

Design and Performance of Optimized Air-Cooled Condenser at Crockett Cogeneration Plant

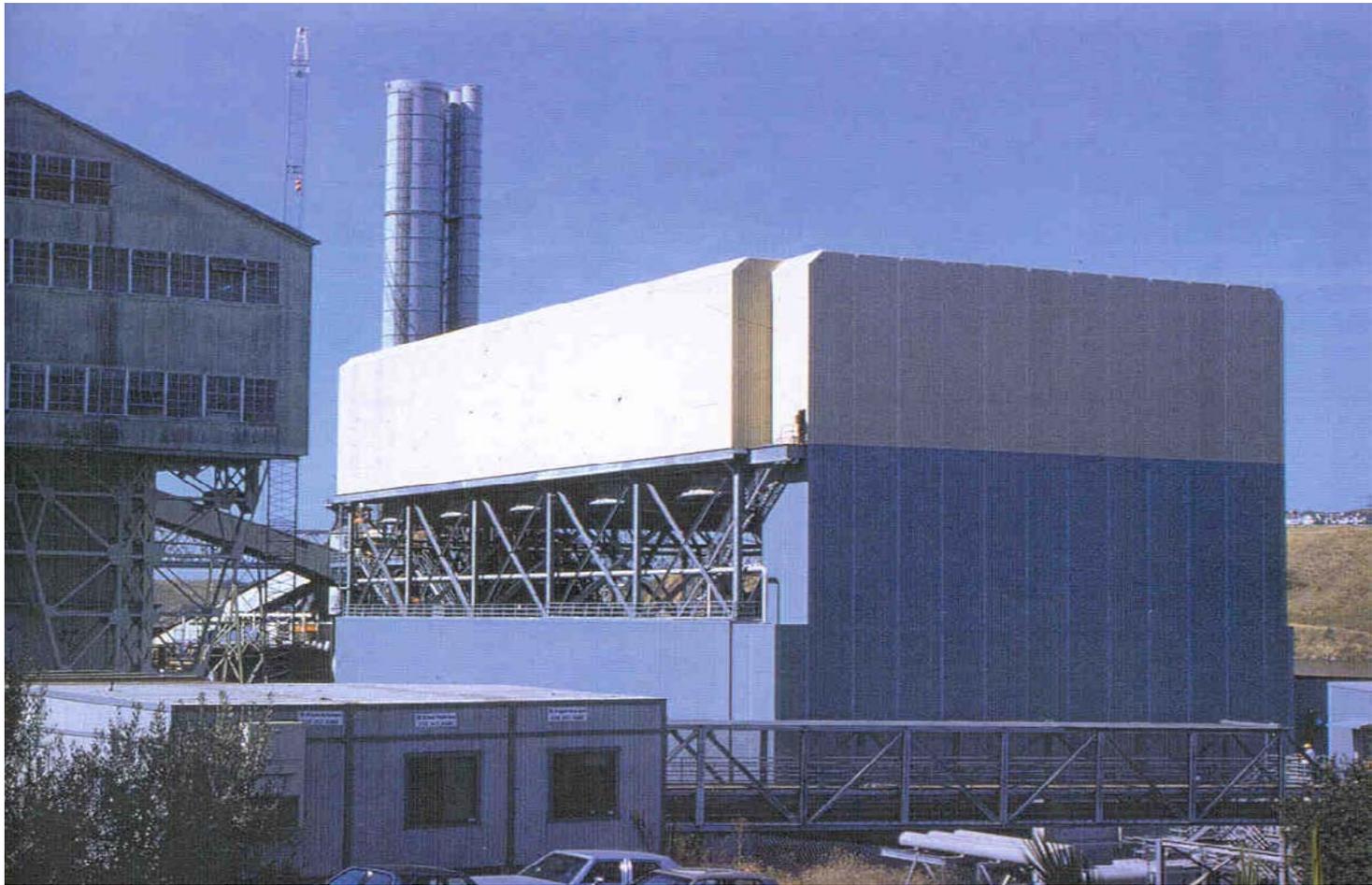
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Roofmounted ACC, 12 cells

Courtesy of Marley Cooling Technologies, Inc.



