APPENDIX A

INSTRUMENT LIST

TABLE OF CONTENTS

SIET Code	Plant Code	Measurement location on plant	Calibration Range (kPa)	Instrument Accuracy (% f.s.)	Pressure Taps Elevation (mm)
TMD024	DP 001	steam/gas mixture inlet line	0 ÷ 50	0.25	4570
TMD162	DP 002	steam/gas mixture inlet line	0 ÷ 50	0.25	4570
TMD168	DP 003	steam/gas mixture inlet line	0 ÷ 25	0.50	642
TMD160	DP 004	steam/gas mixture inlet line	0 ÷ 20	0.50	642
TSD026	DP 005	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD027	DP 006	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD029	DP 008	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD031	DP 009	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD034	DP 010	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD037	DP 011	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD036	DP 012	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD043	DP 013	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD045	DP 014	upper header module 1 - tube bundle	+/- 34	0.50	725
TSD035	DP 015	upper header module 2 - tube bundle	+/- 34	0.50	725
TSD044	DP 016	upper - lower header	+/- 34	0.50	2537
TMD164	DP 017	lower header module 1	0 ÷ 30	0.50	2355
TMD163	DP 018	lower header module 2	0 ÷ 30	0.50	2360
TMD152	DP 019	drain line	0 ÷ 10	0.25	830
TMD020	DP 020	drain line	0 ÷ 10	0.25	835
TMD214	DP 021	lower header module 1	0 ÷ 100	0.50	3838
TMD184	DP 022	lower header module 2	0 ÷ 100	1.00	3848
TMD183	DP 023	vent line	0 ÷ 60	0.50	968
TMD010	DP 024	condensate tank	0 ÷ 70	0.50	5537
TMD003	DP 025	condensate tank	0 ÷ 150	1.00	9519
TSD045	DP 026	upper - lower header	+/- 34	0.50	2547
TSD032	DP 027	upper header module 1 - tube bundle	+/- 34	0.50	725
TMD156	DP 029	drain line	0 ÷ 40	0.50	2865
TMD006	DP 030	vent line	0 ÷ 100	0.25	7695
TMD[illegible]	DP 031	critical valve on air supply line	0 ÷ 2500	1.00	0
TMD197	DP 032	critical valve on steam supply line	0 ÷ 7000	1.00	0
TMD158	DP P001	PCC pool	0 ÷ 50	0.50	678
TMD178	DP P002	PCC pool	0 ÷ 30	0.50	2260
TMD176	DP P003	PCC pool	0 ÷ 50	0.50	2256
TMD181	DP P004	PCC pool	0 ÷ 35	0.50	2274
TMD169	DP P005	PCC pool	0 ÷ 10	0.50	677
TMD182	DP P006	PCC pool	0 ÷ 35	0.50	2248

Tab. A1 - Transmitters and transducers instrument list for Test Condition T43_2

SIET Code	Plant Code	Measurement location on plant	Calibration Range (kPa)	Instrument Accuracy (% f.s.)	Pressure Taps Elevation (mm)
TMD175	DP P007	PCC pool	0 ÷ 30	0.50	1540
TMD161	DP P008	PCC pool	0 ÷ 50	0.50	2260
TMD172	DP P009	PCC pool	0 ÷ 10	0.50	677
TMD194	DP P010	PCC pool	0 ÷ 10	0.50	1538
TMD028	F 1001	steam supply line	0 ÷ 700	0.50	0
TMD007	F 1002	steam supply line	0 ÷ 100	0.25	0
TMD171	F 1003	steam supply line	0 ÷ 10	0.50	0
TMD211	F 2001	air supply line	0 ÷ 500	0.25	0
TMD026	F 2002	air supply line	0 ÷ 100	0.25	0
TMD208	F 3001	steam desuperheating line	0 ÷ 100	0.25	0
TMD025	F L001	CT water discharging line	0 ÷ 25	0.25	0
TMD177	F M001	IC pool make up line	0 ÷ 25	0.50	0
TMD191	F R001	Pool discharging line	0 ÷ 25	0.50	0
TMD027	F T001	vent tank discharging line	0 ÷ 100	0.25	0
TMD210	F T002	vent tank discharging line	0 ÷ 10	0.25	0
TMD209	L I001	vent tank	0 ÷ 50	0.25	2657
TMD174	L I002	vent tank	0 ÷ 15	0.50	850
TMD151	L L001	condensate tank	0 ÷ 100	0.25	9091
TMD192	L L002	condensate tank	0 ÷ 25	0.50	2240
TMD012	L L003	CT water discharging line	0 ÷ 50	1.00	4595
TMD167	L O001	catch tank	0 ÷ 50	0.50	5015
TMD155	L O002	catch tank	0 ÷ 10	0.50	1100
TMD015	L P001	PCC pool	0 ÷ 50	0.50	4205
TMD019	L Q001	IC pool	0 ÷ 50	0.50	4340
TMD009	L Q002	IC pool	0 ÷ 20	0.50	1715
TMR067	P 1001	steam supply line	100 ÷ 20100	0.50	2450
TMR070	P 2001	air supply line	100 ÷ 3600	0.50	0
TMR045	P 4001	steam/gas mixture inlet line	100 ÷ 1100	0.50	890
TMA008	P 4002	steam/gas mixture inlet line	100.15 ÷ 1300.15	0.50	2508
TMA010	P 5001	drain line	100.25 ÷ 1100.25	0.50	1750
TMA007	P 6001	vent line	100.15 ÷ 1300.15	0.50	780
TMR053	P 7001	steam bypass line	100 ÷ 12100	0.50	1050
TMA014	P A001	upper header module 1	99.4 ÷ 1099.4	0.50	2143
TMA011	P I001	vent tank	100.25 ÷ 1100.25	0.50	542
TMA009	P L001	condensate tank	100.15 ÷ 1100.15	0.50	9651
TMA012	P T001	vent tank discharging line	100.25 ÷ 1100.25	0 50	80

Tab. A1 (Cont'd)

SIET code	Plant code	Measurement Location on Plant	Type	Diameter (mm)	Instrument Accuracy (±C)	Calibration range (°C)	Penetration Depth (mm)
TCK456	T-1001	Steam supply line (downstream orifice)	K	2	1.6	50 ÷ 400	10
TCK042	T-2001	Air supply line (downstream orifice)	K	3	1.1	0 ÷ 100	30
TCK464	T-3001	Steam desuperheating line (water temperature)	K	2	1.1	0 ÷ 100	7
TCK033	T-4001	Steam-air mixture supply line (downstream mixing point)	K	3	1.1	20 ÷ 200	20
TCK031	T-4002	PCC inlet section (outside PCC pool)	K	3	1.1	0 ÷ 180	20
TCK480	T-4003	Below steam distributor (inside PCC pool)	K	3	1.1	0 ÷ 200	20
TCK038	T-5001	Drain line (under Tee conjunction)	K	3	1.1	0 ÷ 180	30
TCK039	T-5002	Drain line (CT inlet section)	K	3	1.1	0 ÷ 180	30
TCK040	T-6001	Vent line (under Tee conjunction)	K	3	1.1	0 ÷ 180	30
TCK465	T-6002	Vent line (VT inlet section)	K	2	1.1	0 ÷ 180	30
TCK461	T-7001	Steam bypass line (upstream valve)	K	2	1.6	50 ÷ 400	10
TCK395	T-9001	CT / PCC pressure equalizing line	K	2	1.1	0 ÷ 180	13
TCK471	T-A001	PCC upper header module 1 (back side)	K	3	1.1	0 ÷ 200	165
TCK473	T-A002	PCC upper header module 1 (front side)	K	3	1.1	0 ÷ 200	165
TCK474	T-C001	PCC lower header module 1 (back side)	K	3	1.1	0 ÷ 200	165
TCK475	T-C002	PCC lower header module 1 (front side)	K	3	1.1	0 ÷ 200	165
TCK477	T-D001	PCC upper header module 2 (back side)	K	3	1.1	0 ÷ 200	165
TCK479	T-F001	PCC lower header module 2 (back side)	K	3	1.1	0 ÷ 200	165
TCK051	T-I001	VT (elevation 6106 mm)	K	3	1.1	0 ÷ 180	200
TCK052	T-I002	VT (elevation 3228 mm)	K	3	1.1	0 ÷ 180	200
TCK053	T-I003	VT (elevation 570 mm)	K	3	1.1	0 ÷ 180	200
TCK046	T-L001	CT (elevation 4040 mm)	K	3	1.1	0 ÷ 180	200
TCK047	T-L002	CT (elevation 3545 mm)	K	3	1.1	0 ÷ 180	200
TCK048	T-L003	CT (elevation 1800 mm)	K	3	1.1	0 ÷ 180	200
TCK049	T-L004	CT (elevation 388 mm)	K	3	1.1	0 ÷ 180	200
TCK043	T-L005	CT water discharging line	K	3	1.1	0 ÷ 180	30
TCK398	T-M001	PCC pool make-up line	K	2	1.1	0 ÷ 100	30
TCK500	T-N001	PCC-IC pool lower connecting line	K	2	1.1	0 ÷ 150	30
TCK054	T-O001	Catch tank inlet nozzle	K	3	1.1	0 ÷ 180	30
TCK044	T-R001	PCC pool discharging line	K	3	1.1	0 ÷ 100	30
TCK055	T-T001	VT steam-gas discharging line	K	3	1.1	0 ÷ 180	30

