U.S. capacity factors: Leveled off at last

BY E. MICHAEL BLAKE

The three-year DER net capacity factor over the entire industry was essentially the same in 2003–2005 as it was in 2000–2002. This ends two decades of continuously rising factors.

UNDER THE STRICTEST interpretation of the numerical indicators *Nuclear News* uses to assess capacity factors, the nation's fleet of 104 power reactors did, in fact, perform better in the three-year period of 2003–2005 than they did in 2000–2002. The median design electrical rating (DER) net capacity factor rose from 89.58 percent to 89.60 percent, and the average factor rose from 87.88 percent to 88.04 percent. But it seems safe to state that relative rises of 0.02 and 0.18 percent, respectively, should be considered statistically insignificant. This appears to mean that the dramatic improvement in performance throughout the nuclear industry over more than two decades has leveled off, and that the success of future plant operations should be judged in terms of maintaining the high standard that has been achieved.

To the extent that further improvement could be attained, it might lie in greater consistency among the reactors that are listed toward the bottom in Table I, so this year's capacity factor analysis takes a closer look at the top and bottom quartiles to see (especially with the bottom quartile) whether there continue to be gains by reactors that have routinely lagged behind. (The top quartile is the point above which one quarter of the reactors have higher factors; the bottom quartile is the point below which one quarter of the reactors have lower factors.) In the last few three-year periods, there had been substantial improvement in the bottom quartile, but in 2003–2005, this too appears to have leveled off. After rising more than nine points between 1997–1999 and 2000–2002 (from 76.40 percent to 85.86 percent), the bottom quartile in 2003–2005 slid backward very slightly, to 85.82.

Neither reactor type shows a clear advantage over the other. After lagging several points behind for essentially the entire history of nuclear power in the United States, boiling water reactors caught up with pressurized water reactors at the start of the millennium, and even moved ahead slightly, but now that small gap has gotten smaller. The median BWR factor in 2003–2005 was 90.14, down slightly from 90.40 in 2000–2002, while the PWR median rose about the same amount, to 89.55 in 2003–2005 from 89.23 in 2000–2002. The

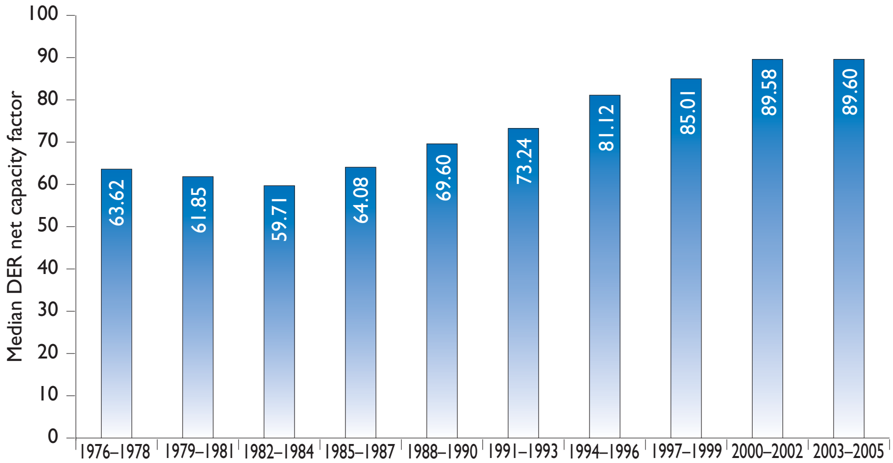

Fig. 1: All reactors. The rising trend that led to a 30-point improvement in two decades appears to have ended, with the 2003–2005 median essentially a repeat of that in 2000–2002. The chart shows only reactors that are still in service now. In 1976–1978 there were 40 such reactors, and in each succeeding period there were 52, 59, 70, 91, 102, 103, and 104 in each of the last three. If closed reactors were included to show the median factor for the industry as it was for each period, the medians in the first seven periods would be 63.39 percent (51 reactors), 60.60 (63), 59.51 (71), 63.62 (81), 69.02 (100), 72.44 (108), and 80.64 (109). None of these medians differs by more than one and a quarter percentage points from the medians shown above.