Ravenswood Cogen ACC

Courtesy of New York Department of Environmental Conservation



View of the Ravenswood Cogeneration Facility, facing Southwest

Plant Plot Restrictions

- 2.4 acre site (140' x 740')
- Water to the north & east
- Railroad to the south
- Sugar mill to the west
- No room for ACC, except on power plant roof
- Seismic zone 4



Plant Design and Performance Parameters

- Rated output of 240 MW at 96 °F
- Single GE Frame 7FA turbine
- Vogt heat recovery steam generator
- 260 MMBtu/hr duct burner system
- ~750,000 lb/hr HP steam maximum
- Local steam host (C&H Sugar) requires 260,000 lb/hr steam on average, varies from 70,000 to 400,000 lb/hr

ACC Design and Performance Parameters

- 12 ACC cells
- Overall ACC height of 70.5 feet
- 519 MMBtu/hr rating
- 3,350,385 ft² of heat transfer surface
- 150 hp two-speed fans (63/32.5 rpm)
- ACC fan diameter of 29 feet
- 3 additional ACC cells for auxiliary cooling

Thermal Design Parameters

	<u>Case A</u>	<u>Case B</u>	<u>Case G</u>
Air inlet temp., °F	85	65	96
Gross output, MW	262	248	248
Steam injection	on	off	on
Gas turbine, MW	175	158	172
Steam turbine, MW	87	69	79
Total steamflow, lb/h	733 k	510 k	688 k
ACC steamflow, lb/h	604 k	510 k	567 k
Backpressure, HgA	6.5	3.1	7.7

ACC Hot Day Performance

Hoteling load only at C&H Sugar of 70,000 lb/hr steam

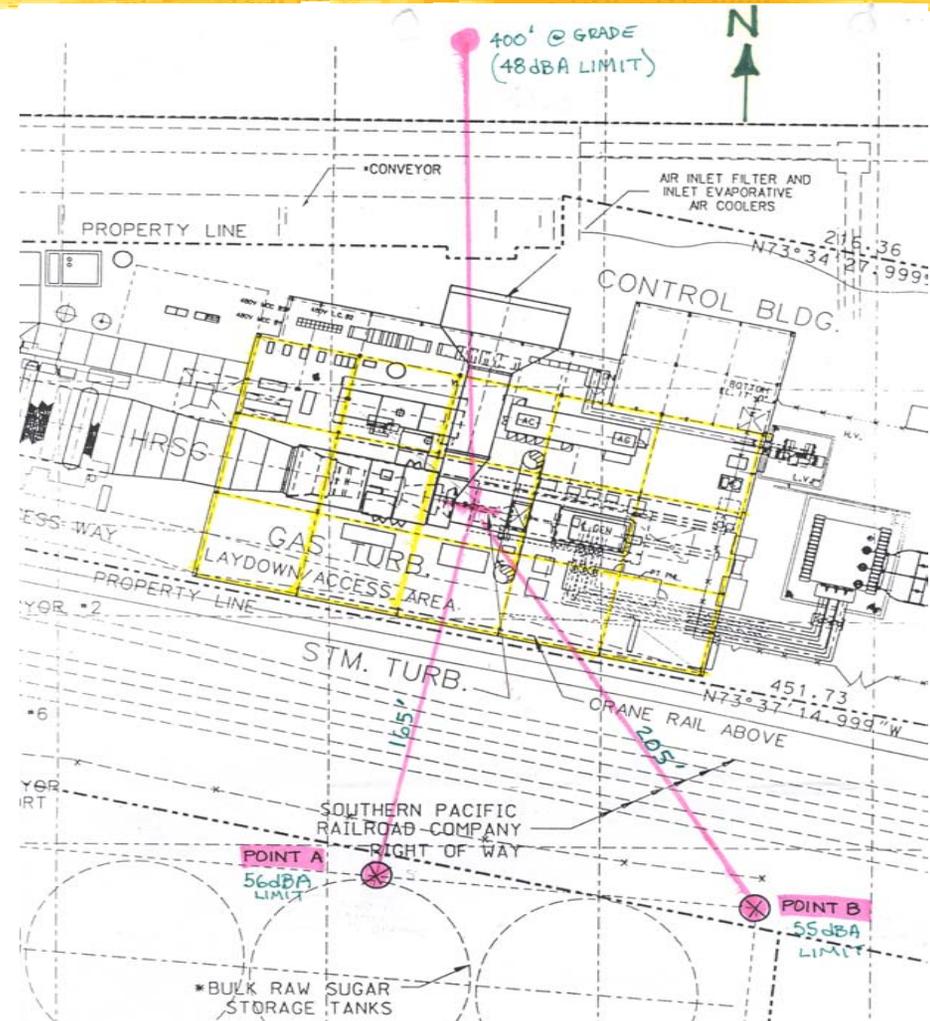
Date	Time	Temp., °F	kpph steam to ACC	" Hg vacuum
8/26/02	5:31 pm	89	670	8.0
8/26/02	6:41 pm	90	667	8.3
8/27/02	1:36 pm	81	676	7.0
8/27/02	4:26 pm	85	676	8.3
8/27/02	6:27 pm	87	656	7.5

