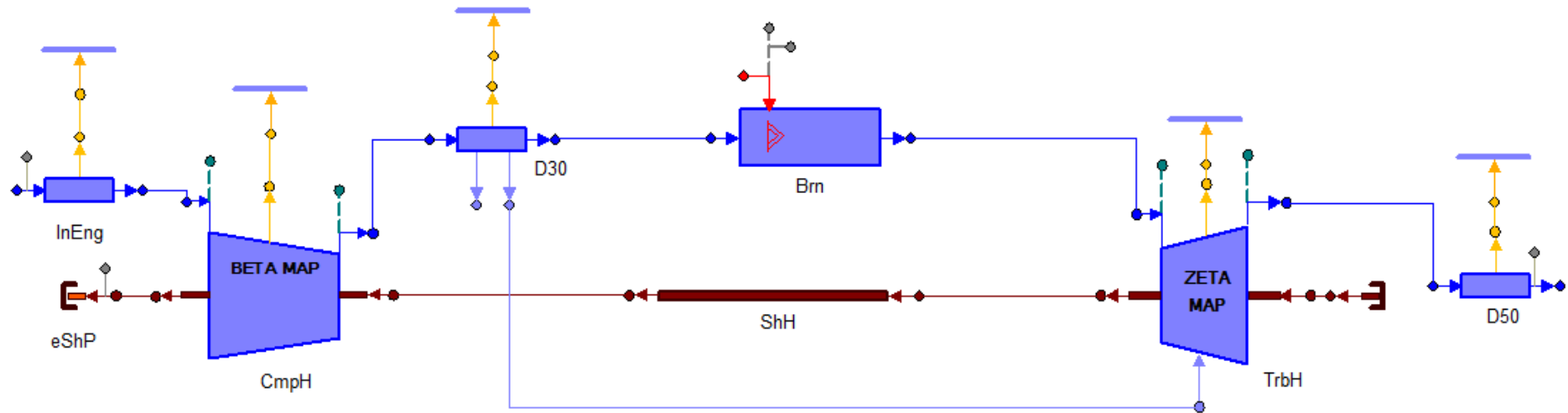
Appendix I: Modelled Set-ups

Component	Description
	Duct
	Compressor
	Intercooler
	Recuperator
	Burner/Reheater
	Turbine
	Shaft
	Fluid port
	Fuel port
	Thermal port
	Secondary Air Stream (SAS) port
	Mechanical port

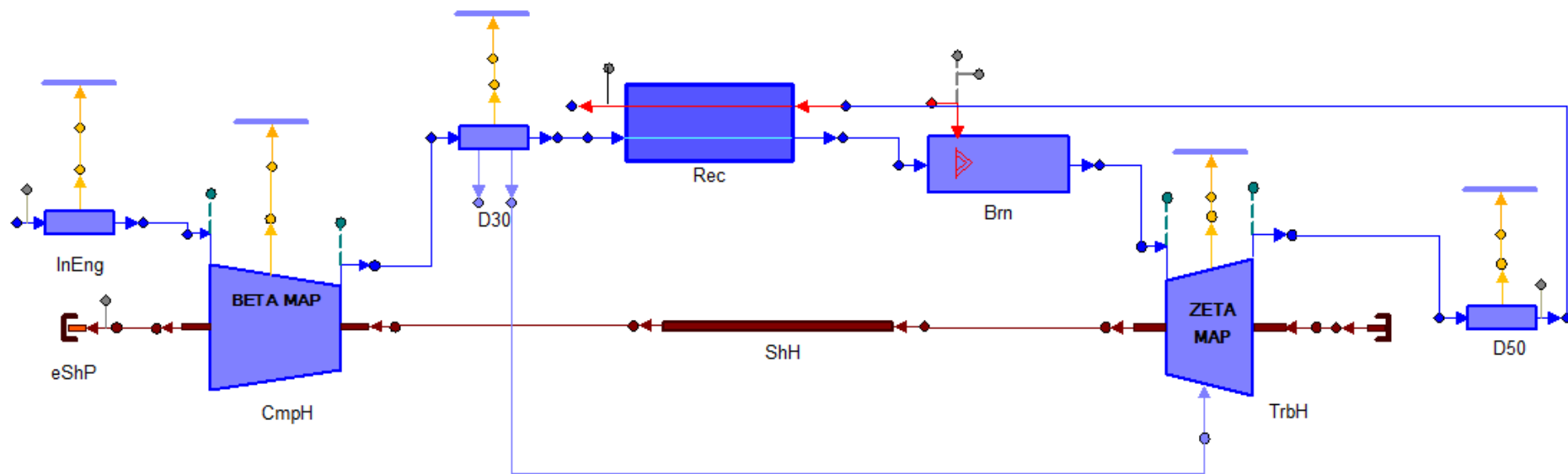
The ports mentioned are used as connective factors between components. Each port is dedicated to transfer certain information between components about the characteristics of the flow (fluid port), information about the fuel (fuel port), the thermal transfer to the casing (thermal port), the characteristics of secondary air stream (SAS port) and the velocity and torque on shafts (mechanical port).