Tab. A2 - Fluid thermocouples instrument list for Test Condition T43_2

SIET Code	Plant Code	Tube Measurement Location on Plant	Type	Diameter (mm)	Maximum Calibration Error (+/- °C)	Calibration Range (°C)	Cavity Nominal Depth of Condenser Tubes (mm)
TCK085	TW-B011e	Tube 1A elevation a, external wall	K	0.5	1	0 : 210	0.5
TCK082	TW-B011i	Tube 1A elevation a, internal wall	K	0.5	1	0 : 210	1.55
TCK079	TW-B012e	Tube 1A elevation b, external wall	K	0.5	1.3	0 : 210	0.5
TCK070	TW-B012i	Tube 1A elevation b, internal wall	K	0.5	1.4	0 : 210	1.55
TCK125	TW-B013e	Tube 1A elevation c, external wall	K	0.5	1.1	0 : 210	0.5
TCK075	TW-B013i	Tube 1A elevation c, internal wall	K	0.5	1.5	0 : 210	1.55
TCK102	TW-B014e	Tube 1A elevation d, external wall	K	0.5	1.1	0 : 210	0.5
TCK068	TW-B014i	Tube 1A elevation d, internal wall	K	0.5	1.1	0 : 210	1.55
TCK095	TW-B015e	Tube 1A elevation e, external wall	K	0.5	1.2	0 : 210	0.5
TCK063	TW-B015i	Tube 1A elevation e, internal wall	K	0.5	1.2	0 : 210	1.55
TCK127	TW-B016e	Tube 1A elevation f, external wall	K	0.5	1.2	0 : 210	0.5
TCK116	TW-B016i	Tube 1A elevation f, internal wall	K	0.5	1.2	0 : 210	1.55
TCK126	TW-B017e	Tube 1A elevation g, external wall	K	0.5	0.9	0 : 210	0.5
TCK105	TW-B017i	Tube 1A elevation g, internal wall	K	0.5	0.9	0 : 210	1.55
TCK081	TW-B018e	Tube 1A elevation h, external wall	K	0.5	0.6	0 : 210	0.5
TCK135	TW-B018i	Tube 1A elevation h, internal wall	K	0.5	0.4	0 : 210	1.55
TCK076	TW-B019e	Tube 1A elevation i , external wall	K	0.5	0.5	0 : 210	0.5
TCK119	TW-B019i	Tube 1A elevation i , internal wall	K	0.5	0.5	0 : 210	1.55
TCK056	TW-B020e	Tube 4A elevation a, external wall	K	0.5	1	0 : 210	0.5
TCK097	TW-B020i	Tube 4A elevation a, internal wall	K	0.5	1	0 : 210	1.55
TCK060	TW-B021e	Tube 4A elevation b, external wall	K	0.5	2.1	0 : 210	0.5
TCK099	TW-B021i	Tube 4A elevation b, internal wall	K	0.5	1.9	0 : 210	1.55
TCK118	TW-B022e	Tube 4A elevation c, external wall	K	0.5	0.7	0 : 210	0.5
TCK100	TW-B022i	Tube 4A elevation c, internal wall	K	0.5	0.6	0 : 210	1.55
TCK071	TW-B023e	Tube 4A elevation d, external wall	K	0.5	0.9	0 : 210	0.5
TCK103	TW-B023i	Tube 4A elevation d, internal wall	K	0.5	0.9	0 : 210	1.55
TCK080	TW-B024e	Tube 4A elevation e, external wall	K	0.5	1.1	0 : 210	0.5
TCK101	TW-B024i	Tube 4A elevation e, internal wall	K	0.5	1.1	0 : 210	1.55
TCK132	TW-B025e	Tube 4A elevation f, external wall	K	0.5	0.8	0 : 210	0.5
TCK086	TW-B025i	Tube 4A elevation f, internal wall	K	0.5	0.8	0 : 210	1.55
TCK129	TW-B026e	Tube 4A elevation g, external wall	K	0.5	1.3	0 : 210	0.5

Tab. A3 - Brazed Thermocouple Instrument List for Test Condition T43_2

SIET Code	Plant Code	Measurement Location on Plant	Type	Diameter (mm)	Maximum Calibration Error (+/-°C)	Calibration Range (°C)	Cavity Nominal Depth of Condenser Tubes (mm)
TCK069	TW-B026i	Tube 4A elevation g, internal wall	K	0.5	1.2	0 : 210	1.55
TCK065	TW-B027e	Tube 4A elevation h, external wall	K	0.5	1.4	0 : 210	0.5
TCK067	TW-B027i	Tube 4A elevation h, internal wall	K	0.5	1.4	0 : 210	1.55
TCK069	TW-B028e	Tube 4A elevation i, external wall	K	0.5	1.3	0 : 210	0.5
TCK083	TW-B028i	Tube 4A elevation i, internal wall	K	0.5	1.3	0 : 210	1.55
TCK087	TW-B029e	Tube 5Q elevation a, external wall	K	0.5	0.8	0 : 210	0.5
TCK109	TW-B029i	Tube 5Q elevation a, internal wall	K	0.5	0.8	0 : 210	1.55
TCK093	TW-B030e	Tube 5Q elevation b, external wall	K	0.5	1.5	0 : 210	0.5
TCK108	TW-B030i	Tube 5Q elevation b, internal wall	K	0.5	1.5	0 : 210	1.55
TCK078	TW-B031e	Tube 5Q elevation c, external wall	K	0.5	1	0 : 210	0.5
TCK134	TW-B031i	Tube 5Q elevation c, internal wall	K	0.5	1	0 : 210	1.55
TCK110	TW-B032e	Tube 5Q elevation d, external wall	K	0.5	0.9	0 : 210	0.5
TCK133	TW-B032i	Tube 5Q elevation d, internal wall	K	0.5	0.9	0 : 210	1.55
TCK112	TW-B033e	Tube 5Q elevation e, external wall	K	0.5	1.3	0 : 210	0.5
TCK131	TW-B033i	Tube 5Q elevation e, internal wall	K	0.5	1.3	0 : 210	1.55
TCK057	TW-B034e	Tube 5Q elevation f, external wall	K	0.5	1.6	0 : 210	0.5
TCK058	TW-B034i	Tube 5Q elevation f, internal wall	K	0.5	1.6	0 : 210	1.55
TCK077	TW-B035e	Tube 5Q elevation g, external wall	K	0.5	1.4	0 : 210	0.5
TCK107	TW-B035i	Tube 5Q elevation g, internal wall	K	0.5	1.4	0 : 210	1.55
TCK061	TW-B036e	Tube 5Q elevation h, external wall	K	0.5	1.6	0 : 210	0.5
TCK114	TW-B036i	Tube 5Q elevation h, internal wall	K	0.5	1.2	0 : 210	1.55
TCK115	TW-B037e	Tube 5Q elevation i , external wall	K	0.5	1.4	0 : 210	0.5
TCK117	TW-B037i	Tube 5Q elevation I , internal wall	K	0.5	1.44	0 : 210	1.55
TCK096	TW-B038e	Tube 8Q elevation a, external wall	K	0.5	1.7	0 : 210	0.5
TCK072	TW-B038i	Tube 8Q elevation a, internal wall	K	0.5	1.1	0 : 210	1.55
TCK090	TW-B039e	Tube 8Q elevation b, external wall	K	0.5	1.5	0 : 210	0.5
TCK064	TW-B039i	Tube 8Q elevation b, internal wall	K	0.5	2.1	0 : 210	1.55
TCK092	TW-B040e	Tube 8Q elevation c, external wall	K	0.5	1.2	0 : 210	0.5
TCK106	TW-B040i	Tube 8Q elevation c, internal wall	K	0.5	1	0 : 210	1.55
TCK088	TW-B041e	Tube 8Q elevation d, external wall	K	0.5	1	0 : 210	0.5
TCK122	TW-B041i	Tube 8Q elevation d, internal wall	K	0.5	0.9	0 : 210	1.55

