U.S. capacity factors: Does new ownership matter?

BY E. MICHAEL BLAKE

The fleet as a whole showed slight improvement, but reactors that have changed owners and/or operator organizations appear to have done better.

WHILE 2004 WAS the most productive year ever for nuclear power in the United States, and performance in general appears to have been the best ever—even after adjusting for power uprates and the year's inclusion of a leap day—three-year design electrical rating (DER) net capacity factors in 2002 through 2004 showed only slight improvement over those in 1999 through 2001. The gains, generally in the range of 1 to 2 percentage points (depending on how the data are interpreted) may suggest that power reactor performance is finally reaching a plateau. In the past, however, this writer has looked ridiculous when making such suggestions, so for now this will not be declared a long-term trend.

The real story here, as it has been for about 20 years, is that not only has power reactor performance risen to heights far beyond what anyone would have dared to promise when those plants were first being ordered and built, but the improvement has spread through the entire industry, despite wide variation in reactor type and size, owner/operator organizations, and, more recently, state-level regulation. Also, although it appears that reactors that have changed hands—through sale, merger, or revised operating entity—have improved more in the past three years than reactors that remained under the same regimes, there is nothing to suggest that all other reactors would benefit if swallowed up by a few mega-owners. It appears that the companies that have devoted themselves to nuclear plant ownership have done a great service through their new acquisitions, and a few other reactors may have their long-term futures secured if their proposed acquisitions take place—but the reactors that had seemed to be in the greatest need of help in the mid- to late 1990s have had their rescues completed.

Here are the basic data. In 2002–2004, the median DER net capacity factor among the 104 licensed power reactors was 89.77 percent, compared with 88.38 percent in 1999–2001. (Henceforth, the terms "capacity factor" and "factor" refer to three-year DER net capacity factor.) The average capacity factor in 2002–2004 was 88.22 percent, up from 86.25 percent in 1999–2001. Sixty power reactors had higher factors in 2002–2004 than in 1999–2001, 43 had lower factors, and one was unchanged (Browns Ferry-1, out of service during both periods).

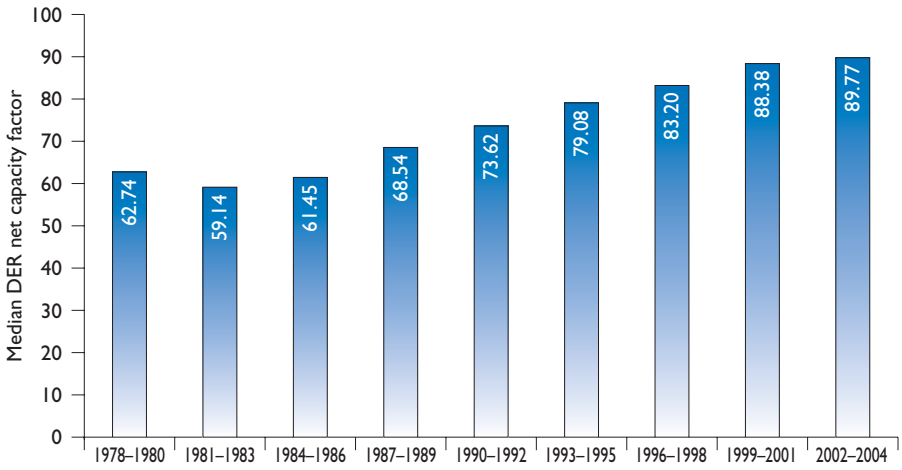

Fig. 1: All reactors. From 1984–1986 to 1999–2001, the median factor for the entire nuclear fleet improved by roughly four to seven percentage points in each three-year period. The gain in the most recent period was less than a point and a half, suggesting that there is coming to be less room for improvement. The chart shows only reactors that are still in service now. In 1978–1980 there were 49 such reactors, and in each succeeding period there were 55, 65, 85, 99, 102, 103, 104, and 104. If closed reactors were included, to show the median factor for the industry as it was during each period, the medians in the first six periods would be 62.56 percent (60 reactors), 59.14 (67), 62.08 (77), 68.83 (95), 73.15 (107), and 78.88 (108). None of these medians differs by more than two-thirds of one percentage point from the medians shown above.

For pressurized water reactors, the 2002–2004 median factor was 89.80 percent, up from 88.50 in the previous period. (The average was 88.93 percent in 2002–2004, and 86.71 percent in 1999–2001.) Thirty-nine PWRs had higher factors in 2002–2004 than in 1999–2001, and 30 had lower factors.