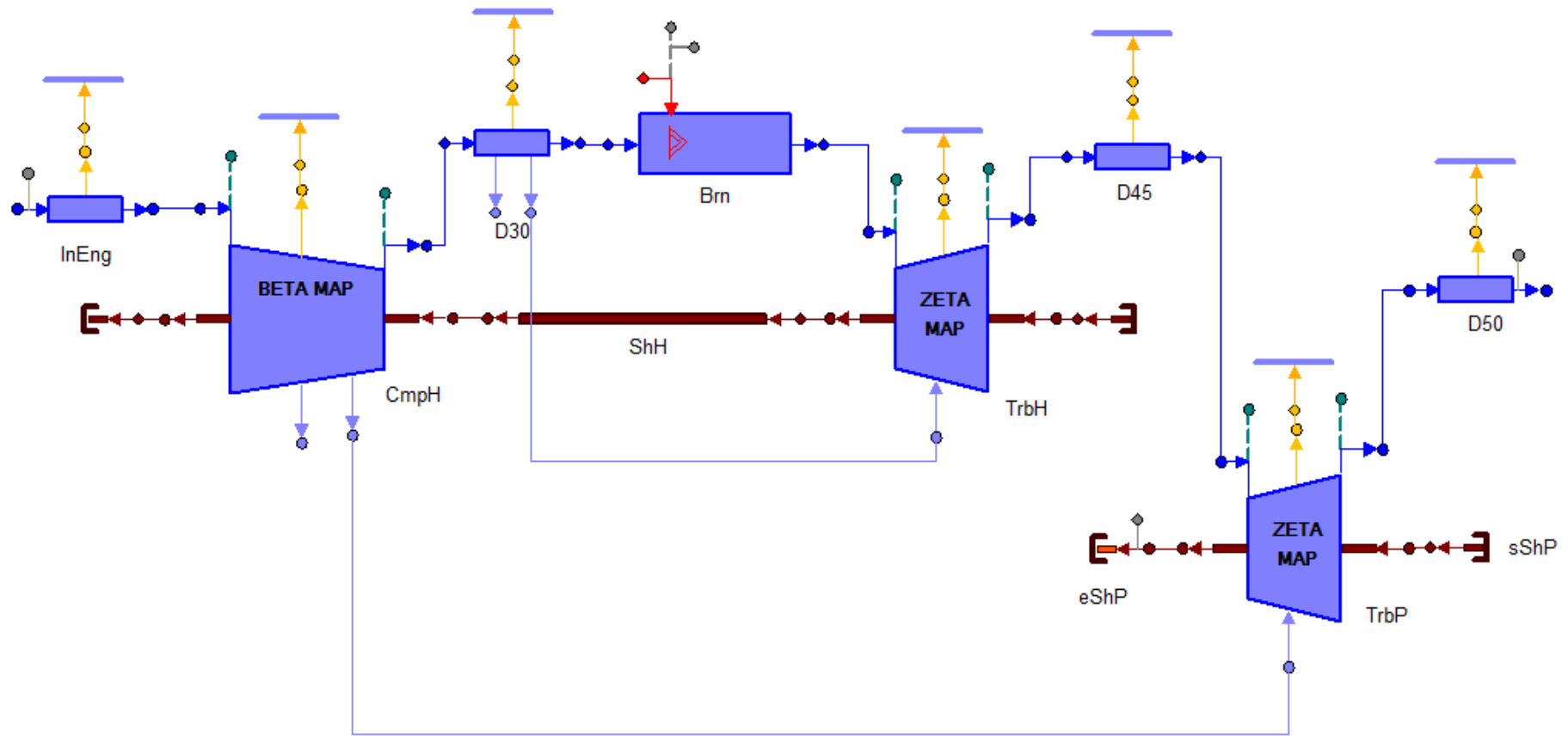
One spool one shaft



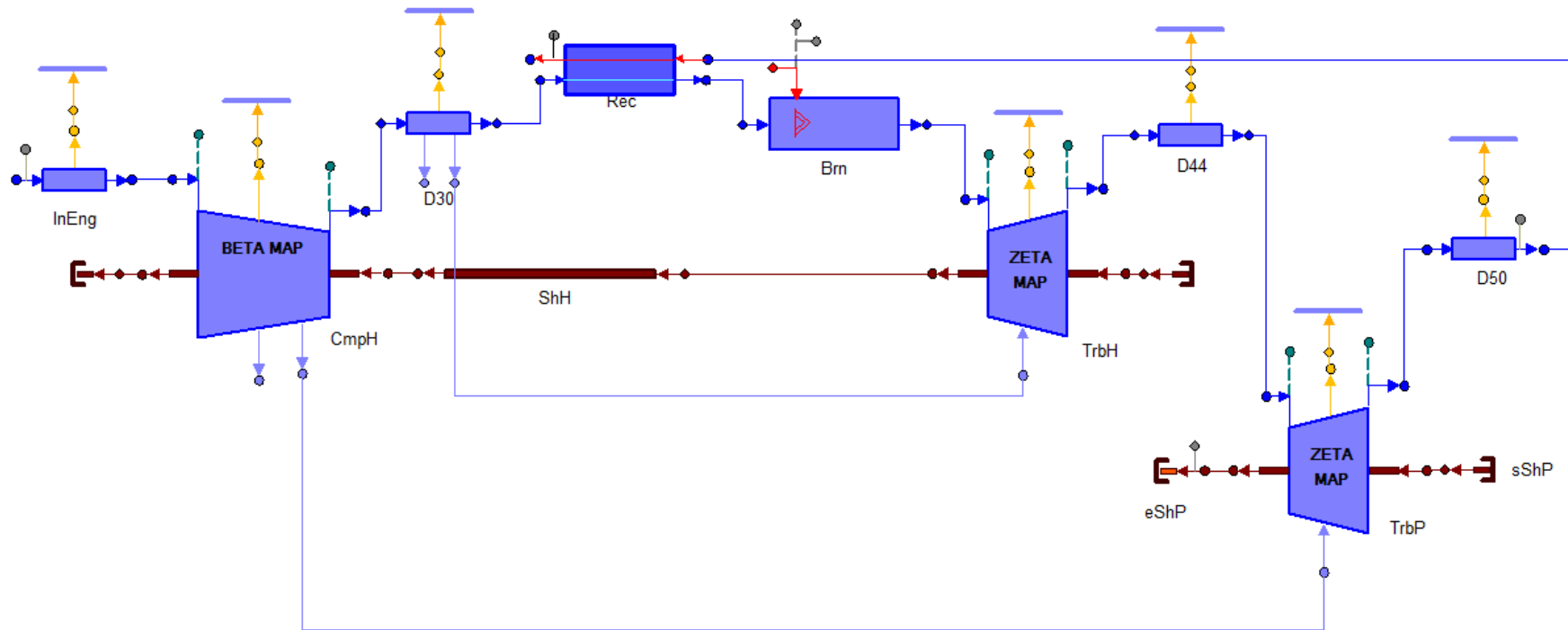
One spool one shaft with recuperator



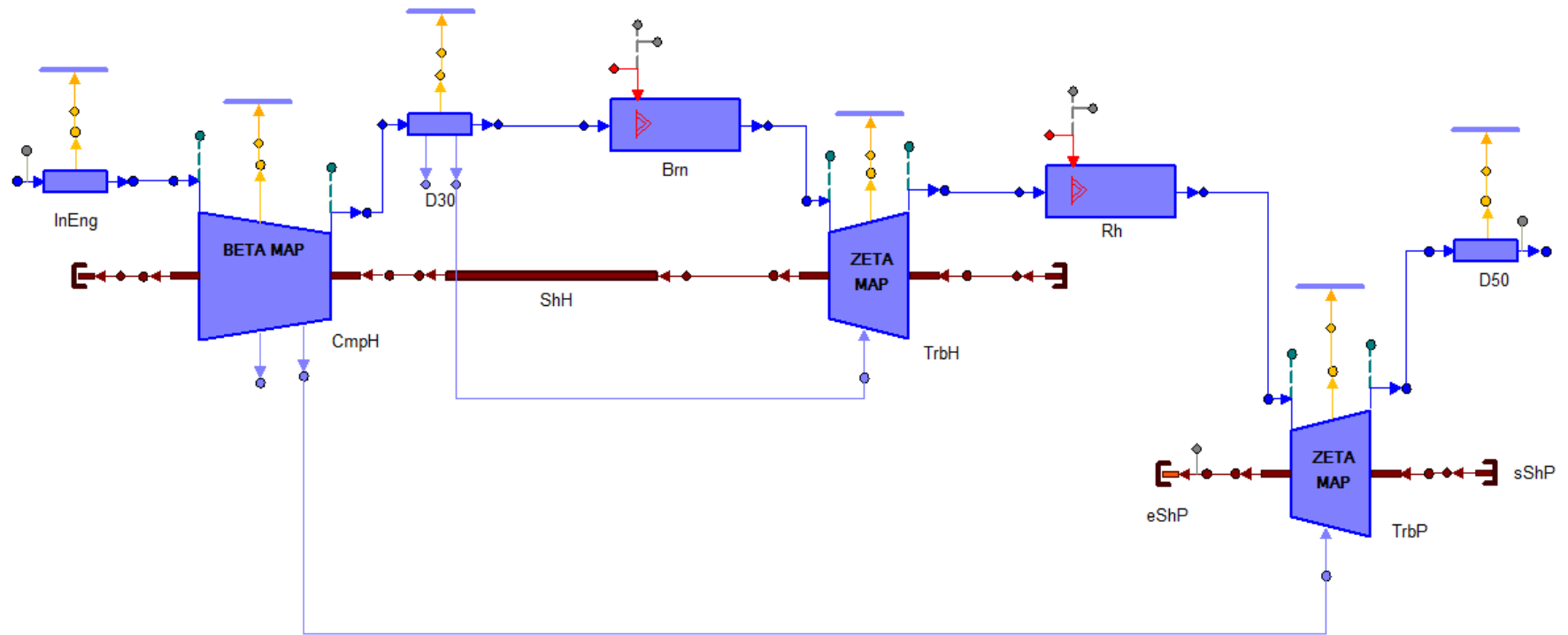
One pool two shafts



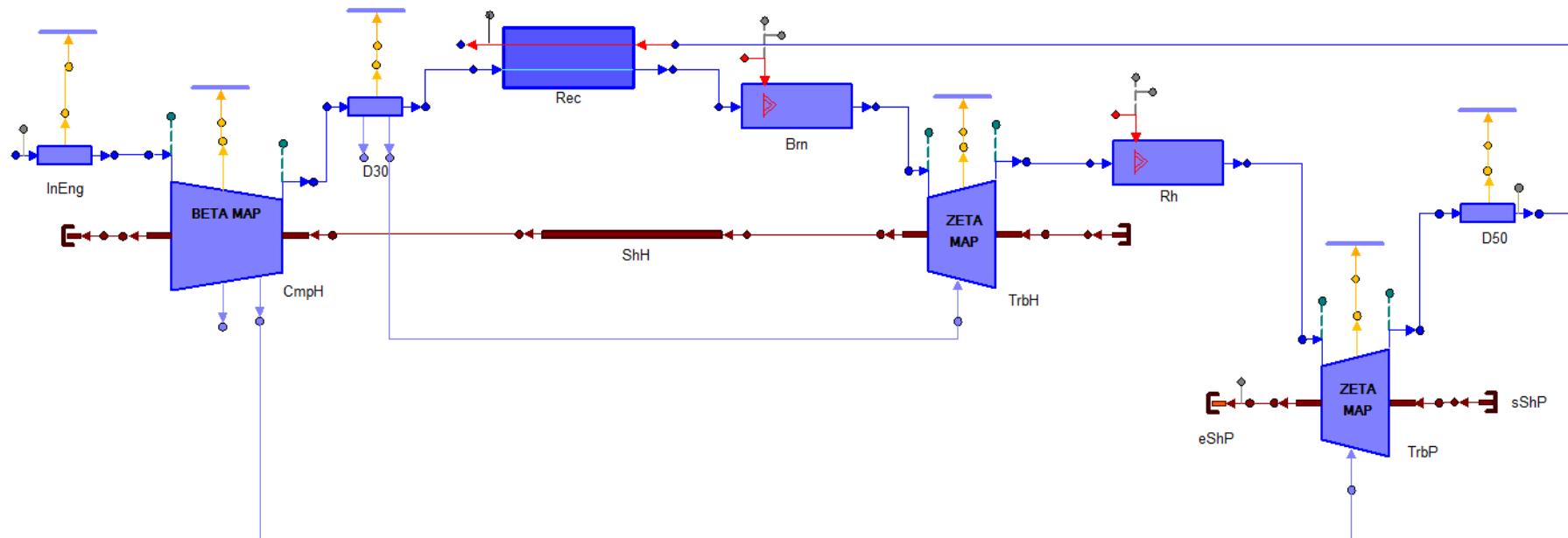