Tab. A3 (Cont'd)

SIET Code	Plant Code	Measurement Location on Plant	Type	Diameter (mm)	Maximum Calibration Error +/-°C	Calibration Range (°C)	Cavity Nominal Depth of Condenser Tubes (mm)
TCK111	TW-B042e	Tube 8Q elevation e, external wall	K	0.5	1.1	0 : 210	0.5
TCK098	TW-B042i	Tube 8Q elevation e, internal wall	K	0.5	1.1	0 : 210	1.55
TCK091	TW-B043e	Tube 8Q elevation f, external wall	K	0.5	1.1	0 : 210	0.5
TCK062	TW-B043i	Tube 8Q elevation f, internal wall	K	0.5	1.1	0 : 210	1.55
TCK113	TW-B044e	Tube 8Q elevation g, external wall	K	0.5	0.9	0 : 210	0.5
TCK059	TW-B044i	Tube 8Q elevation g, internal wall	K	0.5	0.9	0 : 210	1.55
TCK128	TW-B045e	Tube 8Q elevation h, external wall	K	0.5	0.6	0 : 210	0.5
TCK074	TW-B045i	Tube 8Q elevation h, internal wall	K	0.5	0.5	0 : 210	1.55
TCK084	TW-B046e	Tube 8Q elevation I , external wall	K	0.5	0.4	0 : 210	0.5
TCK130	TW-B046i	Tube 8Q elevation I , internal wall	K	0.5	0.4	0 : 210	1.55

Tab. A3 (Cont'd)

SIET Code	Plant Code	Measurement Location on Plant			Type	Diameter (mm)	Instrument Accuracy (+/- °C)	Calibration Range (°C)
		X dir. (mm)	Y dir. (mm)	Z dir. (mm)				
TR008	T-P001	1610	5420	3120	PT-100	4.5	0.45	0 ÷ 150
TR009	T-P002	1610	4625	3120	PT-100	4.5	0.45	0 ÷ 150
TR011	T-P003	50	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR013	T-P004	720	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR014	T-P005	720	3745	2495	PT-100	4.5	0.45	0 ÷ 150
TR016	T-P006	720	3745	2195	PT-100	4.5	0.45	0 ÷ 150
TR019	T-P007	720	3745	1795	PT-100	4.5	0.45	0 ÷ 150
TR021	T-P008	720	3745	1195	PT-100	4.5	0.45	0 ÷ 150
TR022	T-P009	880	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR023	T-P010	1080	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR025	T-P011	1080	3745	2495	PT-100	4.5	0.45	0 ÷ 150
TR089	T-P012	1080	3745	2195	PT-100	4.5	0.45	0 ÷ 150
TR028	T-P013	1080	3745	1795	PT-100	4.5	0.45	0 ÷ 150
TR037	T-P014	1080	3745	1195	PT-100	4.5	0.45	0 ÷ 150
TR038	T-P015	1260	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR039	T-P016	1610	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR101	T-P017	1910	3745	5650	PT-100	4.5	0.45	0 ÷ 150
TR041	T-P018	1910	3745	5025	PT-100	4.5	0.45	0 ÷ 150
TR042	T-P019	1910	3745	3810	PT-100	4.5	0.45	0 ÷ 150
TR043	T-P020	1910	3745	3220	PT-100	4.5	0.45	0 ÷ 150
TR044	T-P021	1910	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR045	T-P022	1910	3745	2495	PT-100	4.5	0.45	0 ÷ 150
TR046	T-P023	1910	3745	2195	PT-100	4.5	0.45	0 ÷ 150
TR047	T-P024	1910	3745	1795	PT-100	4.5	0.45	0 ÷ 150
TR098	T-P025	1910	3745	1195	PT-100	4.5	0.45	0 ÷ 150
TR049	T-P026	1910	3745	860	PT-100	4.5	0.45	0 ÷ 150
TR050	T-P027	1910	3745	480	PT-100	4.5	0.45	0 ÷ 150
TR051	T-P028	1910	3745	50	PT-100	4.5	0.45	0 ÷ 150

Tab. A4 - Resistance thermometers instrument list for Test Condition T43_2

SIET Code	Plant Code	Measurement Location on Plant			Type	Diameter (mm)	Instrument Accuracy (+/- °C)	Calibration Range (°C)
		X dir. (mm)	Y dir. (mm)	Z dir. (mm)				
TR053	T-P029	2725	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR058	T-P030	3540	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR059	T-P031	3840	3745	2695	PT-100	4.5	0.45	0 ÷ 150
TR060	T-P032	1260	2480	2695	PT-100	4.5	0.45	0 ÷ 150
TR062	T-P033	1260	2480	2495	PT-100	4.5	0.45	0 ÷ 150
TR064	T-P034	1260	2480	2195	PT-100	4.5	0.45	0 ÷ 150
TR066	T-P035	1260	2480	1795	PT-100	4.5	0.45	0 ÷ 150
TR099	T-P036	1260	2480	1195	PT-100	4.5	0.45	0 ÷ 150
TR071	T-P037	1610	2480	5650	PT-100	4.5	0.45	0 ÷ 150
TR100	T-P038	1610	2480	5025	PT-100	4.5	0.45	0 ÷ 150
TR097	T-P039	1610	2480	2695	PT-100	4.5	0.45	0 ÷ 150
TR076	T-P040	1610	2480	2595	PT-100	4.5	0.45	0 ÷ 150
TR079	T-P041	1610	2480	2495	PT-100	4.5	0.45	0 ÷ 150
TR080	T-P042	1610	2480	2395	PT-100	4.5	0.45	0 ÷ 150
TR081	T-P043	1610	2480	2195	PT-100	4.5	0.45	0 ÷ 150
TR082	T-P044	1610	2480	1995	PT-100	4.5	0.45	0 ÷ 150
TR084	T-P045	1610	2480	1795	PT-100	4.5	0.45	0 ÷ 150
TR085	T-P046	1610	2480	1495	PT-100	4.5	0.45	0 ÷ 150
TR086	T-P047	1610	2480	1195	PT-100	4.5	0.45	0 ÷ 150
TR102	T-P049	1610	1960	2695	PT-100	4.5	0.45	0 ÷ 150
TR092	T-P050	1910	1960	2695	PT-100	4.5	0.45	0 ÷ 150
TR093	T-P051	2725	1960	2695	PT-100	4.5	0.45	0 ÷ 150
TR094	T-P052	3540	1960	2695	PT-100	4.5	0.45	0 ÷ 150
TR096	T-P053	3840	1960	2695	PT-100	4.5	0.45	0 ÷ 150

Tab. A4 (Cont'd)