Among boiling water reactors, the median factor in 2002–2004 was 89.74, compared with 88.34 in 1999–2001. (The average was 86.83 percent in 2002–2004, and 85.33 percent in 1999–2001.) There were 21 BWRs with higher factors in 2002–2004 than in 1999–2001, 13 with lower factors, and Browns Ferry-1 remained unchanged.

Not only have BWRs essentially pulled even with PWRs after lagging by several percentage points for most of the industry's history, but the continuing development of each reactor type is very nearly the same. In 1999–2001, the BWR and PWR medians were 0.16 percentage points apart; in 2002–2004 they were even closer, with a 0.06 percentage point difference. The PWR average remains higher than the BWR average, but if Browns Ferry-1 were excluded (because it has been out of service since 1985 and is not scheduled for restart until the end of the current rehabilitation project in 2007), the BWR average would be 89.66 percent, higher than the PWR average.

Because it is very difficult for a reactor with a factor of 95 percent or higher to keep improving, the fact that some of the top performers have fallen back by a few points is no surprise, and certainly no cause for alarm. Much of the improvement in 2002–2004 took place among reactors with lower factors, closing the gap with those near the top. The top quartile capacity factor (with one-fourth of the fleet having higher factors, and the rest with lower factors) was 92.61 percent in 2002–2004, up only slightly from 92.36 percent in 1999–2001. The bottom quartile, however, was 86.62 percent in 2002–2004, more than two percentage points better than the 84.24 percent in 1999–2001.

The tables and charts show the data in more detail, and with longer-term histori-