One spool two shafts with recuperator



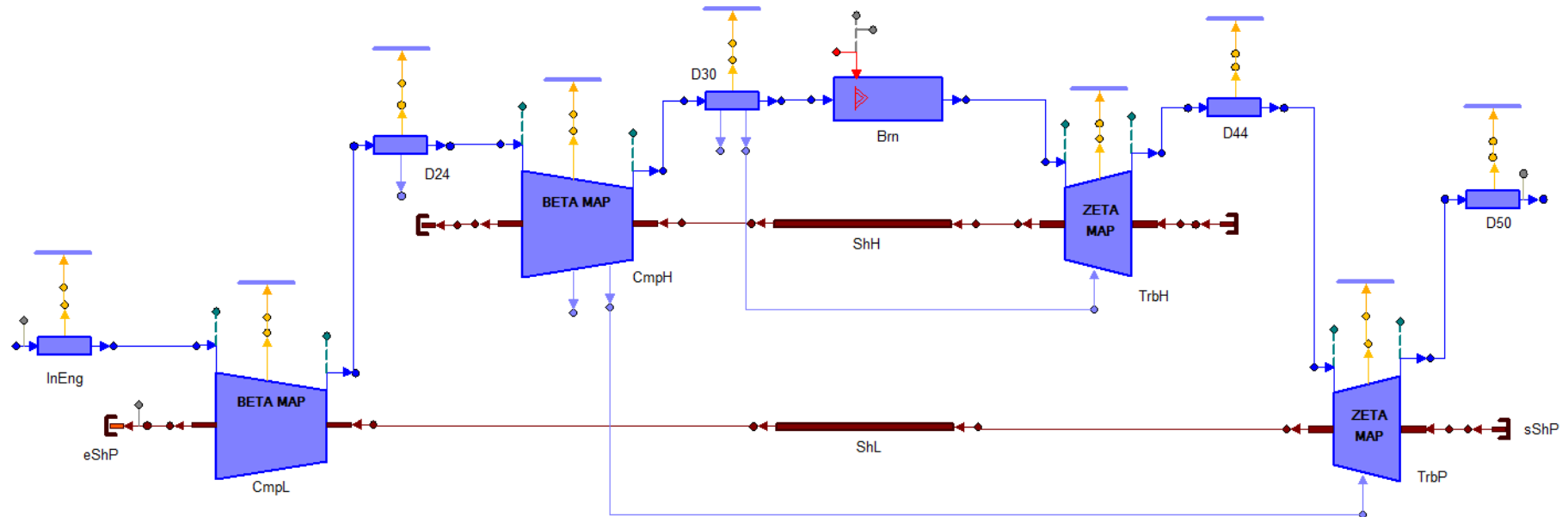
One spool two shafts with reheater



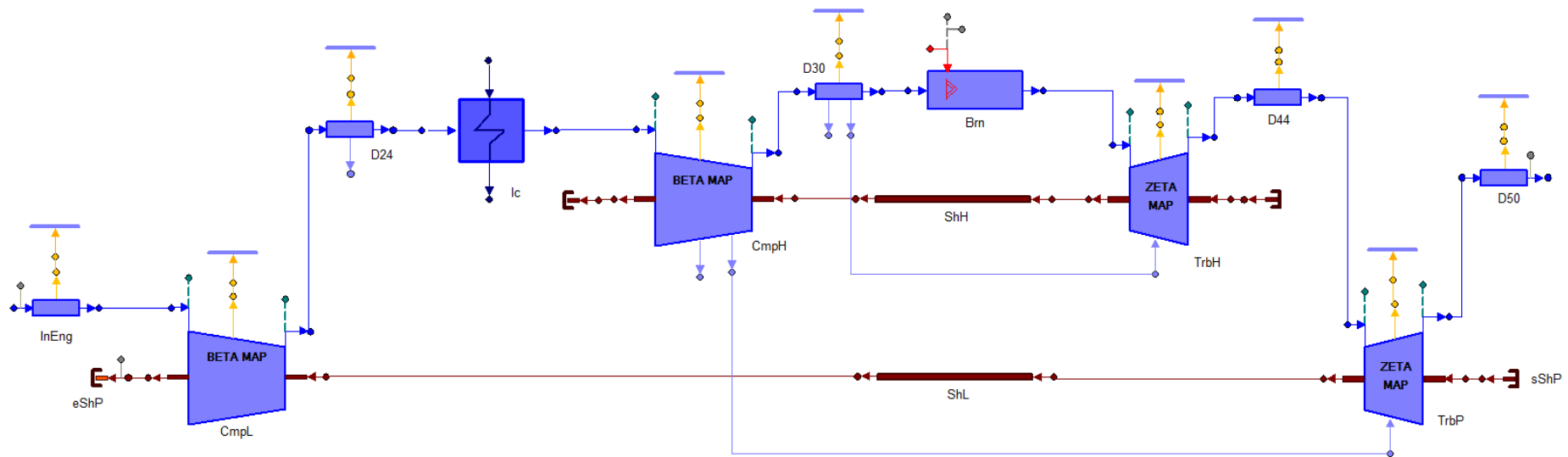
One spool two shafts with recuperator and reheater