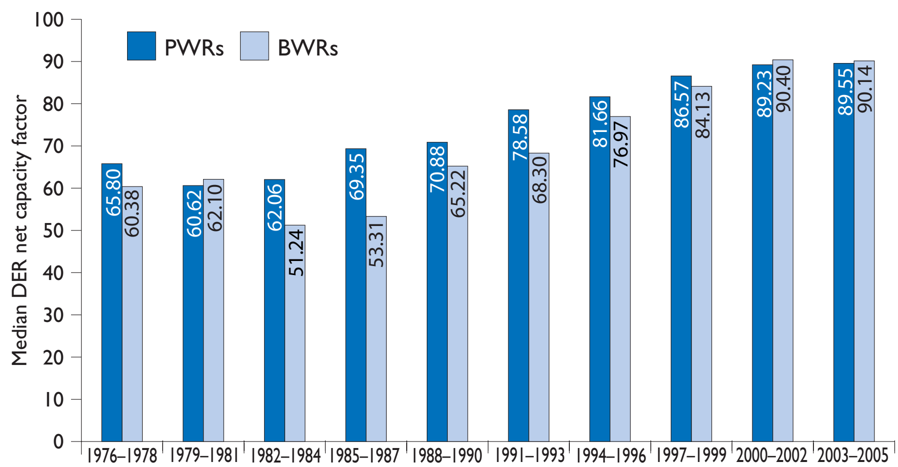

Fig. 2: Reactors by type. The boiling water reactor median trailed that of pressurized water reactors for nearly the entire history of the industry, but in 2000–2002, BWRs pulled ahead slightly. BWRs stayed ahead in 2003–2005, but the gap is even smaller. Only reactors still in service today are shown; if closed plants were included, the trends would look about the same, with all medians within two points of the medians shown above.