APPENDIX B

MODIFIED INSTRUMENTS

TABLE OF CONTENTS

TEST NUMBER	INSTRUMENT REPLACEMENT	NEW MEASUREMENT
T43_2	Reference instrument list (see Appendix A)	
T01_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T02_1; T02_2; T02_3	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T03_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T04_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T05_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T06_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T07_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T08_1; T08_2	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T09_1, T09_6; T09_7; T09_8	T-4001 (TCK034)	
T09_9; T09_10	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T10_2	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T11_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T12_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T13_1; T13_2; T13_3; T13_4; T13_5	T-4001 (TCK542); T-4002 (TCK026)	T-T002 (TCK035)
T14_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T15_1; T15_2; T15_3; T15_4; T15_5; T15_6; T15_7	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T16_1; T16_2; T16_3; T16_5; T16_6; T16_7	T-4001 (TCK542); T-4002 (TCK026)	T-T002 (TCK035)
T17_1; T17_2; T17_3; T17_4; T17_5	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T18_1; T18_2; T18_3; T18_4; T18_5; T18_6	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T19_1; T19_2; T19_3; T19_4; T19_5	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T20_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T21_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T22_1; T22_2; T22_3; T22_4; T22_5	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T23_1; T23_2, T23_3	T-4001 (TCK029)	
T23_4; T23_5; T23_6	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T24_1	T-4001 (TCK539); T-4002 (TCK026)	T-T002 (TCK035)
T25_1; T25_2; T25_3; T25_4; T25_5	T-4001 (TCK542); T-4002 (TCK026)	T-T002 (TCK035)
T35_1; T35_2; T35_3; T35_4; T35_5; T35_6	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T36_1; T36_2; T36_3; T36_4; T36_5	T-4001 (TCK542); T-4002 (TCK026)	T-T002 (TCK035)
T37_1	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T38_1	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T39_1	T-4001 (TCK029)	
T41_1	T-4001 (TCK029)	
T42_1	T-4001 (TCK029)	
T44_1	T-4001 (TCK542); T-4002 (TCK026)	T-T002 (TCK035)
T45_1	T-4001 (TCK542); T-4002 (TCK026)	T-T002 (TCK035)
T46_1	T-4001 (TCK542); T-4002 (TCK026)	T-T002 (TCK035)
T47_1	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T48_1	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T49_1	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T50	T-4001 (TCK534); T-4002 (TCK026)	T-T002 (TCK035)
T51	T-4001 (TCK542); T-4002 (TCK026)	T-T002 (TCK035)
T52	T-4001 (TCK534); T-4002 (TCK026)	T-T002 (TCK035)
T53	T-4001 (TCK534); T-4002 (TCK026)	T-T002 (TCK035)
T54	T-4001 (TCK545); T-4002 (TCK026)	T-T002 (TCK035); T-2002 (TCK543)
T55	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)
T56	T-4001 (TCK534); T-4002 (TCK026)	T-T002 (TCK035)
T75	T-4001 (TCK545); T-4002 (TCK026)	T-T002 (TCK035); T-2002 (TCK543)
T76	T-4001 (TCK545); T-4002 (TCK026)	T-T002 (TCK035); T-2002 (TCK543)
T77	T-4001 (TCK545); T-4002 (TCK026).	T-T002 (TCK035); T-2002 (TCK543)
T78	T-4001 (TCK545); T-4002 (TCK026)	T-T002 (TCK035); T-2002 (TCK543)
SLP06 / 07 / 08 / 10 / 11 / 12 / 13 / 14 / 15 / 16	T-4001 (TCK460); T-4002 (TCK026)	T-T002 (TCK035)

Note: all the modifications refer to T43_2 test instrument list, reported in Appendix A

Tab. B1 - Modification on thermocouples during PANTHERS-PCC testing

TEST NUMBER (see NOTE)	INSTRUMENT REPLACEMENT	INSTRUMENT RANGE VARIATION	INSTRUMENT NOT AVAILABLE	NEW MEASUREMENT	MEASUREMENT NOT REQUESTED
T43_2					
T01_1	(1)	(5)	(15)	(18)	(21)
T02_1; T02_2; T02_3		(6)		(19)	(21)
T03_1	(1)	(5)	(15)	(18)	(21)
T04_1	(1)	(5)	(15)	(18)	(21)
T05_1	(1)	(7)	(15)	(18)	(21)
T06_1	(1)	(7)	(15)	(18)	(21)
T07_1	(1)	(7)	(15)	(18)	(21)
T08_1; T08_2	(1)	(5)	(15)	(18)	(21)
T09_1; T09_6; T09_7; T09_8					
T09_9; T09_10		(6)		(19)	(21)
T10_2	(2)	(8)	(15)	(18)	(21)
T11_1	(2)	(8)	(15)	(18)	(21)
T12_1	(1)	(7)	(15)	(18)	(21)
T13_1; T13_2; T13_3; T13_4	(2)	(9)	(15)	(18)	(21)
T13_5	(2)	(9)	(15)	(18)	(21)
T14_1	(1)	(7)	(15)	(18)	(21)
T15_1; T15_2; T15_3; T15_5; T15_6; T15_7		(6)		(19)	(21)
T16_1; T16_2; T16_3	(2)	(9)	(15)	(18)	(21)
T16_5; T16_6; T16_7	(2)	(9)	(15)	(18)	(21)
T17_1; T17_2; T17_3; T17_4; T17_5		(6)		(19)	(21)
T18_1; T18_2; T18_3; T18_4; T18_5; T18_6		(6)		(19)	(21)
T19_1; T19_2; T19_3; T19_4; T19_5		(6)		(19)	(21)
T20_1	(2)	(8)	(15)	(18)	(21)
T21_1	(2)	(8)	(15)	(18)	(21)
T22_1; T22_2; T22_3; T22_4; T22_5		(6)		(19)	(21)
T23_1; T23_2, T23_3		(10)			
T23_4; T23_5		(6)		(19)	(21)
T23_6		(6)		(19)	(21)
T24_1	(2)	(8)	(15)	(18)	(21)
T25_1; T25_2; T25_3; T25_4; T25_5	(2)	(9)	(15)	(18)	(21)
T35_1; T35_2; T35_3; T35_4; T35_5; T35_6		(6)		(19)	(21)
T36_1; T36_2; T36_3; T36_4; T36_5	(2)	(9)	(15)	(18)	(21)
T37_1		(6)		(19)	(21)
T38_1		(6)		(19)	(21)
T39_1		(10)			
T40_1		(10)			
T41_1					
T42_1					

Tab. B2 - Modification on pressure instruments during PCC testing, referred to "Instrument List" of Appendix A

TEST NUMBER (see NOTE)	INSTRUMENT REPLACEMENT	INSTRUMENT RANGE VARIATION	INSTRUMENT NOT AVAILABLE	NEW MEASUREMENT	MEASUREMENT NOT REQUESTED
T44_1	(2)	(9)	(15)	(18)	(21)
T45_1	(2)	(9)	(15)	(18)	(21)
T46_2	(2)	(9)	(15)	(18)	(21)
T47_1		(6)		(19)	(21)
T48_1		(6)		(19)	(21)
T49_1		(6)		(19)	(21)
T50	(2)	(8)	(15)	(18)	(21)
T51		(11)	(16)	(19)	(21)
T52	(2)	(8)	(15)	(18)	(21)
T53	(2)	(8)	(15)	(18)	(21)
T54	(3)	(12)	(15)	(20)	(Δ)
T55		(6)	(16)	(19)	(21)
T56	(2)	(8)	(15)	(18)	(21)
T75	(4)	(14)	(15)	(20)	(22)
T76	(1)	(13)	(15)	(20)	(22)
T77	(4)	(12)	(15)	(20)	(22)
T78	(3)	(12)	(15)	(20)	(22)
SLP06 / 07 / 08		(6)		(19)	(21)
SLP10 / 11 / 12 / 13 / 14 / 15 / 16		(6)		(19)	(21)
SLP14		(6)	(17)	(19)	(21)

NOTE : 1) ALL THE MODIFICATIONS REFER TO T43_2 TEST INSTRUMENT LIST, REPORTED IN APPENDIX A

2) FOR EACH TEST A LIST OF INSTRUMENTS WITH ZERO NOT IN TOLLERANCE AND THE OVER RANGE SIGNALS IS REPORTED IN THE "APPARENT TEST RESULT"

LEGEND

INSTRUMENT REPLACEMENT

(1) DP-022 (TMD234); DP-025 (TMD226)
(2) DP-022 (TMD234)
(3) DP-022 (TMD234); DP-025 (TMD226); P-2002 (TMR002); P-4001 (TMR164)
(4) DP-022 (TMD234); DP-025 (TMD226); P-2002 (TMR002)

Tab. B2 - Modification on pressure instruments during PCC testing, referred to "Instrument List" of Appendix A

INSTRUMENT RANGE VARIATION

(5) P-4002 (TMA008, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14 ÷ 1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 25 kPa); F-2002 (TMD026, 0 ÷ 50 kPa); DP-007 (TMD233, 0 ÷ 10 kPa); DP-022 (TMD234, 0 ÷ 50 kPa)

(6) P-4002 (TMA008, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14 ÷ 1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 25 kPa)