TABLE I.
2002–2004 DER NET CAPACITY FACTORS OF INDIVIDUAL REACTORS

Rank	Reactor	Factor[1]	Design Electrical Rating (DER), MWe[2]	Type	Operator[3]	Rank	Reactor	Factor[1]	Design Electrical Rating (DER), MWe[2]	Type	Operator[3]
1.	ANO-2	102.36	912	PWR	Entergy	53.	Brunswick-1	89.74	972	BWR	Progress
2.	Braidwood-1	97.73	1187	PWR	Exelon	54.	Beaver Valley-1	89.48	835	PWR	FENOC
3.	Braidwood-2	97.37	1155	PWR	Exelon	55.	Vermont Yankee	89.32	522	BWR	Entergy
4.	Ginna	97.23	470	PWR	Constellation	56.	Prairie Island-1	89.17	536	PWR	NMC
5.	Byron-2	96.97	1155	PWR	Exelon	57.	Harris	89.14	941.7	PWR	Progress
6.	Indian Point-3	96.72	979	PWR	Entergy	58.	Comanche Peak-2	89.11	1150	PWR	TXU
7.	Three Mile Island-1	96.51	819	PWR	AmerGen	59.	Vogtle-2	88.86	1169	PWR	Southern
8.	Peach Bottom-3	96.39	1138	BWR	Exelon	60.	Palo Verde-1	88.74	1265	PWR	APS
9.	Byron-1	96.30	1187	PWR	Exelon	61.	Clinton	88.68	1062	BWR	AmerGen
10.	Calvert Cliffs-2	95.33	845	PWR	Constellation	62.	Point Beach-2	88.58	522	PWR	NMC
11.	Seabrook	95.19	1148	PWR	FPL Energy	63.	Nine Mile Point-2	88.54	1143.3	BWR	Constellation
12.	Crystal River-3	95.04	860	PWR	Progress	64.	Oyster Creek	88.52	650	BWR	AmerGen
13.	St. Lucie-1	95.04	830	PWR	FP&L	65.	San Onofre-3	88.46	1080	PWR	SCE
14.	Grand Gulf	94.88	1250	BWR	Entergy	66.	Nine Mile Point-1	88.40	613	BWR	Constellation
15.	Catawba-2	94.05	1145	PWR	Duke	67.	Arnold	88.39	581.4	BWR	NMC
16.	Limerick-2	93.68	1191	BWR	Exelon	68.	Dresden-2	88.35	867	BWR	Exelon
17.	Pilgrim	93.64	690	BWR	Entergy	69.	McGuire-1	87.80	1180	PWR	Duke
18.	Prairie Island-2	93.60	536	PWR	NMC	70.	South Texas-1	87.64	1250.6	PWR	STP
19.	Beaver Valley-2	93.48	836	PWR	FENOC	71.	Point Beach-1	87.50	522	PWR	NMC
20.	San Onofre-2	93.41	1070	PWR	SCE	72.	Comanche Peak-1	87.37	1150	PWR	TXU
21.	FitzPatrick	93.26	816	BWR	Entergy	73.	Sequoyah-1	87.27	1160	PWR	TVA
22.	Waterford-3	93.00	1104	PWR	Entergy	74.	Dresden-3	87.15	867	BWR	Exelon
23.	Monticello	92.78	600	BWR	NMC	75.	Kewaunee	86.91	574	PWR	NMC
24.	River Bend	92.69	966	BWR	Entergy	76.	Perry	86.76	1260	BWR	FENOC
25.	North Anna-1	92.64	907	PWR	Dominion	77.	Quad Cities-2	86.73	867	BWR	Exelon
26.	Browns Ferry-3	92.62	1120	BWR	TVA	78.	Palo Verde-3	86.63	1269	PWR	APS
27.	Hatch-2	92.59	908	BWR	Southern	79.	Millstone-2	86.62	883.5	PWR	Dominion
28.	Surry-2	92.59	788	PWR	Dominion	80.	Turkey Point-3	86.57	720	PWR	FP&L
29.	Susquehanna-2	92.41	1182	BWR	PPL	81.	Sequoyah-2	86.38	1160	PWR	TVA
30.	Turkey Point-4	92.38	720	PWR	FP&L	82.	Cook-1	86.26	1020	PWR	AEP
31.	Limerick-1	92.20	1191	BWR	Exelon	83.	Calvert Cliffs-1	86.16	845	PWR	Constellation
32.	St. Lucie-2	92.04	830	PWR	FP&L	84.	Palo Verde-2	85.88	1336	PWR	APS
33.	Browns Ferry-2	91.87	1120	BWR	TVA	85.	Quad Cities-1	85.76	867	BWR	Exelon
34.	Surry-1	91.79	788	PWR	Dominion	86.	Susquehanna-1	85.71	1177	BWR	PPL
35.	Vogtle-1	91.75	1169	PWR	Southern	87.	Fermi-2	85.57	1150	BWR	Detroit
36.	Brunswick-2	91.67	935	BWR	Progress	88.	Oconee-2	85.20	886	PWR	Duke
37.	Farley-2	91.45	855	PWR	Southern	89.	Diablo Canyon-2	85.03	1119	PWR	PG&E
38.	Millstone-3	91.40	1153.6	PWR	Dominion	90.	Salem-2	84.92	1131	PWR	PSE&G
39.	LaSalle-1	91.31	1154	BWR	Exelon	91.	North Anna-2	84.50	907	PWR	Dominion
40.	Wolf Creek	91.23	1170	PWR	WCNOC	92.	Palisades	84.41	805	PWR	NMC
41.	LaSalle-2	91.07	1154	BWR	Exelon	93.	Columbia	84.34	1153	BWR	Northwest
42.	Robinson-2	90.97	765	PWR	Progress	94.	Callaway	84.18	1171	PWR	AmerenUE
43.	Catawba-1	90.88	1145	PWR	Duke	95.	Salem-1	83.90	1193	PWR	PSE&G
44.	Fort Calhoun	90.59	478	PWR	OPPD	96.	Oconee-3	83.79	886	PWR	Duke
45.	Peach Bottom-2	90.57	1138	BWR	Exelon	97.	South Texas-2	83.43	1250.6	PWR	STP
46.	Watts Bar-1	90.47	1155	PWR	TVA	98.	Cooper	82.98	778	BWR	NPPD
47.	ANO-1	90.30	850	PWR	Entergy	99.	Diablo Canyon-1	82.26	1103	PWR	PG&E
48.	Farley-1	90.17	854	PWR	Southern	100.	Oconee-1	82.01	886	PWR	Duke
49.	Indian Point-2	90.02	993	PWR	Entergy	101.	Cook-2	79.31	1090	PWR	AEP
50.	McGuire-2	90.00	1180	PWR	Duke	102.	Hope Creek	77.76	1083	BWR	PSE&G
51.	Hatch-1	89.98	885	BWR	Southern	103.	Davis-Besse	28.15	906	BWR	FENOC
52.	Summer	89.80	972.7	PWR	SCE&G	104.	Browns Ferry-1	0.00	1065	BWR	TVA

[1] These figures are rounded off. There are no ties. Crystal River-3 is in 12th place with a factor of 95.0400, and St. Lucie-1 is in 13th with 95.0357.