TABLE I.
2003–2005 DER NET CAPACITY FACTORS OF INDIVIDUAL REACTORS

Rank	Reactor	Factor[1]	Design Electrical Rating (DER), MWe[2]	Type	Operator[3]
1.	ANO-2	102.18	912	PWR	Entergy
2.	Calvert Cliffs-1	99.58	845	PWR	Constellation
3.	Ginna	98.47	470	PWR	Constellation
4.	Braidwood-2	97.60	1155	PWR	Exelon
5.	Byron-2	96.91	1155	PWR	Exelon
6.	Braidwood-1	96.66	1187	PWR	Exelon
7.	Byron-1	95.54	1187	PWR	Exelon
8.	FitzPatrick	95.39	816	BWR	Entergy
9.	Grand Gulf	94.94	1250	BWR	Entergy
10.	San Onofre-2	94.91	1070	PWR	SCE
11.	Seabrook	94.41	1220	PWR	FPL
12.	Limerick-1	94.24	1191	BWR	Exelon
13.	LaSalle-1	94.23	1154	BWR	Exelon
14.	Three Mile Island-1	93.92	819	PWR	AmerGen
15.	Indian Point-3	93.84	1034	PWR	Entergy
16.	Beaver Valley-2	93.82	836	PWR	FENOC
17.	Catawba-2	93.81	1145	PWR	Duke
18.	Calvert Cliffs-2	93.69	845	PWR	Constellation
19.	Nine Mile Point-2	93.68	1143.3	BWR	Constellation
20.	Indian Point-2	93.65	1035	PWR	Entergy
21.	Vogtle-1	93.64	1169	PWR	Southern
22.	Peach Bottom-3	93.18	1138	BWR	Exelon
23.	Peach Bottom-2	92.66	1138	BWR	Exelon
24.	Surry-2	92.40	788	PWR	Dominion
25.	North Anna-1	92.34	907	PWR	Dominion
26.	Browns Ferry-3	92.26	1120	BWR	TVA
27.	Comanche Peak-1	92.11	1150	PWR	TXU
28.	North Anna-2	91.98	907	PWR	Dominion
29.	Browns Ferry-2	91.50	1120	BWR	TVA
30.	Millstone-3	91.39	1156.5	PWR	Dominion
31.	St. Lucie-1	91.23	830	PWR	FPL
32.	Brunswick-1	91.21	972	BWR	Progress
33.	Hatch-1	91.05	885	BWR	Southern
34.	Farley-1	90.97	854	PWR	Southern
35.	Clinton	90.89	1062	BWR	AmerGen
36.	Farley-2	90.89	855	PWR	Southern
37.	Limerick-2	90.86	1191	BWR	Exelon
38.	Beaver Valley-1	90.85	835	PWR	FENOC
39.	LaSalle-2	90.76	1154	BWR	Exelon
40.	Comanche Peak-2	90.54	1150	PWR	TXU
41.	Oyster Creek	90.53	650	BWR	AmerGen
42.	Wolf Creek	90.51	1170	PWR	WCNOC
43.	Prairie Island-2	90.43	536	PWR	NMC
44.	Pilgrim	90.43	690	BWR	Entergy
45.	Vermont Yankee	90.37	522	BWR	Entergy
46.	Prairie Island-1	90.20	536	PWR	NMC
47.	Summer	90.15	972.7	PWR	SCE&G
48.	River Bend	90.14	966	BWR	Entergy
49.	Catawba-1	89.87	1145	PWR	Duke
50.	Surry-1	89.85	788	PWR	Dominion
51.	Waterford-3	89.78	1104	PWR	Entergy
52.	Watts Bar-1	89.60	1155	PWR	TVA
53.	Dresden-3	89.60	867	BWR	Exelon
54.	Crystal River-3	89.55	860	PWR	Progress
55.	Harris	89.53	941.7	PWR	Progress
56.	Vogtle-2	89.43	1169	PWR	Southern
57.	Monticello	89.35	600	BWR	NMC
58.	Susquehanna-2	89.34	1182	BWR	PPL
59.	Robinson-2	89.21	765	PWR	Progress
60.	Hatch-2	89.19	908	BWR	Southern
61.	Millstone-2	88.92	883.5	PWR	Dominion
62.	McGuire-2	88.82	1180	PWR	Duke
63.	Susquehanna-1	88.73	1177	BWR	PPL
64.	South Texas-2	88.65	1250.6	PWR	STPNOC
65.	Quad Cities-2	88.54	867	BWR	Exelon
66.	Brunswick-2	88.22	935	BWR	Progress
67.	San Onofre-3	88.18	1080	PWR	SCE
68.	Arnold	87.94	593.8	BWR	NMC
69.	Sequoyah-1	87.55	1160	PWR	TVA
70.	Sequoyah-2	87.48	1160	PWR	TVA
71.	Cook-1	87.43	1020	PWR	IMP
72.	McGuire-1	87.37	1180	PWR	Duke
73.	St. Lucie-2	86.81	830	PWR	FPL
74.	Salem-2	86.66	1131	PWR	PSEG
75.	Diablo Canyon-1	86.66	1103	PWR	PG&E
76.	ANO-1	86.61	850	PWR	Entergy
77.	Nine Mile Point-1	86.45	613	BWR	Constellation
78.	Quad Cities-1	85.92	867	BWR	Exelon
79.	Palisades	85.72	805	PWR	NMC
80.	Diablo Canyon-2	85.56	1119	PWR	PG&E
81.	Oconee-2	85.46	886	PWR	Duke
82.	Cook-2	85.33	1090	PWR	IMP
83.	Salem-1	85.06	1193	PWR	PSEG
84.	South Texas-1	84.70	1250.6	PWR	STPNOC
85.	Point Beach-1	84.67	522	PWR	NMC
86.	Turkey Point-3	84.37	720	PWR	FPL
87.	Dresden-2	84.20	867	BWR	Exelon
88.	Turkey Point-4	83.86	720	PWR	FPL
89.	Fermi-2	83.80	1150	BWR	Detroit
90.	Fort Calhoun	83.52	478	PWR	OPPD
91.	Oconee-3	82.81	886	PWR	Duke
92.	Callaway	82.77	1228	PWR	AmerenUE
93.	Palo Verde-2	82.62	1336	PWR	APS
94.	Point Beach-2	82.56	522	PWR	NMC
95.	Oconee-1	82.53	886	PWR	Duke
96.	Columbia	81.90	1153	BWR	Northwest
97.	Palo Verde-1	81.25	1265	PWR	APS
98.	Cooper	80.90	778	BWR	NPPD
99.	Palo Verde-3	80.71	1269	PWR	APS
100.	Perry	79.80	1260	BWR	FENOC
101.	Kewaunee	75.21	574	PWR	Dominion
102.	Hope Creek	73.70	1083	BWR	PSEG
103.	Davis-Besse	54.36	906	PWR	FENOC
104.	Browns Ferry-1	0.00	1065	BWR	TVA

[1] These figures are rounded off. There are no ties. Clinton is in 35th place with a factor of 90.8896, and Farley-2 is in 36th with 90.8888.

[2] The rating shown is effective as of December 31, 2005. If the reactor's rating has changed during the three-year period, the capacity factor is computed with appropriate weighting.

[3] As of December 31, 2005. In most cases this also means the reactor's owner, but the plants listed for NMC are operated, but not owned, by Nuclear Management Company, LLC (NMC). Entergy is the contracted operator of Cooper, and Exelon is in the same role at Hope Creek/Salem, but because their decision-making power is not as extensive as NMC's, these plants are listed under Nebraska Public Power District and PSEG Nuclear, respectively.

average factors showed similar movement, with the PWR average rising from 88.21 to 88.94, and the BWR factor declining from 87.21 to 86.27. (The BWR average is dragged down by the inclusion of the long-dormant Browns Ferry-1, which is scheduled for restart next year; without Browns Ferry-1, the BWR average was 90.11 in 2000–2002 and 89.05 in 2003–2005.)