(7) P-4002 (TMA008, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14÷1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 5 kPa); F-2002 (TMD026, 0 ÷ 50 kPa); DP-007 (TMD233, 0 ÷ 10 kPa); DP-022 (TMD234, 0 ÷ 50 kPa)

(8) P-4002 (TMA008, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14÷1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 25 kPa); F-2002 (TMD026, 0 ÷ 5 kPa); DP-007 (TMD233, 0 ÷ 10 kPa); DP-022 (TMD234, 0 ÷ 50 kPa)

(9) P-4002 (TMA008, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14÷1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 25 kPa); F-2002 (TMD026, 0 ÷ 100 kPa); DP-007 (TMD233, 0 ÷ 10 kPa); DP-022 (TMD234, 0 ÷ 50 kPa)

(10) F-3001 (TMD208, 0 ÷ 25 kPa)

(11) P-4002 (TMA008, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14÷1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 25 kPa); F-2002 (TMD026, 0 ÷ 5 kPa)

(12) P-4002 (TMA009, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14÷1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 25 kPa); F-2002 (TMD026, 0 ÷ 5 kPa); P-2002 (TMD068, 100 ÷ 4100 kPa); P-4001 (TMR164, 100 ÷ 2100 kPa) F-2003 (TMD236, 0 ÷ 25 kPa); DP-007 (TMD233, 0 ÷ 10 kPa); DP-022 (TMD234, 0 ÷ 50 kPa)

(13) P-4002 (TMA008, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14÷1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 25 kPa); F-2002 (TMD026, 0 ÷ 50 kPa); P-2002 (TMD068, 100 ÷ 2600 kPa); F-2003 (TMD236, 0 ÷ 25 kPa); DP-007 (TMD233, 0 ÷ 10 kPa); DP-022 (TMD234, 0 ÷ 50 kPa)

Tab. B2 - Modification on pressure instruments during PCC testing, referred to "Instrument List" of Appendix A

(14) P-4002 (TMA008, 101.14 ÷ 1301.14 kPa); P-5001 (TMA010, 101.14 ÷ 1101.14 kPa); P-6001 (TMA007, 101.14 ÷ 1301.14 kPa); P-L001 (TMA009, 101.3 ÷ 1101.3 kPa); P-I001 (TMA011, 101.14 ÷ 1101.14 kPa); P-T001 (TMA012, 101.14 ÷ 1101.14 kPa); P-T002 (TMD151, 100 ÷ 800 kPa); F-3001 (TMD208, 0 ÷ 25 kPa); F-2002 (TMD026, 0 ÷ 50 kPa); ; P-2002 (TMD068, 100 ÷ 4100 kPa); F-2003 (TMD236, 0 ÷ 25 kPa); DP-007 (TMD233, 0 ÷ 10 kPa); DP-022 (TMD234, 0 ÷ 50 kPa)

INSTRUMENT NOT AVAILABLE

(15) DP-016 (TSD044); DP-P005 (TMD169); DP-P008 (TMD161); DP-P009 (TMD172); L-L003 (TMD012)
(16) DP-022 (TMD184); DP-016 (TSD044); L-L003 (TMD012)
(17) F-L001 (TMD025)

NEW MEASUREMENT

(18) P-T002 (TMD151); F-T003 (TMD027 / TMD210); DP-007 (TMD233)
(19) P-T002 (TMD151); F-T003 (TMD027 / TMD210)
(20) P-T002 (TMD151); F-T003 (TMD027 / TMD210); DP-007 (TMD233); F-2003 (TMD236); P-2002 (TMR068)

MEASUREMENT NOT REQUESTED

(21) L-L001 (TMD151)
(22) L-L001 (TMD151); DP031 (TMD198); DP-032 (TMD197)

Tab. B2 - Modification on pressure instruments during PCC testing, referred to "Instrument List" of Appendix A

APPENDIX C

FACILITY CHARACTERIZATION TESTS

TABLE OF CONTENTS

C1. SHAKEDOWN TESTS

The PANTHERS-PCC plant has been characterized by two kinds of pre-operational tests: cold and hot tests.

The cold shakedown tests were performed with water and air at ambient conditions. The fluid operating conditions in the hot shakedown tests were similar to test matrix conditions.

C2. COLD SHAKEDOWN TESTS

Four cold shakedown tests have been performed in the period from July 93 to May 94.

C2.1 C01 Test

The objective of the test was to verify the PCC and IC pool support structure when both the pools were at the maximum gravitational load (full of cold water at the normal level of 4.4 m). The analysis of the test results show that the pool structure deformation at full load are below the allowable value.

C2.2 C02 Test

Objectives:

a) verify the pool level control system;
b) verify the adequacy of the lower 8" connecting line in terms of pressure drops;
c) functional of make-up and discharging line Gilflo flow meters.

Results:

a) four tests were performed at different make-up flowrates: 1, 3, 6 and 9 kg/s.
Since the controller parameters were optimized the level control system worked well for each of the above mentioned conditions;

b) the level difference between the PCC and IC pool was within the error specified for level measurement at the maximum make-up flowrate. This means that the pool connecting 8" line is well sized for minimize the hydraulic resistance;

c) the make-up and discharging flow meter devices have been checked during the tests. The only problem detected was some oscillations in the flow meter of the pool discharging line around 6 kg/s. These oscillations were due to the presence of air in the 4" discharging line. The measure

has been stabilized sligtly increasing the fluid back pressure downstream the Gilflo by means of a throttling valve.

C2.3 C03 Test

Objectives:

a) determine the hydraulic resistance of the PCC riser, PCC tube bundle, vent line, vent tank and vent discharging line at different air flowrates;

b) verify the air compressors C002 and C003 capability and the adeguacy of the VT pressure control system (PIC 4002).

Results:

a) the analysis of the test results showed the DP values across the PCC riser, tube bundle, vent line and vent tank kept always below the overall instruments error at the maximum air flowrate. The hydraulic resistance of these components and pipes were therefore considered negligible;

b) the performance of compressors C002 and C003 has been measured. The maximum total air flowrate was 0.92 kg/s at 1.8 MPa.
The PCC pressure control system (PIC 4002) has been checked in the range of test matrix conditions. The pressure oscillations in steady state conditons have been within ? % of pressure average value.

C3. HOT SHAKEDOWN TESTS

Three hot shakedown tests have been performed in the period from December 93 to July 94.

C3.1 H02 Test

Objectives:

a) measure the condensate tank (CT) heat losses at different fluid temperature;
b) evaluate the amount of steam by-passed into CT through the equalizing line, connecting the mixture supply line to CT.

Test conditions:

To meet the above mentioned objectives, the test has been performed in two different steps:

a) in the first one the CT was pressurized with steam at four different pressure values: 0.26; 0.41; 0.59 and 0.79 MPa;

b) the second part of the test was performed with an air/steam mixture, and the CT filled with cold water up to its normal water level; two different air mass fraction of the inlet mixture have been tested.

Test results:

a) the results of the test analysis are summrized in the following table:

P (MPa)	T (°C)	Tr (°C)	Tin (°C)	Γ cond			W (kW)
				g/s	ΔP (Pa)	Δt (s)	
0.7858	169.3	10.5	171.3	2.37	6102	4320	4.85
0.5872	157.9	10.5	159.8	2.11	3404	2700	4.40
0.4083	144.3	12	146.0	1.18	6048	5580	3.86
0.2579	128.4	12	129.8	1.37	5017	6120	2.98

where:

P average pressure in the Condensate Tank (P-L001)

T average temperature in the Condensate Tank (T-L001; T-L002; T-L003; T-L004)

Tr average room temperature

Tin average Condensate Tank inlet temperature (T-9001)

$\Gamma_{cond} = \frac{(\Delta P) * A}{g * \Delta t}$ condensate water draining from the wall

ΔP CT level variation (L-L003)

A inlet cross section total area of the CT 4" draining tubes (2 tubes in parallel)

Δt time interval

g gravity acceleration

$W = \Gamma \cdot h_{gl}(P)$ Condensate Tank heat losses

h_{gl} latent heat at the Condensate Tank pressure (P)

Figure C1 shows the CT heat losses behaviour versus inner-outer temperature difference;

b) the experimental data have showed that the quantity of steam by-passed and condensed in CT depend on heat losses and on air mass fraction in the inlet mixture. Due to the very small rate of condensation in the CT, the fluid temperature in the CT upper plenum decreased very slowly vs time as shown in Figure C1.
In any case the by-passed steam flowrate was negligible if compared with the steam flowrate values at the PCC inlet, as reported in the test matrix.