ACC and Steam Cycle Output

- Crockett is fully dispatchable from 120 to 240 MW
- Allowed 16 hr/yr of forced outage w/o penalty, equal to $16 \text{ hr/yr} \times 240 \text{ MW} = 3,840 \text{ MW/yr}$
- Worst case conditions, 96 °F, dry heat, C&H Sugar in forced outage (0 lb/hr steam demand), occurred < 10 hr in 2002
- Crockett can be limited to 235 to 238 MW during worst case conditions (must reduce duct firing)
- Typical ACC MW-hr/yr penalty is $\leq 20 \text{ MW-hr/yr}$

ACC Noise Requirements

- Three noise receptors
- Most stringent - Point A, 56 dBA at 113 ft from edge of ACC



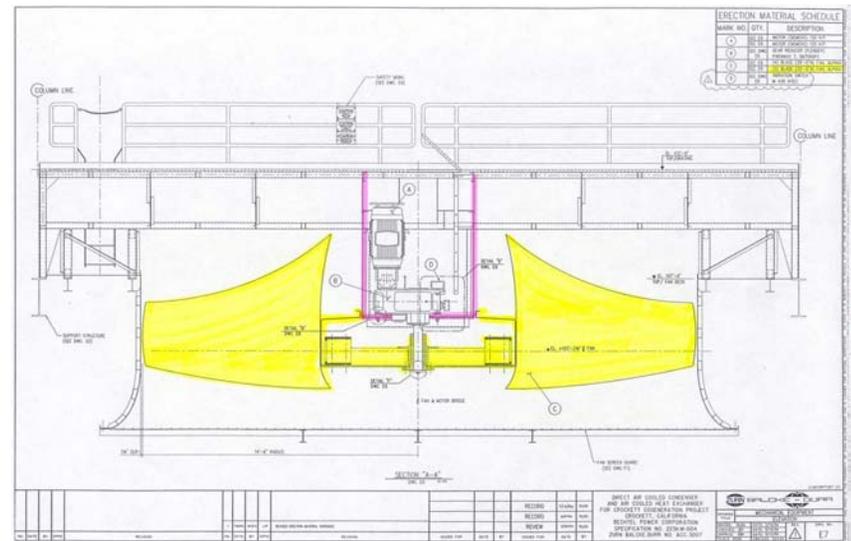
Noise Reduction Measures

Courtesy of Marley Cooling Technologies, Inc.