Not only will power reactors be expected to remain at their current performance level, but many of them will be called upon to do so with higher rated power than established in their original baseline design, and for more years than the design anticipated. Results, in many cases preliminary, are already available on how some reactors have adjusted to substantial power uprates, and a modest effort to analyze these data is made later in this article. The real effects of license renewal, however, will not be known for several more years. No power reactor in the United States has yet operated into the renewal regime, beyond 40 years, and despite all of the focus on aging management by licensees and the Nuclear Regulatory Commission, the effects of operation into a fifth and sixth decade—especially at around 90 percent capacity the whole time—cannot be predicted clearly this far in advance.

We usually caution readers against putting too much emphasis on the precise numbers shown here, both for the fleet as a

TABLE II.
CAPACITY FACTOR CHANGE, 2000–2002 TO 2003–2005

Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)
1.	Indian Point-2	+30.56	27.	Clinton	+1.92	53.	Peach Bottom-3	-1.03	79.	Susquehanna-2	-3.43
2.	Cook-1	+29.00	28.	Ginna	+1.86	54.	Calvert Cliffs-2	-1.12	80.	Sequoyah-2	-3.57
3.	Palisades	+17.37	29.	Peach Bottom-2	+1.84	55.	Byron-2	-1.16	81.	Oconee-2	-3.76
4.	Calvert Cliffs-1	+16.12	30.	Catawba-2	+1.74	56.	LaSalle-2	-1.22	82.	Callaway	-4.12
5.	Cook-2	+14.04	31.	Grand Gulf	+1.63	57.	Braidwood-1	-1.30	83.	Catawba-1	-4.37
6.	ANO-2	+13.87	32.	Braidwood-2	+1.58	58.	Byron-1	-1.57	84.	Limerick-2	-4.82
7.	North Anna-2	+10.23	33.	Cooper	+1.44	59.	Watts Bar-1	-1.71	85.	Perry	-4.83
8.	Summer	+10.02	34.	Prairie Island-1	+1.17	60.	Indian Point-3	-1.94	86.	River Bend	-4.86
9.	Three Mile Island-1	+9.69	35.	McGuire-2	+1.04	61.	Wolf Creek	-1.96	87.	Surry-1	-4.90
10.	Nine Mile Point-2	+9.62	36.	Hatch-1	+0.96	62.	North Anna-1	-1.96	88.	Robinson-2	-5.06
11.	Seabrook	+8.61	37.	Limerick-1	+0.95	63.	Vermont Yankee	-1.99	89.	Point Beach-2	-5.08
12.	Oyster Creek	+7.68	38.	Brunswick-1	+0.80	64.	Hatch-2	-2.10	90.	St. Lucie-1	-5.61
13.	Farley-1	+7.22	39.	San Onofre-3	+0.67	65.	McGuire-1	-2.13	91.	Fort Calhoun	-5.80
14.	Comanche Peak-1	+6.65	40.	San Onofre-2	+0.66	66.	ANO-1	-2.19	92.	South Texas-1	-5.88
15.	Monticello	+6.12	41.	Susquehanna-1	+0.48	67.	Vogtle-2	-2.33	93.	Palo Verde-2	-6.42
16.	Harris	+6.10	42.	Prairie Island-2	+0.03	68.	Brunswick-2	-2.43	94.	Diablo Canyon-2	-6.62
17.	Beaver Valley-1	+4.96	43.	Browns Ferry-1	0.00	69.	Salem-2	-2.47	95.	Crystal River-3	-7.28
18.	Oconee-3	+4.49	44.	Dresden-3	-0.07	70.	Point Beach-1	-2.53	96.	Turkey Point-3	-7.64
19.	Farley-2	+3.77	45.	Nine Mile Point-1	-0.16	71.	Waterford-3	-2.73	97.	Kewaunee	-8.14
20.	FitzPatrick	+3.56	46.	Browns Ferry-2	-0.35	72.	Pilgrim	-2.77	98.	Turkey Point-4	-8.81
21.	Beaver Valley-2	+2.77	47.	LaSalle-1	-0.42	73.	Oconee-1	-2.77	99.	St. Lucie-2	-9.09
22.	Vogtle-1	+2.65	48.	Comanche Peak-2	-0.50	74.	Surry-2	-3.05	100.	Palo Verde-1	-9.60
23.	Millstone-2	+2.59	49.	Quad Cities-2	-0.66	75.	Fermi-2	-3.12	101.	Davis-Besse	-10.28
24.	South Texas-2	+2.57	50.	Sequoyah-1	-0.67	76.	Columbia	-3.29	102.	Dresden-2	-10.85
25.	Millstone-3	+2.27	51.	Arnold	-0.67	77.	Browns Ferry-3	-3.32	103.	Hope Creek	-11.85
26.	Diablo Canyon-1	+2.03	52.	Salem-1	-0.76	78.	Quad Cities-1	-3.40	104.	Palo Verde-3	-11.90