C3.2 H04 Test

Objectives:

a) determine the heat losses of the vent line and vent tank;
b) confirm the plant stability to perform test type A.1.3 (steady-state test with steam only);

Results:

a) the test has beeen performed at the following steady-state conditions:

Vent Tank pressure	0.4	MPa
Vent Tank temperature	143	°C
Room temperature	25	°C
Inlet saturated steam flowrate	6.7	kg/s

During the test time the total increase of Vent Tank level was of 3.9 mm . A conservative calculation of the steam condensed in the Vent Tank, due to the heat losses in the vent line and Vent Tank, was made considering the level in the cylindrical part of the tank. Since the tank diameter is 1.7 m , 3.9 mm of level incease correspond to 8.85 liters. The density of water at the measured temperature of 143 °C was 923 kg/m^3; therefore the total mass condensed during the test time of 22 minutes was 8.17 kg equivalent to a condensation rate of 6.2 g/s . The specific heat of evaporation at the measured temperature is 2133 kJ/kg so that a conservative value of the heat losses in the Vent Tank and vent line at the test condition was:

$$W = 2133 \cdot 6.2\,E\text{-}3 = 13.2\ kW$$

b) the performance of the test facility has been measured. The maximum steam flowrate in steady state conditions was 6.7 kg/s at 0.4 MPa and 153 °C, equivalent to 10 °C of superheating. When the steady state conditions were reached the stability of the plant was maintened for 15 minutes and all instrument signals were measured and recorded. The PCC inlet pressure and temperature oscillations have been within 2% of the corresponding average values.

Test shakedown H04 has been repeated at different steam flowrates following the same pre-test check list and test procedeure. For this test, named H04_1 the plant has been modified adding a 4" by-pass line to the VT discharging line in order to reach a lower PCC inlet pressure; a new PCC pool vent line (1 m OD) has been also installed to discharge steam directly to the atmosphere to avoid overpressure inside the pool.
The objectives of this test was:

a) confirm the plant capability to run test type A.1.3 (steady state - steam only) at different steam flowrate: 1.0; 2.5; 4.0; 5.5 and 6.6 kg/s or maximum available;

b) check the mass balance across the heat exchanger (F_{steam} - F_{cond})

The results of the experimental data are summarized as follows:

Γ_{steam} (kg/s)	Pressure (kPa)	Temperature (°C)	Steam superheating (°C)
5.40	361	148	2.4
6.65	415	152	7.1
3.98	297	142	8.8
2.56	226	133	8.9
1.36	170	127	11.5
6.65	394	150	7.0

C3.3 H05 Test

The objective of test H05 was to corfirm the plant capability to run tests type A.1.1: steady-state tests with a mixture of saturated steam and air.

The results of the experimental data are summarized in the following table:

Γ steam (kg/s)	Γ air (kg/s)	Inlet Pressure (kPa)	Inlet temperature (kPa)
5.05	0.0	297	141
5.07	0.163	335	144
5.09	0.163	417	151
5.08	0.162	534	160
5.05	0.162	655	167
5.04	0.162	784	173

Test shakedown H05 has been repeated at different steam and air flowrates following the same test procedure. For this test, named H05_1, the plant has been modified adding a 4" by-pass line to the VT discharging line in order to reach a lower PCC inlet pressure, a new PCC pool vent line (1 m OD) has been also installed to discharge steam directly to the atmosphere to avoid overpressure inside the pool.

The objectives of this test was to confirm the plant capability to run test type A.1.1 and A.1.2 (steady state tests with a mixture of saturated or supereated steam and air) at the maximum steam flowrate (6.6 kg/s) and at two different air flowrate : 0.9 and 0.1 kg/s,

The results of the experimental data are summarized as follows:

Γ steam (kg/s)	Γ air (kg/s)	Inlet Pressure (kPa)	Inlet temperature (kPa)
6.53	0.9	503	156
6.16	0.086	323	144

APPENDIX D

ERROR ANALYSIS

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D1. INTRODUCTION

The uncertainty (Δ) of the directly measured physical quantities (absolute and differential pressure, temperature) is defined in a conservative way as:

$$\Delta = \left(\Delta_I^2 + \Delta_A^2 + \Delta_J^2 + \Delta_W^2\right)^{0.5} \qquad \text{(D1)}$$

where:

Δ_I = assigned accuracy rating of the instrument for absolute and differential pressure; ANSI Standard accuracy for thermocouples; UNI 7937 Standard accuracy for resistance thermometers.

Δ_A = acquisition card A/D converter and amplification maximum error

Δ_J = cold junction maximum error (only for thermocouples)

Δ_W = connection wire maximum error (only for thermocouples)

The uncertainty of the derived quantities (flowrate, level, etc.) is calculated using the following error propagation formula:

$$\Delta Y = \left[\sum_{i=1}^{n}\left(\frac{\partial Y}{\partial X_i}\right)^2 * (\Delta X_i)^2\right]^{0.5} \qquad \text{(D2)}$$

where:

$Y = Y(X_i)$ derived quantity depending on X_i variables, with $i = 1, 2, ..., n$

ΔX_i uncertainty of the X_i quantity.

D2. TEMPERATURE MEASUREMENT UNCERTAINTY

Pool water temperatures were measured by means of resistance thermometers (RTDs) type PT100
All other temperatures were measured by means of sheathed Cromel-Alumel thermocouples type K.

D2.1 Thermocouples

With reference to formula (D1) the following terms are considered for thermocouples uncertainty calculation:

a) *calibration error*

With reference to UNI 7938 Standard the accuracy for ANSI Special thermocouples type K is:

± 1.1 °C or ± 0.4 % full scale

whichever is greater.

All thermocouples in PANTHERS-PCC test facility, except T-1001 and T-7001, have a calibration range less than 210 °C and therefore their accuracy is ± 1.1 °C.

Thermocouples T-1001 and T-7001 have a calibration range of 400 °C and therefore an accuracy of ± 1.6 °C.

b) *acquisition card error*

According to the DAS manual, the acquisition card error is 0.3 °C.

c) *cold junction error*

According to the DAS manual, the cold junction error is 0.4 °C.

d) *connection wire error*

According to ANSI ASTM E 230-77 Standard, the error introduced by the connection wires is ± 1.1 °C

The uncertainty of temperature measurements is therefore:

± 2	°C	for thermocouple T-1001 and T-7001
± 1.6	°C	for all other thermocouples

D2.2 Resistance thermometers

a) *calibration error*

According to UNI 7937 Standard, the resistance thermometers used in PANTHERS-PCC testing were in class GI. The instrument accuracy reported in the Standard is:

± 0.15 °C ± 0.002 | T |

where | T | is the absolute value of temperature in °C.

Considering a conservative temperature in operating conditions of 120 °C, the calibration error of these instruments is ± 0.39 °C.

b) *acquisition card error*

According to the DAS manual, the acquisition card error is 0.4 °C.

The uncertanty of all the resistance thermometers is therefore ± 0.56 °C .

D3. PRESSURE MEASUREMENT UNCERTAINTY

Pressure and differential pressure quantities are calculated as :

$$P = P_I + B$$

where:

P = pressure or differential pressure to be measured

P_I = directly measured value by instrument

B = static pressure due to the presence of cold water inside the hydraulic connections

The B value is calculated as:

$$B = \rho\, g\, H$$

where:

ρ = density of cold water inside the hydraulic connection lines

g = gravity acceleration

H = pressure taps elevation difference (for DP measurements) or pressure tap-instrument elevation difference (for P measurements); H values are reported in Table A1 of Appendix A.

With reference to formula (D2), the uncertainty ΔP of pressure measurements is calculated as:

$$\Delta P = \sqrt{(\Delta P_I)^2 + (\Delta B)^2}$$

where:

ΔP_I = instrument and acquisition card error

ΔB = hydraulic connection elevation difference measurement error

The uncertainty of all the pressure measurement instruments is reported in Table D1 .