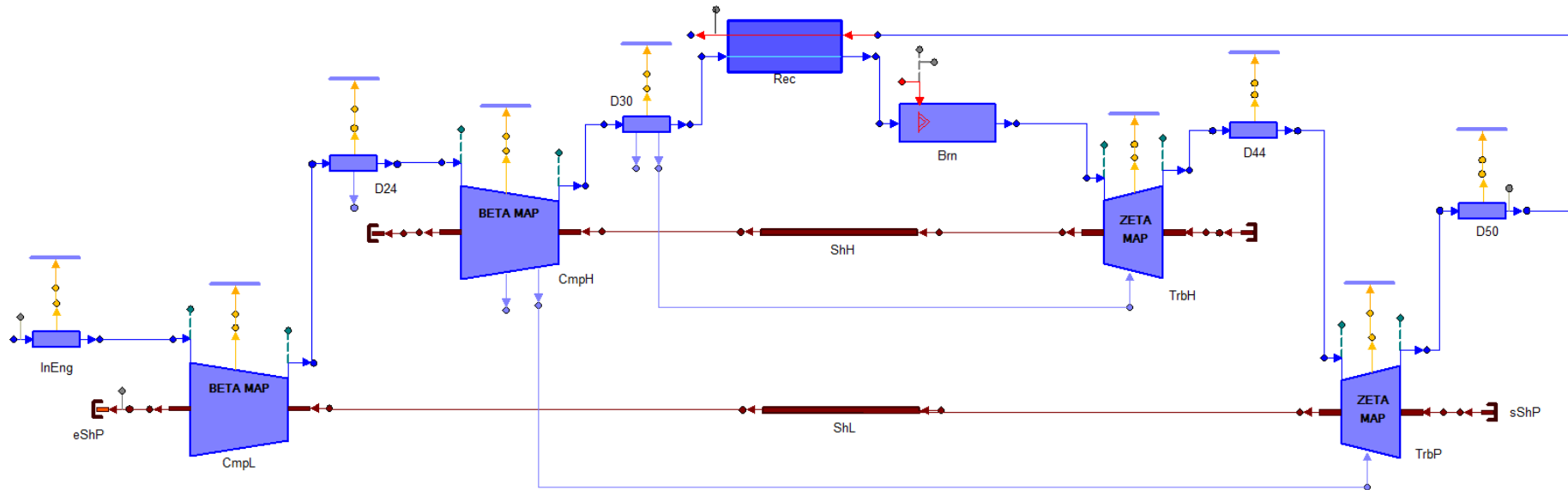
Two spools two shafts



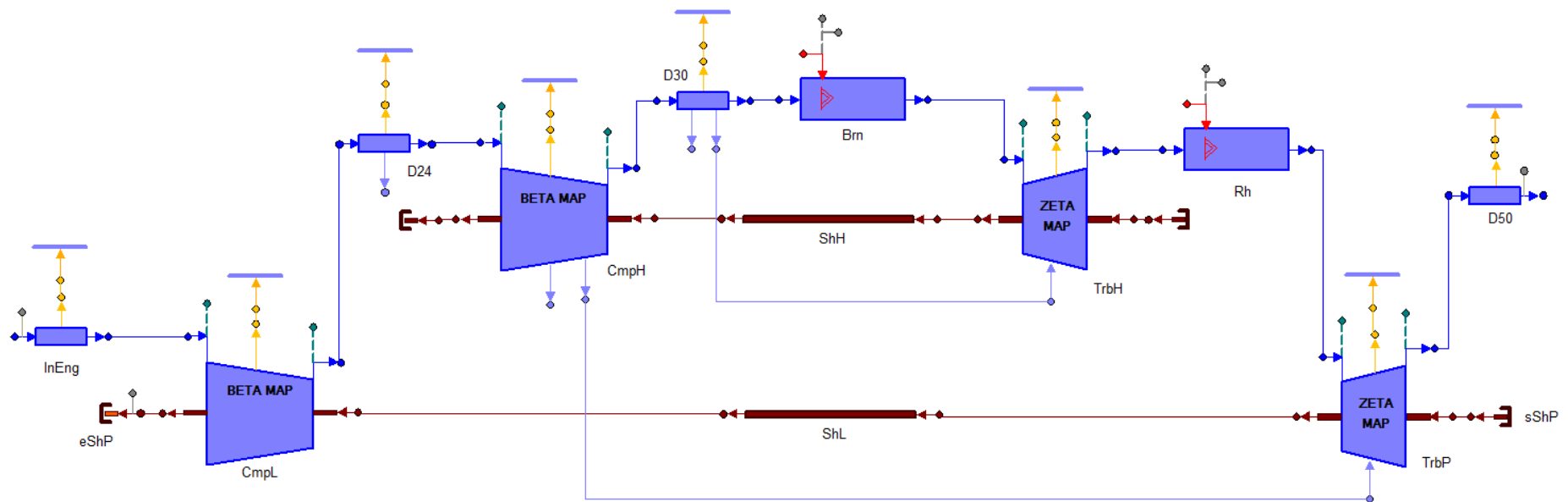
Two spools two shafts with intercooler



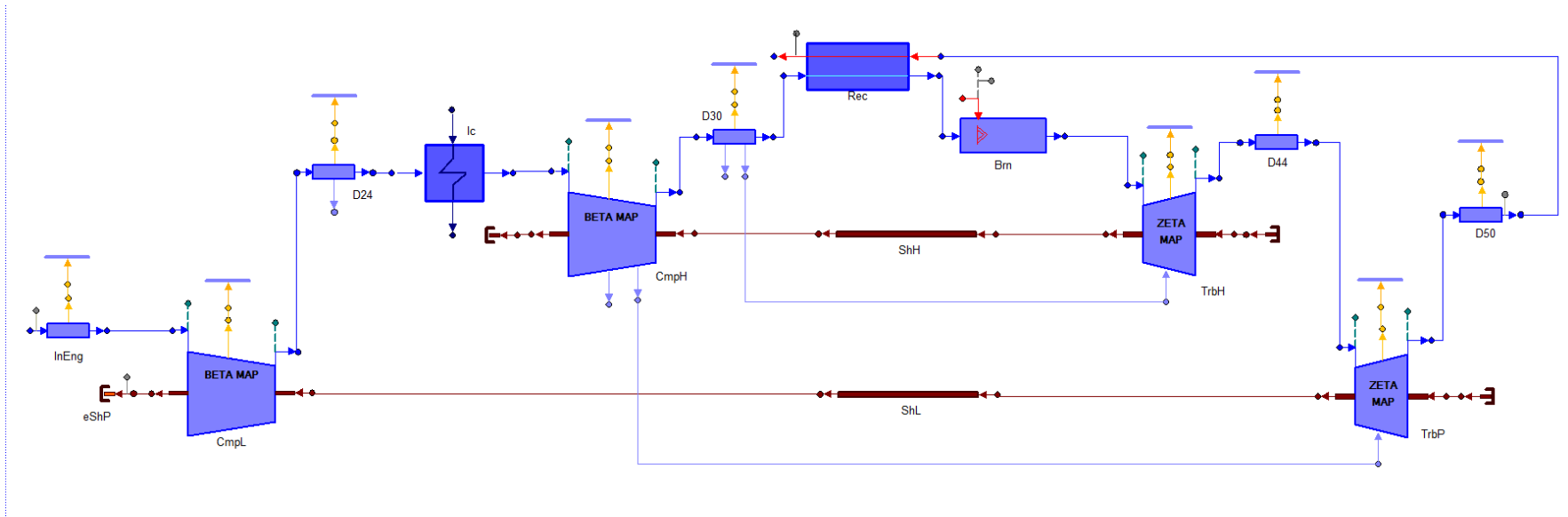