whole and for individual reactors. This year, we want to emphasize this point, because Table II should not be taken as a cause for panic. Yes, for the first time since the aftermath of Three Mile Island-2 in the early 1980s, more reactors had lower factors in 2003–2005, compared with 2000–2002, than had higher factors. To be precise, 42 reactors gained, and 61 declined. But 71 of the reactors' gains or losses were five percentage points or less—which, over three years, might simply be in the range of ordinary fluctuation—and beyond five points, 16 reactors improved and 17 fell back. By the Table II criterion alone, both Byron reactors were "losers," but their factors are still greater than 95 percent, and they placed fifth and seventh in Table I. If, three years from now, there continue to be significantly more losers than gainers, there may be some cause for concern, but only because it could indicate that the current high level of overall performance might be too difficult to maintain.

Bringing up the rear

As has been noted before in this annual series of surveys, the most remarkable development in the U.S. power reactor community in the past quarter century is not that some reactors have managed to get their three-year capacity factors above 90 percent (which no reactor had done until the early 1990s), but that every one of the operating reactors has improved to the point where a factor well over 80 percent is expected. When these reactors were being planned and built, utilities would routinely make their case to state-level rate-making commissions for the recovery of plant costs in electricity rates by basing the reactor's performance on a capacity factor of about 65 percent. For much of the industry's history, before and after the Three Mile Island-2 accident, good performance by a growing percentage of the operating reactors was offset by a clutch of 10 to 20 poor performers, many of them chronic underachievers. Yet now, if one assumes continued steady output from Davis-Besse and a productive return by Browns Ferry-1, it appears that there no longer is a reactor underclass.

If further improvement is possible in the reactor fleet, it seems reasonable that it will be among the reactors that now have factors a few percentage points on either side of 80, simply because they can make gains more readily than a reactor with a 95 factor can. A look at the trend for the bottom quartile in Fig. 3 shows dramatic improvement during the 1990s, and—as with the entire sample of reactors—essentially no change since then. The top quartile has been fairly close to level over the last three three-year periods.

Even if one looks at what could uncharitably be thought of as the worst of the worst—the bottom decile, with only 10 percent of the reactors having a lower figure—the indication is still that there has been no significant overall change in the most recent three-year period. Cutting the data into

The data, and what was done to them

Each year *NN* presents an analysis of U.S. power reactor capacity factors, within limits. The raw data—each reactor's annual electricity output and its design electrical rating (DER)—are provided to us by Tom Smith at Idaho National Laboratory (thanks, as always, Tom). The Nuclear Regulatory Commission now gives licensees the option of not submitting monthly operating reports, so a great deal of data is no longer available on the ADAMS document retrieval system at the NRC Web site, <www.nrc.gov>, but the data are still sent to INL, and because they are public documentation, Tom makes them available to us.

The author then computes three-year capacity factors for each reactor in the belief that this time frame shows sustained performance and helps to even out fueling cycles of different lengths. The historical material shown in the figures includes only reactors that were in service in those earlier time periods and are still in service today. The potential for discrepancies between three-year periods is declining because no reactors have started up since 1996, and none have closed since 1998.

DER has been chosen for each reactor's generating capacity in the belief that it provides the best indication of what a reactor was intended to accomplish. As noted in the text, even DER can be of dubious value if it is not adjusted to reflect a power uprate, but an attempt has been made to counteract any misleading results.—*E.M.B.*