Ultra-low noise fans



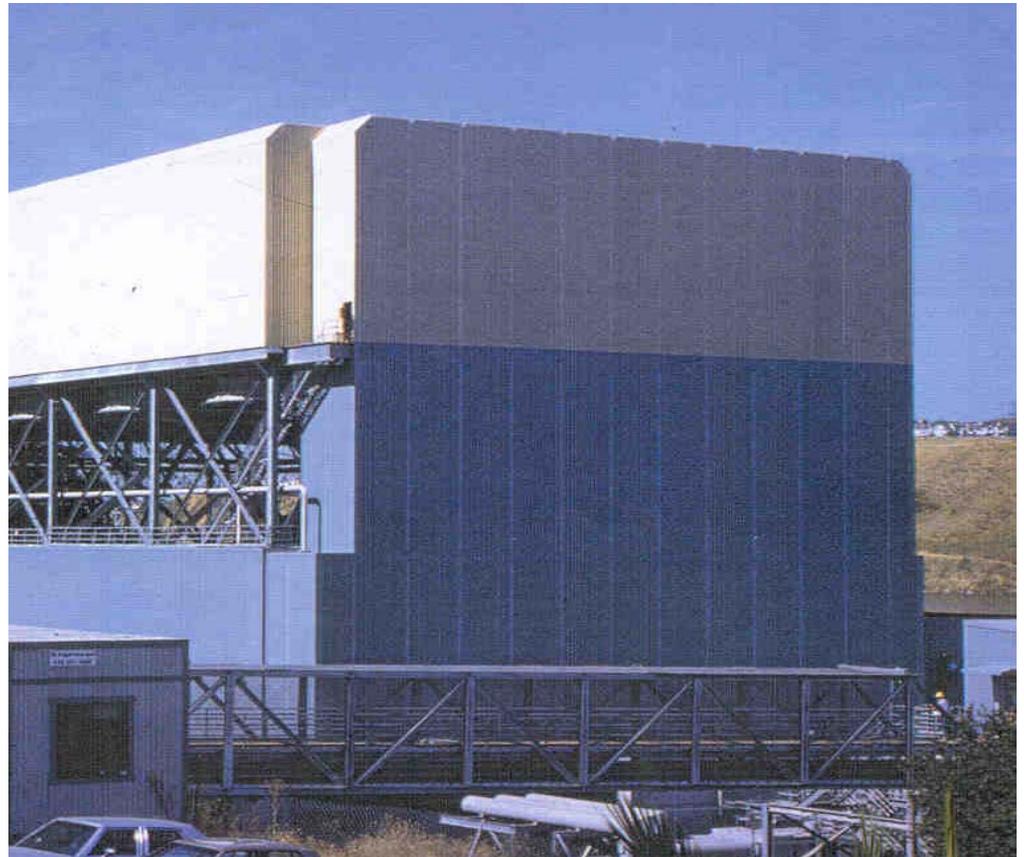
Gear motor enclosures



Noise Reduction Measures

Courtesy of Marley Cooling Technologies, Inc.

- Steam duct riser chase
- Acoustically insulated ducting to mitigate bypass operation noise
- Perimeter siding to top of steam header



ACC Height Minimization

- Economical minimum height in range of 70 to 75 feet (to top of ACC steam duct)
- By comparison, HRSG height often 90 to 100 feet
- Height minimization is important issue in populated areas
- Evaporative wet cooling alternative in populated areas is plume abatement wet tower
- Plume abatement tower height ~ 65 feet, plume height is 40 feet or less (humid days)

Plume Abatement Function

Courtesy of Marley Cooling Technologies, Inc.

- Two cells to right are operating in standard wet tower mode.
- Next two cells have damper 100% open (max. plume abate).
- Next three cells have dampers open 25%.



ACC Height Minimization

Courtesy of GEA Power Cooling Systems, Inc.

Samalayuca II 630 MW Combined Cycle Plant



ACC Operating Experience

- Crockett Cogen ACC has performed well over seven year operating history
- Relatively little maintenance has been required on ACC, ACC fans, or fan motors
- Periodic washdown of tube bundles necessary, due to insect buildup and condensation of sugar compounds on tubes
- Inleakage of ambient air at north ACC takeoff duct interface with steam turbine has been ongoing minor maintenance issue

ACC Heat Rate Penalty

- Facility considers heat rate data proprietary
- 2.0 - 2.5 "Hg backpressure at average annual daytime temperature of 65 °F and typical C&H Sugar steam load of 260 kpph
- Once-through system typically 1.5 -2.0 "Hg
- Annual thermal efficiency penalty of ACC estimated at 1 percent or less, little difference in heat rate under average operating conditions

Crockett ACC Cost

- \$8MM to \$8.5MM equipment cost for 15 ACC cells with ultra-low noise, 29-foot fans
- Steam turbine ~\$1MM less expensive
- ACC manufacturer not responsible for installation at Crockett - install costs higher than typical due to rooftop location
- Estimated ACC installation costs (by Marley) for hypothetical greenfield, groundlevel location: \$3.8MM non-union, \$4.5MM union

Transferability of Crockett Experience to Larger Combined-Cycle Plants

- 170 MW GE Frame 7FA or equivalent is basic building block of all utility scale combined-cycle plants
- ACC noise optimization features readily transferrable
- ACC height optimization to 70 - 75 feet readily transferable (Otay Mesa example)

Transferability of Crockett Experience to Larger Combined-Cycle Plants

- Groundlevel installation necessary to take full advantage of optimized height and to minimize “visual bulk.”
- ACC sized to avoid any significant MW derate under “hottest hour” conditions
- ACC sized to minimize heat rate penalty, estimated at $\leq 1\%$ for Crockett (assuming average steamflow of 260 kpph to C&H)