Two spools two shafts with recuperator



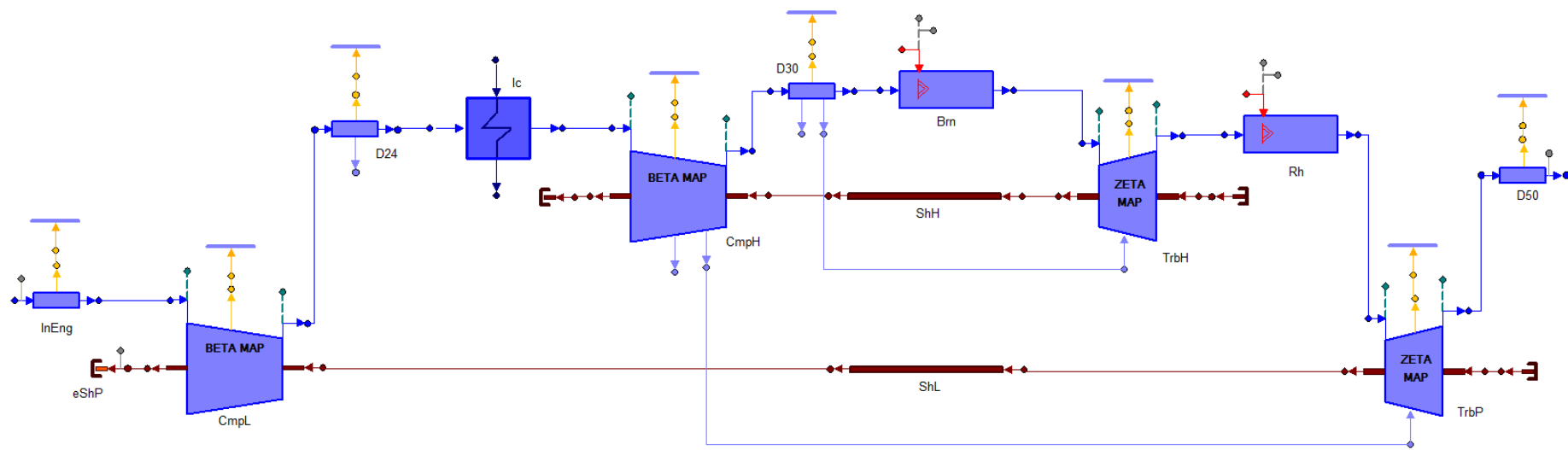
Two spools two shafts with reheater



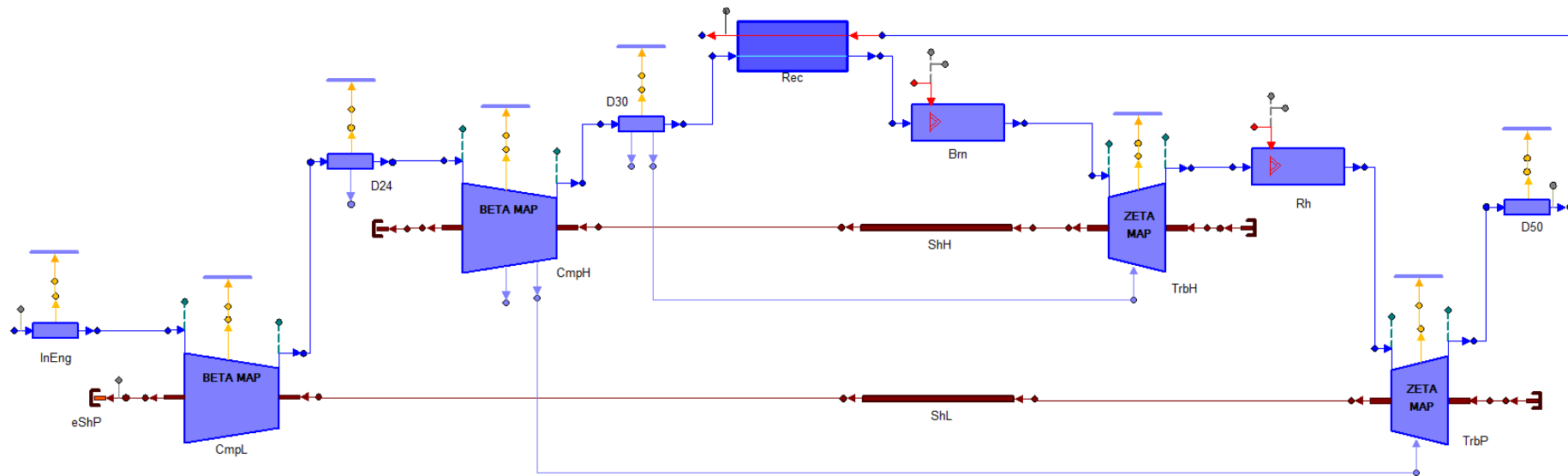
Two spools two shafts with intercooler and recuperator