[2] The rating shown is effective as of December 31, 2004. If a reactor's rating has changed during the three-year period, the capacity factor is computed with appropriate weighting.

[3] As of December 31, 2004. In most cases this also means the reactor's owner, but the plants listed for NMC are only operated, not owned, by Nuclear Management Company, LLC.

cal perspective. Before we move on, however, one apparent numerical anomaly should be addressed: ANO-2's factor, shown here as 102.36 percent. Entergy Nuclear certainly deserves praise for operating this reactor so well, but the number is misleading. As was pointed out last year (*NN*, May 2004, p. 25), a number of the reactors that have been granted power uprates have not reflected this in their design electrical ratings. ANO-2, in particular, received the Nuclear Regulatory Commission's permission in April 2002 to boost thermal power by 7.5 percent, and this is the largest uprate that has not been accompanied by a higher DER. On that basis—and allowing for the fact that the uprate has not been in effect for the entire three-year period—a factor of about 97 percent might be more reasonable. This survey, however, is by our own choice bound to each plant's official DER, so 102.36 percent is shown here.

Reactors as commodities

It is probably incorrect to think of something as heavily regulated as a power reactor as a "merchant" plant. This is a term more correctly applied to other plant types, generally fueled by natural gas (although sometimes hydro- or wind-powered), acquired by entities that may not be utilities in the traditional sense. Even so, an entrepreneurial approach similar to that involved in merchant plant acquisition emerged in the late 1990s as a few companies willing to take full advantage of their nuclear power experience found ways to work within the requirements of reactor licensing and regulation to take over plants from other com-

TABLE II.
CAPACITY FACTOR CHANGE, 1999–2001 TO 2002–2004

Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)	Rank	Reactor	Change (percentage points)
1.	Cook-1	+56.67	27.	Brunswick-2	+5.33	53.	ANO-1	+0.85	79.	Brunswick-1	-2.55
2.	Cook-2	+34.83	28.	Waterford-3	+5.33	54.	South Texas-1	+0.77	80.	Surry-1	-2.80
3.	Indian Point-2	+27.97	29.	LaSalle-2	+5.03	55.	Browns Ferry-2	+0.64	81.	Fermi-2	-2.84
4.	Palisades	+21.92	30.	San Onofre-3	+4.94	56.	Byron-1	+0.37	82.	St. Lucie-2	-2.89
5.	ANO-2	+21.45	31.	Susquehanna-2	+4.37	57.	Turkey Point-4	+0.34	83.	Salem-2	-3.22
6.	Three Mile Island-1	+16.85	32.	Arnold	+4.03	58.	Surry-2	+0.25	84.	Dresden-2	-3.36
7.	Monticello	+11.87	33.	Millstone-3	+3.90	59.	Braidwood-1	+0.23	85.	Callaway	-3.39
8.	Seabrook	+11.41	34.	Kewaunee	+3.87	60.	San Onofre-2	+0.11	86.	Dresden-3	-3.57
9.	Nine Mile Point-1	+10.11	35.	Point Beach-2	+3.62	61.	Browns Ferry-1	0.00	87.	Robinson-2	-3.72
10.	Summer	+9.42	36.	Oyster Creek	+3.58	62.	St. Lucie-1	-0.04	88.	Vermont Yankee	-3.74
11.	Clinton	+9.35	37.	Nine Mile Point-2	+3.38	63.	McGuire-1	-0.05	89.	Hope Creek	-4.15
12.	Farley-2	+9.20	38.	McGuire-2	+3.25	64.	Salem-1	-0.23	90.	Limerick-1	-4.18
13.	Columbia	+8.69	39.	Perry	+3.18	65.	Comanche Peak-1	-0.78	91.	North Anna-2	-4.27
14.	Millstone-2	+8.14	40.	Ginna	+3.12	66.	Byron-2	-0.89	92.	Diablo Canyon-2	-4.29
15.	Pilgrim	+7.96	41.	Point Beach-1	+3.09	67.	Sequoyah-1	-1.23	93.	Browns Ferry-3	-4.56
16.	River Bend	+7.93	42.	Fort Calhoun	+3.05	68.	North Anna-1	-1.49	94.	Vogtle-2	-4.86
17.	Beaver Valley-1	+7.62	43.	Cooper	+2.59	69.	Oconee-1	-1.59	95.	Turkey Point-3	-4.90
18.	Harris	+6.92	44.	Crystal River-3	+2.49	70.	Wolf Creek	-1.62	96.	Quad Cities-2	-5.26
19.	Grand Gulf	+6.54	45.	Prairie Island-1	+2.30	71.	Vogtle-1	-1.80	97.	Palo Verde-3	-5.45
20.	Catawba-2	+6.36	46.	Hatch-1	+1.82	72.	Comanche Peak-2	-1.80	98.	Susquehanna-1	-5.53
21.	Farley-1	+6.33	47.	Braidwood-2	+1.77	73.	Palo Verde-1	-1.96	99.	Sequoyah-2	-6.27
22.	Beaver Valley-2	+6.27	48.	Watts Bar-1	+1.74	74.	Catawba-1	-2.00	100.	Quad Cities-1	-6.83
23.	Peach Bottom-3	+5.89	49.	Hatch-2	+1.61	75.	Peach Bottom-2	-2.36	101.	Diablo Canyon-1	-6.91
24.	Oconee-3	+5.88	50.	FitzPatrick	+1.56	76.	LaSalle-1	-2.37	102.	South Texas-2	-7.45
25.	Calvert Cliffs-2	+5.69	51.	Limerick-2	+1.28	77.	Palo Verde-2	-2.50	103.	Calvert Cliffs-1	-7.86
26.	Indian Point-3	+5.52	52.	Prairie Island-2	+1.06	78.	Oconee-2	-2.51	104.	Davis-Besse	-63.52