D3.1 Instrument and acquisition card error

a) *overall instrument error*

The pressure measurement instruments are calibrated in SIET laboratory; one of the following overall instrument errors is assigned to each instrument:

0.25 % full scale
0.5 % full scale
1 % full scale

The overall instrument error takes into account the calibration error and the effect of the environmental conditions and instrument mounting. The overall instrument error values are reported in Table A1 of Appendix A.

b) *acquisition card error*

According to the DAS manual, the acquisition card error for pressure transmitters and transducers is 0.15 % full scale.

D3.2 Hydraulic connection error

Using the formula (D2) for B value uncertainty calculation and considering the following maximum errors:

$\Delta\rho$ = 3 kg/s
Δg = 0.01 m/s^2
ΔH = 0.005 m

the hydraulic connection elevation difference error is calculated as:

$$\Delta B = \frac{H}{1000}\sqrt{966\left(1+\frac{2.5}{H^2}\right)}$$

with ΔB in [kPa] and H in [m].

D4. LEVEL MEASUREMENT UNCERTAINTY

Levels are calculated as:

$$L = DP / (\rho_l \cdot g)$$

where:

L	=	liquid level	(m)
DP	=	differential pressure measured	(Pa)
ρ_l	=	liquid density at measured temperature	(kg/m^3)
g	=	gravity acceleration	(m/s^2)

With reference to formula (D2) the uncertainty of level measurements, ΔL, is calculated as:

$$\Delta L = \sqrt{\left(\frac{\Delta(DP)}{\rho_l * g}\right)^2 + \left(\frac{\Delta\rho_l * DP}{\rho_l^2 * g}\right)^2 + \left(\frac{\Delta g * DP}{\rho_l * g^2}\right)^2}$$

where:

Δ (DP)			uncertainty of differential pressure measurement [Pa]
ρ_l	= 900	kg/m^3	density of hot water in PCC pool, condensate tank, vent tank and catch tank
ρ_l	= 990	kg/m^3	density of cold water in IC pool
$\Delta\rho_l$	= 2	kg/m^3	maximum error on density measurement
g	= 9.81	m/s^2	gravity acceleration
Δg	= 0.01	m/s^2	maximum error on gravity acceleration

The result of uncertainty calculation in level measurements is summarized in Table D2.

D5. FLOWRATE MEASUREMENTS UNCERTAINTY

Flowrates are calculated as:

$$F = \alpha * \varepsilon * \sqrt{\rho * DP}$$

where:

α = calculated or calibrated flux coefficient (m^2)

ε = compressibility coefficient ($\varepsilon = 1$ for liquid)

ρ = fluid density (kg/m^3)

DP = measured pressure drop (Pa)

With reference to formula (D2) the uncertainty of flowrate measurements, ΔF, referred to the F value is calculated as:

$$\frac{\Delta F}{F} = \sqrt{\left(\frac{\Delta\alpha}{\alpha}\right)^2 + \left(\frac{\Delta\varepsilon}{\varepsilon}\right)^2 + \left(\frac{1}{2}\frac{\Delta\rho}{\rho}\right)^2 + \left(\frac{1}{2}\frac{\Delta(DP)}{DP}\right)^2}$$

For each test this error would be calculated for the different flowrate values. However it can be demonstrated that it never exceeds 2 % of the measured values for all the flowrates, measured by means of orifice plates or venturi nozzles. For the actual uncertainty calculation $\Delta F/F = 2$ % is assumed for all the flowrates.
In the case of GILFLO measurement devices and specifically for the outlet condensate the calibration shows that a good estimate of the error is:

$\Delta F = 2$ % of the measured value for $F \geq 2$ kg/s

$\Delta F = 0.2 - 0.08 \cdot F$ for $F < 2$ kg/s

D6. SUPERHEATED STEAM MEASUREMENT UNCERTAINTY

Two cases were considered:

first case: steam only tests

In this case saturation temperature at the measured pressure is calculated by a computer routine.
The error in superheating temperature is due to uncertainty of pressure and temperature measurement, and used routine.
Considering the pressure uncertainties reported in Table D1, the superheating temperature uncertainty never exceeds 2 °C;

second case: air-steam mixture tests

In this case the steam partial pressure is calculated. This value is then used to calculate the saturation temperature.

Considering an uncertainty of 2 % of the measured value for air and steam flowrates, the uncertainty in pressure measurements as reported in Table D1 and the test conditions, the uncertainty of superheating never exceeds 2.5 °C.

D7. HEAT REJECTION RATE MEASUREMENT UNCERTAINTY

For the steam only tests, the heat rejection rate is calculated as:

$$W = (F_{steam} \cdot h_{steam}) + (F_{liq} \cdot h_{liq}) - (F_{cond} \cdot h_{cond}) = W_{steam} + W_{liq} - W_{cond}$$

With reference to formula (D2) the uncertainty, ΔW, is calculated as:

$$\Delta W = \left[\sum_{i=1}^{3} W_i^2 \left(\frac{\Delta W_i}{W_i} \right)^2 \right]^{0.5}$$

where:

$$\frac{\Delta W_i}{W_i} = \left[\left(\frac{\Delta F_i}{F_i} \right)^2 + \left(\frac{\Delta h_i}{h_i} \right)^2 \right]^{0.5}$$

The uncertainty of specific is considered in all cases equal to:

$$\frac{\Delta h}{h} = 0.01$$

If the condensate flowrate is greater or equal to 2 kg/s then:

$$\frac{\Delta F}{F} = 0.02 \qquad \text{for all flowrate measurements}$$

If the condensate flowrate is less than 2 kg/s then:

$$\frac{\Delta F_{cond}}{F_{cond}} = \frac{0.2}{F_{cond}} - 0.08 \qquad \text{with } F_{cond} \text{ in [kg/s]}$$

The results of the uncertainty calculation are reported in Table 7.1 for each test.

For the air-steam mixture tests, the heat rejection rate is calculated as:

$$W = (F_{steam} \cdot h_{steam}) + (F_{liq} \cdot h_{liq}) + (F_{air} \cdot h_{air}) - (F_{cond} \cdot h_{cond}) + F_{out} \cdot [(h_{air\text{-}out} \cdot X_{air\text{-}out}) + h_{steam\text{-}out} \cdot (1 - X_{air\text{-}out})]$$

from which:

$$W = W_{steam} + W_{liq} + W_{air} - W_{cond} - W_{out}$$

where:

F_{out} = Vent Tank outlet flowrate

$X_{air\text{-}out}$ = air quality at Vent Tank outlet section

$h_{air\text{-}out}$ = air specific enthalpy at Vent Tank outlet section

$h_{steam\text{-}out}$ = steam specific enthalpy at Vent Tank outlet section

With reference to formula D2 and considering:

$\frac{\Delta h}{h} = 0.01$ in all cases

$\frac{\Delta F}{F} = 0.02$ for all flowrate measurements except condensate outlet flowrate

$\frac{\Delta F_{cond}}{F_{cond}} = 0.02$ if condensate outlet flowrate is equal or greater than 2 kg/s

$\frac{\Delta F_{cond}}{F_{cond}} = \frac{0.2}{F_{cond}} - 0.08$ if condensate outlet flowrate is less than 2 kg/s

$\frac{\Delta X}{X} = 0.045$

we obtain the results summarized for each test in Table 7.1 .

Note that the large uncertainty on the air quality at the Vent Tank outlet section particularly effects the heat rejection rate uncertainty in tests with low efficiency.