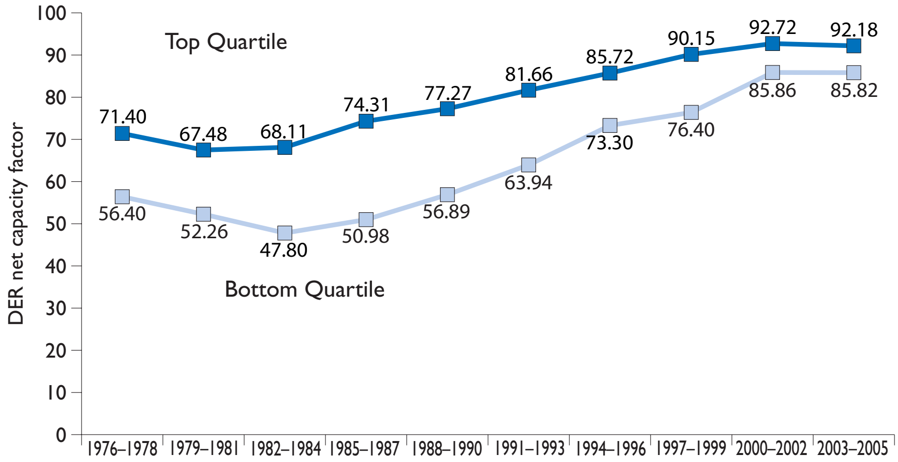

Fig. 3: All reactors, top and bottom quartiles. Both of the curves above have about the same shape as the movement of the median, indicating that the median has been fairly representative of how the industry as a whole has performed. The top and bottom quartiles are essentially unchanged from 2000–2002 to 2003–2005, as the median was. The separation between the top and bottom quartiles during these periods—six to seven points—is smaller than at any period before then, showing that the majority of reactors now perform at roughly the same level.

deciles may not be statistically justifiable, so there are no charts or tables given here on that kind of analysis. In summary, the bottom decile was in the 30s and 40s until about 1990, and in the 50s through the 1990s, and then leaped to 82.85 in 2000–2002. Since then, it has essentially held steady, with 82.55 in 2003–2005.

It should be remembered that trends such as these do not necessarily apply to any *specific* reactor, even to reactors that have been in the bottom quartile (or decile) for much or most of their operating career. Clearly there has been an industry-wide awareness that in the court of public perception, nuclear power is only as strong as its weakest link, and developments such as utility mergers and reactor sales tend to foster adherence to best practices. The numbers suggest that the optimization of basic reactor performance, fleet-wide, was completed around the turn of the millennium, and steady-state operation has been under way since then.

The results of uprates

Any long-term study of capacity factors must eventually confront power uprates, and there are at least two ways to approach this. Perhaps the most useful way, for the immediate concerns of reactor operation, is to compare the factors, before and after the necessary plant modifications, of the most recently uprated reactors, and this article

TABLE III.
DER NET CAPACITY FACTOR OF MULTI-REACTOR SITES[1]

Rank	Site	Factor	Operator	Rank	Site	Factor	Operator
1.	Braidwood	97.12	Exelon	19.	Prairie Island	90.31	NMC
2.	Calvert Cliffs	96.63	Constellation	20.	Hatch	90.11	Southern
3.	Byron	96.22	Exelon	21.	Brunswick	89.72	Progress
4.	ANO	94.67	Entergy	22.	Susquehanna	89.04	PPL
5.	Indian Point	93.74	Entergy	23.	St. Lucie	89.02	FPL
6.	Peach Bottom	92.92	Exelon	24.	McGuire	88.09	Duke
7.	Limerick	92.55	Exelon	25.	Sequoyah	87.51	TVA
8.	LaSalle	92.49	Exelon	26.	Quad Cities	87.23	Exelon
9.	Beaver Valley	92.34	FENOC	27.	Dresden	86.90	Exelon
10.	North Anna	92.16	Dominion	28.	South Texas	86.68	STPNOC
11.	Catawba	91.84	Duke	29.	Cook	86.35	IMP
12.	Vogtle	91.53	Southern	30.	Diablo Canyon	86.11	PG&E
13.	San Onofre	91.53	SCE	31.	Turkey Point	84.12	FPL
14.	Comanche Peak	91.32	TXU	32.	Point Beach	83.61	NMC
15.	Nine Mile Point	91.15	Constellation	33.	Oconee	83.60	Duke
16.	Surry	91.12	Dominion	34.	Hope Creek/Salem	81.95	PSEG
17.	Farley	90.93	Southern	35.	Palo Verde	81.54	APS
18.	Millstone	90.32	Dominion	36.	Browns Ferry	62.28	TVA

[1] Because Nine Mile Point and FitzPatrick have different owners, Nine Mile Point is listed here as a multi-reactor site, but FitzPatrick is not included, even though the plants are on adjacent properties; if taken together, Nine Mile Point and FitzPatrick would have a combined 2003–2005 factor of 92.50. Hope Creek and Salem are treated as a single site because they are adjacent and have the same owner; the two-unit Salem had a 2003–2005 factor of 85.85. The figure given for Browns Ferry is for all three reactors, although Unit 1 has been out of service since 1985; the 2003–2005 factor for Units 2 and 3 only is 91.88.

will mainly explore that approach. Due diligence, however, suggests another way, which might offer a clearer perspective on the statistics of some plants that have been uprated physically but whose rated output does not reflect this.

The NRC has approved 108 uprates throughout the agency's history. The first two went to Calvert Cliffs-1 and -2 in 1977. The thermal power of each reactor was raised 5.5 percent, from 2560 MWt to 2700 MWt. No change was made, however, to the design electrical rating (DER), which remains at 845 MWe for each reactor. An increase of 5.5 percent would bring each DER net up to 890 MWe, but because each net turbine nameplate rating remained 918 MWe, the plant may not have been fully optimized for sustained output of 890 MWe.