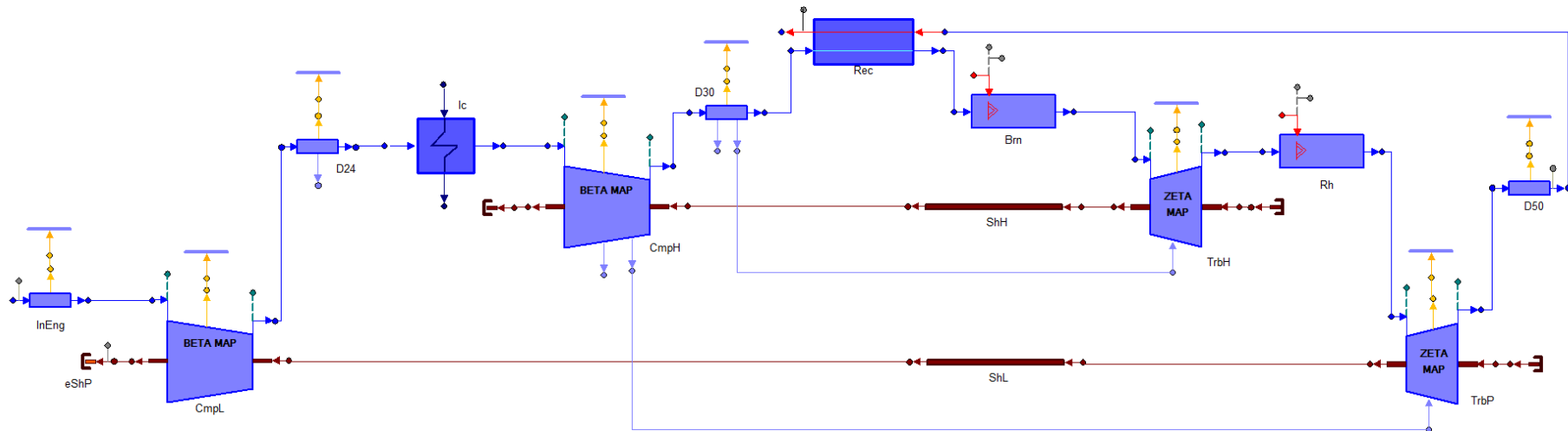
Two spools two shafts with intercooler and reheater



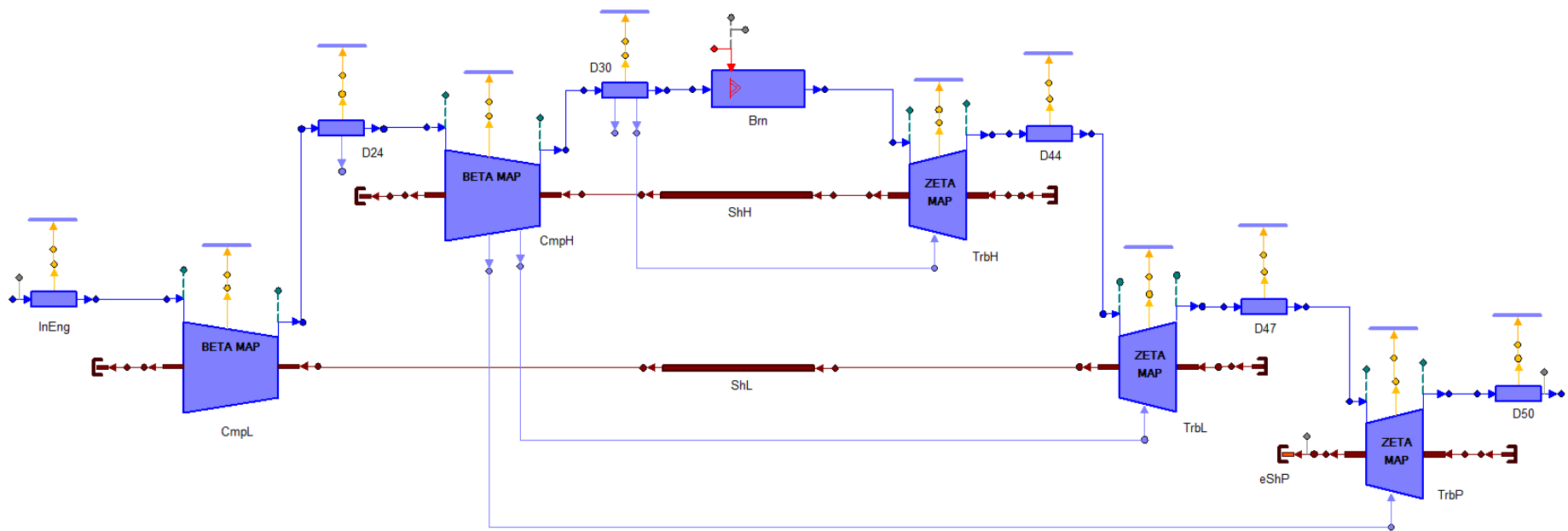
Two spools two shafts with recuperator and reheater