Table D1 - Pressure measurements uncertainty (referred to T43_2 conditions)

Plant Code	Uncertainty (kPa)	Plant code	Uncertainty (kPa)
DP001	0.21	L-Q002	0.13
DP002	0.21	L-P001	0.30
DP003	0.14	F-1001	3.6
DP004	0.12	F-1002	0.29
DP017	0.18	F-1003	0.05
DP018	0.18	F-3001	0.29
DP019	0.04	F-2001	1.46
DP020	0.04	F-2002	0.29
DP021	0.54	F-L001	0.07
DP022	1.02	F-T001	0.29
DP023	0.32	F-T002	0.03
DP024	0.41	F-M001	0.13
DP025	1.55	F-R001	0.13
DP029	0.23	DP-P001	0.15
DP030	0.38	DP-P002	0.18
DP031	25	DP-P003	0.27
DP032	71	DP-P004	0.20
P-1001	105	DP-P005	0.07
P-7001	63	DP-P006	0.20
P-2001	19	DP-P007	0.17
P-4001	5.7	DP-P008	0.27
P-4002	6.8	DP-P009	0.07
P-A001	5.7	DP-P010	0.09
P-5001	5.7	P-6001	6.8
P-L001	5.7	DP005	0.36
P-I001	5.7	DP006	0.36
P-T001	5.7	DP008	0.36
L-L001	0.41	DP009	0.36
L-L002	0.16	DP010	0.36
L-I001	0.18	DP011	0.36
L-I002	0.10	DP012	0.36
L-O001	0.31	DP013	0.36
L-O002	0.08	DP026	0.37
L-Q001	0.30	DP015	0.36
L-L003	0.59	DP027	0.36
		DP016	0.37

Table D2 - Level measurements uncertainty (referred to T78 conditions)

Plant Code	Uncertainty (m)
L-L002	0.019
L-I001	0.024
L-I002	0.012
L-O001	0.037
L-O002	0.009
L-Q001	0.036
L-Q002	0.015
L-P001	0.032

APPENDIX E

DATA RECORDS

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E1. Data Records

Thermal-hydraulic data of all PANTHERS-PCC tests were digitally acquired and stored on hard disk for the entire duration of tests. Data were stored on two separate hard disks: one for directly acquired quantities and one for derived quantities.
At the end of each test day, a copy of all files acquired that day along with configuration files specifying the used data reduction constants and subroutines, was made on floppy disks.
At the end of the test program, all data was collected and stored on 4 mm 120 Mbyte tapes using a Colorado Memory Systems "Trakker 250" backup device.

E.1 Data tapes

Data tapes contain thermal-hydraulic data and configuration files of all the tests run including shakedown and failed tests. They can be read using the same device described above for storage.
Data files are arranged in directories. Each directory contains all data and configuration files of a single test. The directories are named in the following way:

1) Shakedown tests are named with a first character: "C" for cold shakedown tests and "H" for hot shakedown tests. The first character is followed by the test number as reported in the TP&P document (e.g. H02).
2) Simulated LOCA pressurization tests are named with five characters: the first three are "SLP" and the following two are a progressive number (e.g. SLP07).
3) All other tests are named with six characters: the first is a "T", the following two are the test number as referred in the test matrix, the fourth is an underscore and the final two are a progressive number (e.g. T16_06).

The progressive number in the directory names is chronological and has no reference to the pressure at which the test was run.
Each directory contains the following files:

a) *file of instrument zeros*

This file contains values recorded prior to the start of tests for each testing day for comparison to the theoretical instrument zeros.
The file name is composed of eight characters. The first two are "ZA" followed by the date expressed as "day-month-year"; the extension of the file is "ZER".
Example: ZA171194.ZER

b) *file of historical thermal-hydraulic directly acquired quantities*

This file contains the values of selected directly acquired thermal-hydraulic quantities during the entire testing day, at the frequency of 1 sample each 30 seconds.
The file name is composed of eight characters. The first six indicate the date expressed as "day-month-year"; then follow the letters "TH". The extension of the file is "STO".
Example: 171194TH.STO

c) *file of historical thermal-hydraulic derived quantities*

As above, this file contains values of selected derived quantities throughout the whole testing day at the frequency of 1 sample each 30 seconds.
The file name is the same as above except for the letters "EL" instead of "TH".
Example: 171194EL.STO

d) *files of the directly acquired thermal-hydraulic quantities*

This is a group of files containing all the directly acquired thermal-hydraulic quantities.
The DAS used for the directly acquired thermal-hydraulic quantity, records the data in a file with the extension "DTA". When the file reaches 256 bytes, the DAS automatically records the data in a new file with the extension "DTB" and so on in alphabetical order. The number of these files found in the data tapes depends only on the duration of the test.
The file name is composed of eight characters. The first three are "SLP" for LOCA simulation tests or "T" followed by the test number for all other tests. Then follow the letters "TH" and a progressive number.
Example: SLP07TH.DTA or T16TH06.DTA

e) *file of the derived thermal-hydraulic quantities*

This file contains all the derived thermal-hydraulic values of the test.
The file name is again composed as above except for the letters "EL" instead of "TH". The extension is "DAT".
Example: SLP07EL.DAT or T16EL06.DAT

f) *file of constants used for calculation of derived quantities*

This file contains the data reduction constants. The file name is the same as above except for the extension "CST". Example: SLP07EL.CST or T16EL06.CST

g) *file of configuration used in derived quantity calculations*

This file contains the enabled data reduction subroutines and their input and output channels.
The file name is the same as above except for the extension "CFG".
Example: SLP07EL.CFG or T16EL06.CFG

h) *files of fast acquired thermal-hydraulic quantities*

This is a group of files containing the values of selected quantities for which the sampling frequency requested is one sample per second. The first file of this group has the extension "DTA", the second "DTB" and so on as already explained in case d).
The file name is the same as in case d) except for the letters "TF" instead of "TH".
Example: SLP07TF.DTA or T16TF06.DTA

For shakedown tests, a standard method of naming data files was not yet adopted. For tests run before 2 August 1994, and specifically:

T43_2 , T09_1 , T09_6 , T09_7 , T09_8 , T42_1 , T41_1 , T40_1 , T39_1 , T23_1 , T23_2 , T23_3

The files type a) and h) of above do not exist because the storage of these files was not yet introduced.

All files are in ASCII format. The separator character is not the same for all files. Specifically:

"," for the files indicated above as a), b), d) f), g) and h);
";" for the files indicated above as c), and e).

The first 4 lines in the data files indicate, for each column, the measurement name, the measurement unit and the channel number. The measurement names in files type a), b), d) and h) are the plant codes. In files type c) and e), instead, the measurement names have the following meanings:

F-steam	Inlet steam flowrate (before de-superheating)
F-liq	De superheating water flowrate
F-cond	Outlet condensate flowrate
F-m	Pool make-up water flowrate
F-r	Pool water discharge flowrate
X-airout	Air quality at Vent Tank outlet
Tavg-pool	PCC pool water average temperature
Tavg-LCT	Condensate Tank average temperature

LCT-L2	Condensate Tank water level
Lvent-I1	Vent Tank level
Lvent-I2	Vent Tank level
Lcatch-O2	Catch Tank level
Lpool-Q1	IC pool water level
Lpool-Q2	IC pool water level
Lpool-P1	PCC pool water level
H-steam	Inlet steam specific enthalpy (before de-superheating)
H-air	Inlet air specific enthalpy
H-cond	Outlet condensate specific enthalpy
H-m	Pool make-up water specific enthalpy
H-r	Pool discharge water specific enthalpy
Ppvap-out	Vent Tank outlet steam partial pressure
Hsteam-out	Vent Tank outlet steam specific enthalpy
Hair-out	Vent Tank outlet air specific enthalpy
H-5	Condensate specific enthalpy at the PCC outlet section
Wsteam	Steam inlet power
Wair	Air inlet power
W-liq	De superheating water inlet power
W-cond	Condensate outlet power
W-out	Vent Tank outlet power
W-exc	Heat rejection rate
Fin-tot	Total inlet flowrate
Fout-tot	Total outlet flowrate
Fair-out	Vent Tank outlet air flowrate
Fsteam-out	Vent Tank outlet steam flowrate
Xair-in	Air quality at the PCC inlet section
Diff-Ftot	Total inlet-outlet flowrate difference in percentage
Diff Fair	Inlet-outlet air flowrate difference in percentage
P-4002	PCC inlet pressure
T-4002	PCC inlet temperature
Fsteam-true	Inlet steam flowrate + de-superheating water flowrate
T-surr	Inlet steam superheating (referred to steam partial pressure)
F-Hel	Inlet helium flowrate
F-Totgas	Inlet helium + air flowrate

In the case of data files for directly acquired thermal-hydraulic quantities and fast acquired quantities composed of more than one file (DTA, DTB and so on) only the file with extension "DTA" has this heading that is, though, valid also for all other files of the same group.
Data from shakedown tests C01 and C02 are available only as printouts.

Data from the following resistance thermometers were stored in the thermal-mechanical data files and therefore they are not included in the thermal-hydraulic data tapes:

T-P001, T-P002, T-P009, T-P015, T-P031, T-P037, T-P038, T-P048, T-P049, T-P050, T-P051, T-P052, T-P053.