TABLE IV.
DER NET CAPACITY FACTORS OF OWNERS OR OPERATORS OF MORE THAN ONE SITE[1]

Rank	Owner/Operator	Factor
1.	Constellation Energy	93.84
2.	Entergy Nuclear (all divisions)	92.93
3.	Exelon (including AmerGen)	92.49
4.	Dominion Energy	91.17
5.	Southern Nuclear Operating	90.92
6.	Progress Energy	89.56
7.	FPL Energy	88.83
8.	Duke Power	87.63
9.	Nuclear Management Co.	87.23
10.	FirstEnergy Nuclear Operating	79.25
11.	Tennessee Valley Authority	75.56

[1] The factors for some smaller divisions of the organizations listed above are as follows: Entergy Northeast (including Vermont Yankee), 93.07; Entergy South, 92.81; Exelon without AmerGen, 92.61; AmerGen, 91.78; TVA without Browns Ferry-1, 89.65. Entergy's contract operation of Cooper is not included here.

Even so, another three-loop Combustion Engineering PWR—Millstone-2—went through roughly the same uprate in 1979, also raising its thermal output from 2560 MWt to 2700 MWt. The turbine nameplate was, and remained, 909 MWe, slightly lower than that at Calvert Cliffs, but the reactor's owner at the time, Northeast Utilities, raised its DER from 828 MWe to 870 MWe, where it remained until a recent revision to 883.5 MWe, with the thermal output remaining at 2700 MWt. In the 1980s, two more C-E three-loop PWRs—St. Lucie-1 and -2—followed suit, again going from 2560 MWt to 2700 MWt, but with smaller DER boosts (to 830 MWe, from 802 and 804 MWe) because of less powerful turbines. It should be noted that this is still lower than what Calvert Cliffs has claimed as its rating all along, although Millstone-2 shows that the Calvert Cliffs turbines could provide greater overall capability than St. Lucie's.

Because of this, we are presenting Table IA, which provides alternative factors for those reactors that have not reflected power uprates in their DERs (and therefore may have higher rankings in Table I than they actually deserve), and where they would rank in Table I if the alternate factors were used. The purpose of this is to further encourage licensees to make their generation statistics more accurate and meaningful, and for that reason it does not include reactors that kept their DERs low for many years but have recently revised them appropriately (namely Robinson-2 in 2003 and Callaway in 2005). It also excludes Waterford-3, approved in April 2005 for an 8 percent uprate, for which the necessary modifications may not have been completed in time to affect its 2003–2005 factor significantly. Still, a new DER would be appropriate for this reactor some time this year.

TABLE IA.
ALTERNATE CAPACITY FACTORS OF UPRATED REACTORS WITHOUT DER CHANGES

Reactor	Alternate Factor	Table I Factor	Alternate Rank	Table I Rank
ANO-2	95.05	102.18	6	1
Calvert Cliffs-1	94.39	99.58	10	2
FitzPatrick	91.72	95.39	24	8
Calvert Cliffs-2	88.81	93.69	57	18
North Anna-1	88.62	92.34	60	25
Surry-2	88.59	92.40	61	24
North Anna-2	88.27	91.98	63	28
Wolf Creek	86.61	90.51	75	42
Surry-1	86.15	89.85	77	50

This article will not dwell on Table IA, and will move on after two brief observations. First, five percentage points can make a vast difference in placement, especially for Calvert Cliffs-2, which would move from above the top quartile to below the median. Second, rankings for individual reactors in Table I are considered by the author to be largely unimportant. The goal in performance is to deliver the largest reasonably achievable amount of electricity, safely and economically, under each reactor's own unique circumstances.

For the detailed examination of the effects, if any, that power uprates have on capacity factors, we will omit the small "memory uncertainty recapture" uprates and will focus on relatively recent uprates. The first extended power uprate (essentially more than a 6 percent increase in thermal power) was approved in 1998, and these large uprates are of great interest to licensees, but to provide a broader data base, we will include both extended and stretch uprates approved from the start of 1998 until mid-2002 (uprates approved after that time have not been in effect for three full years). This covers 26 uprated reactors. Because the goal is to compare otherwise equal performance conditions before and after an uprate, three of them, Browns Ferry-3 and LaSalle-1 and -2, have been excluded because they were returning from extremely long outages, making the pre- and post-uprate performances incompatible.