Two spools two shafts with intercooler, recuperator and reheater

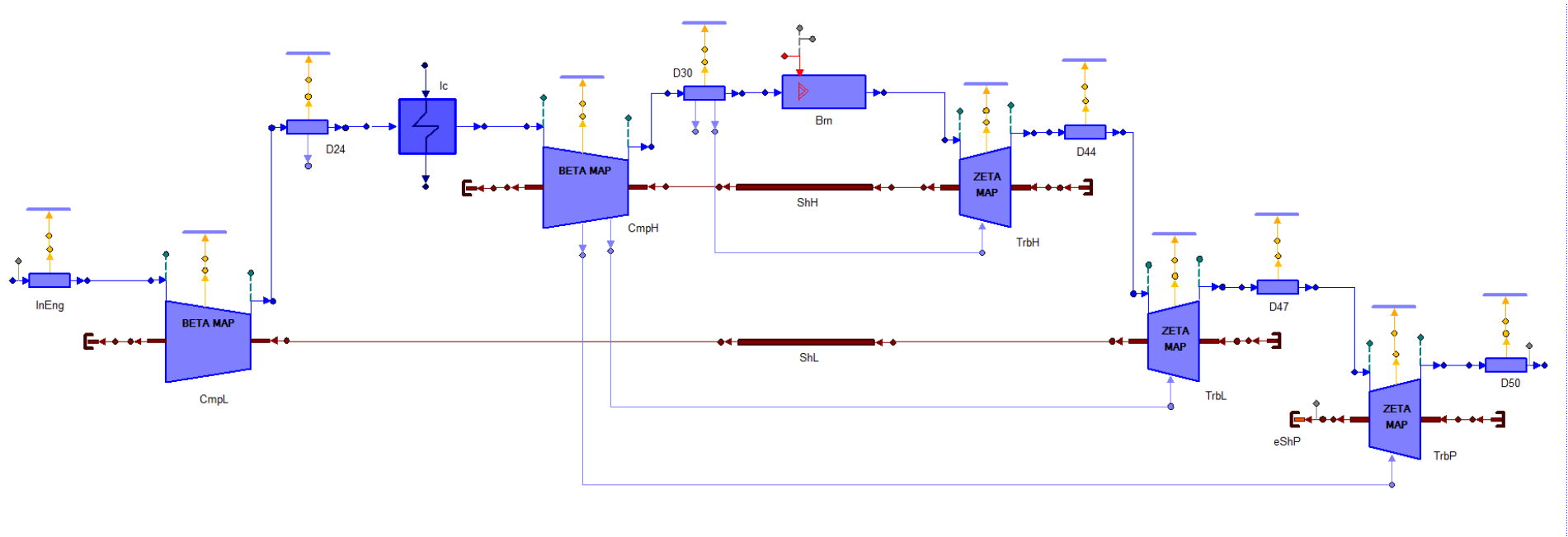


Two spools three shafts

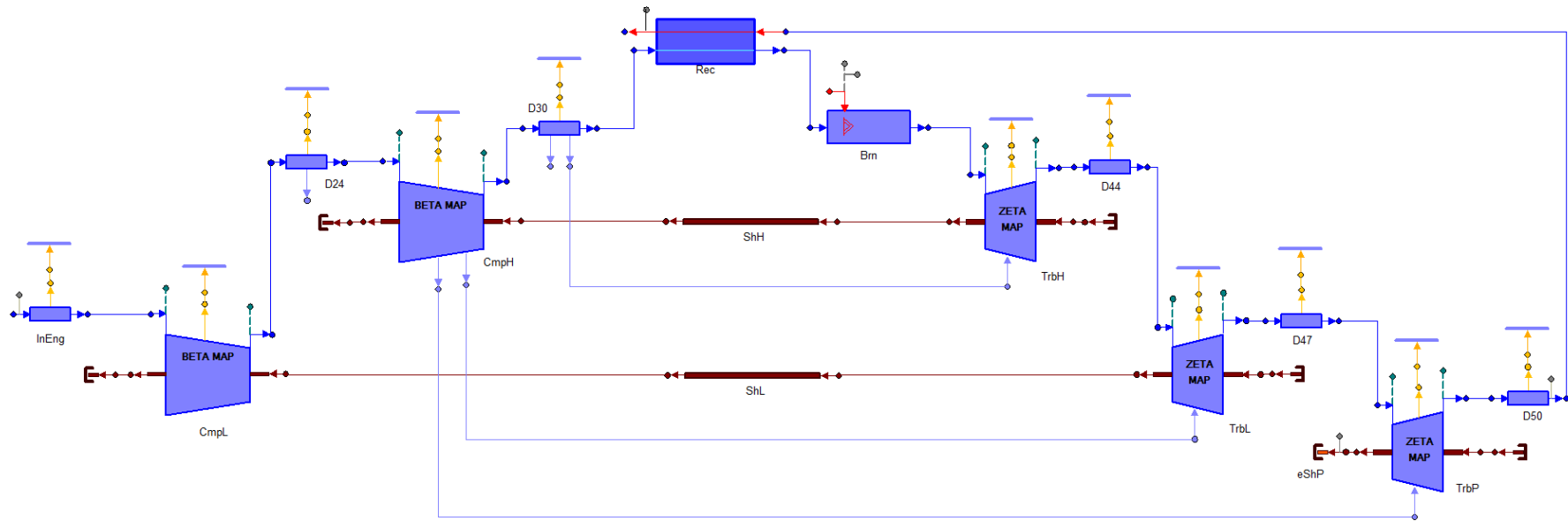




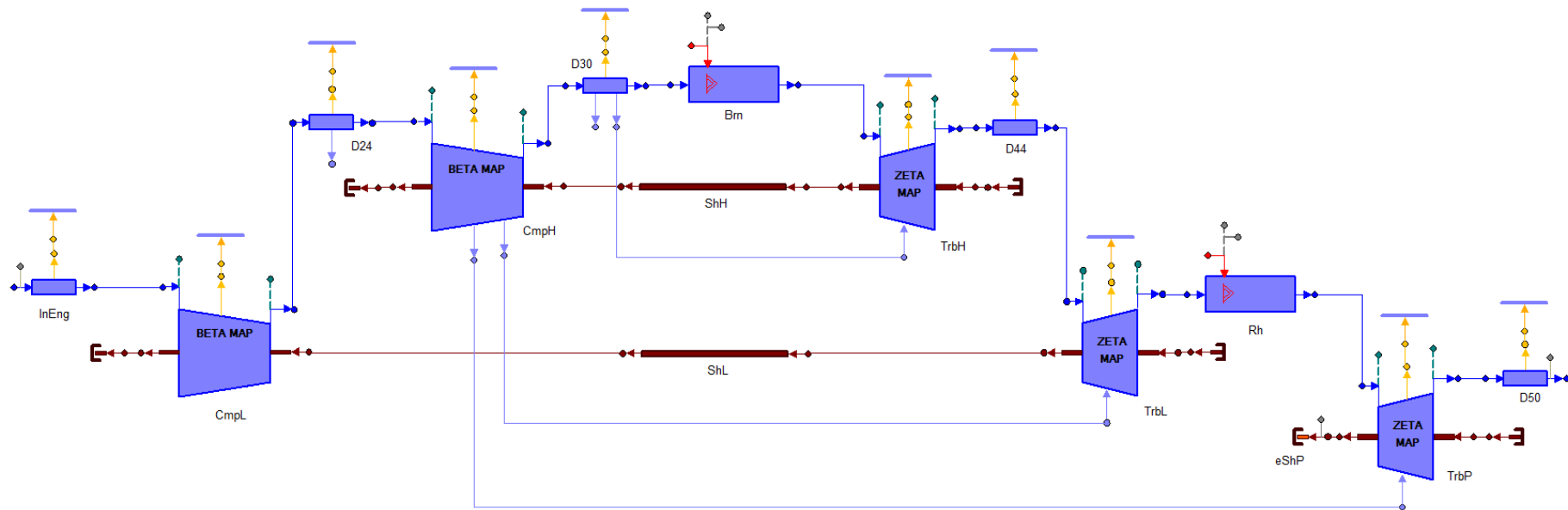
Two spools three shafts with intercooler



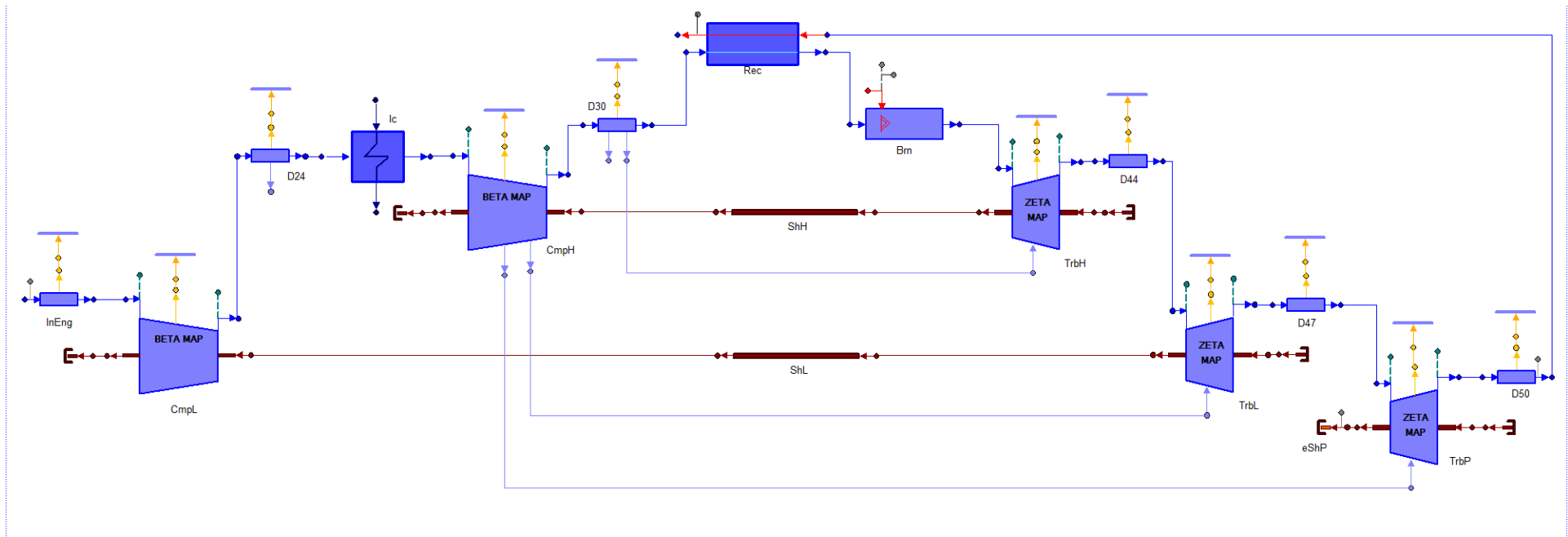
Two spools three shafts with recuperator