For the remaining 23 reactors, we have compared the three-year capacity factors before and after the year in which the uprate was approved. To get a sense of how the uprated reactor did in the overall in-

TABLE V.
CAPACITY FACTOR CHANGE OF UPRATED REACTORS

Reactor	Before Uprate	After Uprate	Change	Relation to Median Change
ANO-2	80.91	95.05	+14.16	+13.04
Clinton	79.34	90.89	+11.55	+10.33
River Bend	82.77	95.28	+12.51	+7.77
Harris	82.22	89.53	+7.31	+6.09
Byron-1	88.21	96.30	+8.09	+5.96
Braidwood-1	90.95	97.73	+6.78	+4.65
Arnold	84.36	87.94	+3.58	+2.46
Brunswick-2	86.34	88.22	+1.88	+0.66
Byron-2	94.27	96.97	+2.70	+0.57
Braidwood-2	95.85	97.37	+1.52	-0.61
Hatch-2	86.66	90.99	+4.33	-1.00
Brunswick-1	92.29	91.21	-1.08	-2.30
Dresden-3	90.71	89.60	-1.11	-2.33
Diablo Canyon-1	88.93	90.25	+1.32	-3.38
Hatch-1	86.28	88.16	+1.88	-3.45
Quad Cities-2	91.99	88.54	-3.45	-4.67
Farley-1	83.92	83.84	-0.08	-5.41
Browns Ferry-2	91.44	91.23	-0.21	-5.94
Farley-2	83.05	82.25	-0.80	-6.13
Quad Cities-1	92.59	85.92	-6.67	-7.89
Dresden-2	91.71	84.20	-7.51	-8.73
Monticello	85.08	80.91	-4.17	-9.50
Perry	87.75	79.34	-8.41	-13.15

dustry context, we compared each reactor's performance change with the change in the median capacity factor over the same periods by subtracting the percentage-point increase in the median from each reactor's change. Because the uprates were made at different times over about four years, there are four different median increases.

What all of that means is this: For a reactor uprated during 1998, its 1995–1997 factor is compared with its 1999–2001 factor, and then the difference in the median factors is subtracted from the difference between the two factors. Any positive number in the far right column of Table V indicates that after the power uprate, the reactor's performance at its new DER was not only better than at its old DER, but better than the trend in the industry in general. (For ANO-2, we have used the alternative factor from Table IA.)

Table V shows that power uprates appear to be a work in progress. In all, 13 of the 23 reactors performed better than they had before being uprated, but only nine outpaced the rise in the industry median. Among the 12 extended uprates, six performed better, and four beat the median change. This is slightly poorer than the record for the 11 stretch uprates, with seven and five, respectively.

High-profile problems such as the steam dryer cracking at Dresden and Quad Cities may be giving power uprates a reputation for riskiness, but as with so many other things, experience and learning curve may be the keys to making an uprate a fully positive experience. Of the six reactors in Table V that were uprated in 1998, all of them have negative numbers in the far-right column, and only three have positive numbers in the near-right. The 2003–2005 factors for those six, however, show that two of the six have improved more than the median change since then, and all six performed better than they had in 1995–1997.

A lesson from long ago

It may be inevitable that with the steady improvement now at an end, and the nation's operating reactors looking to maintain their level of performance, they might too easily be ignored for continuing to do what would have seemed miraculous just a few years ago. With so much attention going now to prospects for new reactor licensing, ordering, and construction, the operating reactors might become even less prominent. To help keep matters in perspective, let's examine the nuclear community's state of mind during a comparable period in the past.

During the last few years of its existence, the Atomic Energy Commission assembled a survey of developments under its purview at the end of each fiscal year, based chiefly on its report to what was then the only congressional body with authority over nuclear matters: the Joint Committee on Atomic Energy. *The Nuclear Industry 1971* (WASH 1174-71), 199 pages long, devoted 32 pages to civilian power. By this time, there were in service 14 power reactors that could be considered commercial (five of them still in operation today), producing not only baseload electricity but significant data about what the operation of a power reactor actually entailed and the day-to-day experience with this new enterprise. Yet the 32 pages in WASH 1174-71 included no generation statistics or experience reports from the 14 operating reactors—just page after page on utility contracts for newer and bigger reactors, construction schedules and budgets, and forecasts for next-phase endeavors, such as the liquid-metal fast-breeder reactor.

Yes, there's a point being made here. However exciting it may be to focus on reactors that don't yet exist, and however dull and routine it may be to focus on one more day of full-power operation at a reactor that's been doing the same thing for years, placing the former above the latter can be perilous. It should not have taken another decade and a partial core melt to get the nuclear community to give priority attention to operating experience, but it did. Here's hoping that a third of a century later, the campaign for new reactors won't mean neglect of the old. NN