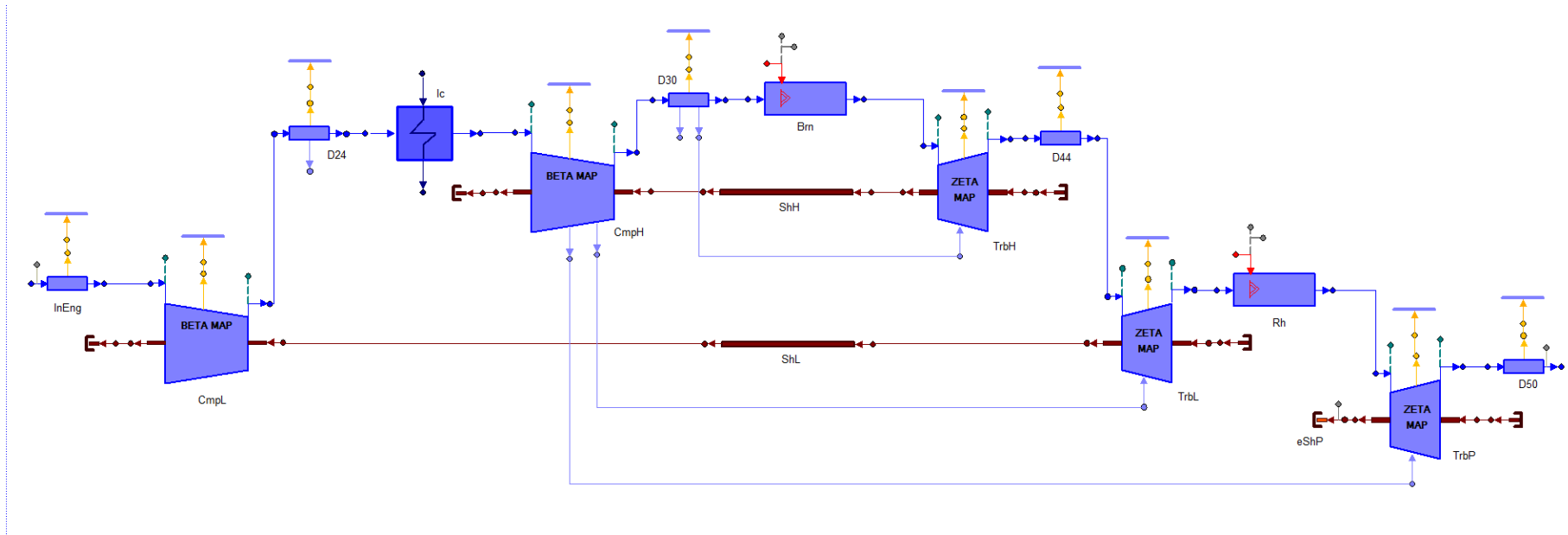
Two spools three shafts with reheat



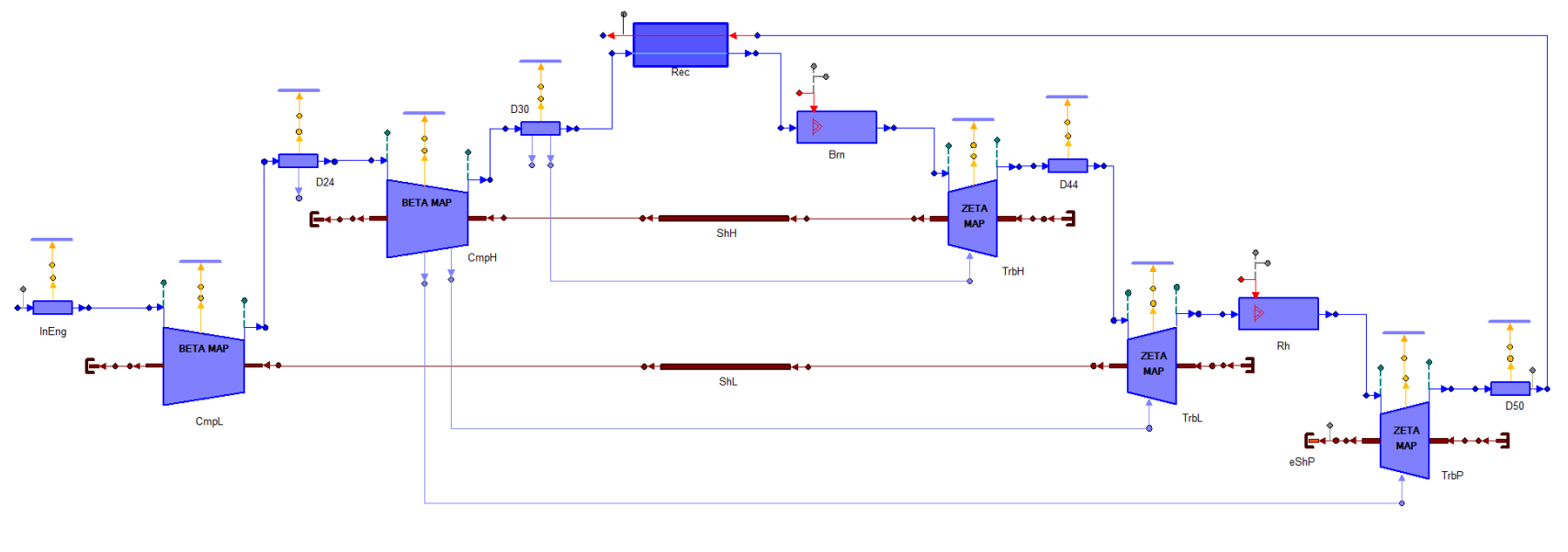
Two spools three shafts with intercooler and recuperator



Two spools three shafts with intercooler and reheater



Two spools three shafts with recuperator and reheater



Two spools three shafts with intercooler, recuperator and reheater