panies that decided they'd had enough of nuclear. This may have happened just in time to save a number of reactors from premature closure, although it came too late to prevent the closure of others.

For all the guarded optimism in the nuclear field these days, from both strong performance by existing plants and tentative steps toward what might become new reactor orders, the outlook was much darker about eight years ago. In 1997, 11 power reactors were off line for the entire year for various reasons (one of them closed that year, and two more closed the next year), and eight others had capacity factors below 50 percent for the year (one of them, Big Rock Point, was closing anyway, but another, Zion-1, closed the next year, well short of its licensed term). Financial analysts, among others, were writing that nuclear power plants might be too large, too inflexible, too expensive, and too regulated to thrive in the developing era of merchant electricity.

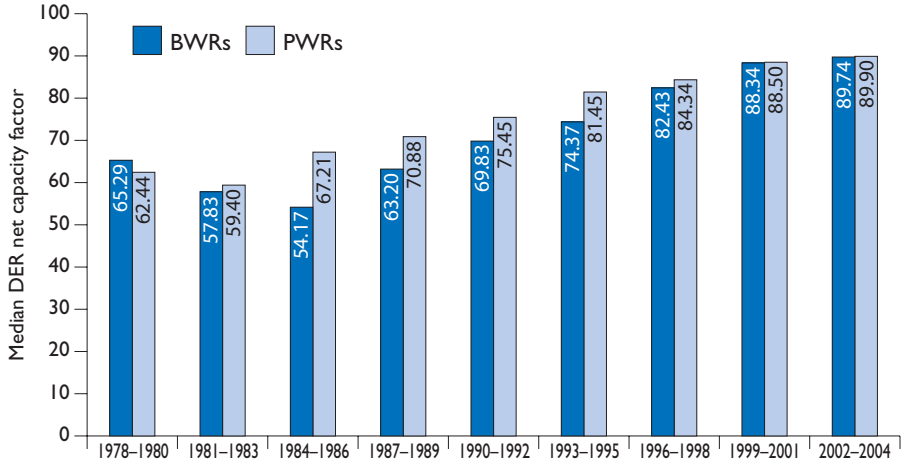

Fig. 2: Reactors by type. Boiling water reactors had a higher median factor than pressurized water reactors in 1978–1980; before then, however, there were so few reactors in service that it may not be valid to say that BWRs had a clear early advantage over PWRs. Three Mile Island-2 was a PWR, but in the post-TMI regulatory climate, BWRs often needed more time to meet new requirements than PWRs did, and large BWRs in particular had more difficulty in their first years of operation than large PWRs did. As much as BWRs improved after 1984–1986, they did not begin to close the gap on PWRs until 1996–1998, and have been essentially even in the last two periods. Only reactors still in service today are shown; if closed plants were included, the general picture would be the same, with only one median varying by more than 1.5 percentage points from what is shown above.

Nothing happened immediately to prove this untrue, and the consequences included the closure of Haddam Neck, Maine Yankee, Millstone-1, and both Zion units. But other developments were taking place, generally unnoticed outside the industry. Even with all the operational difficulties at several plants and worries about rising costs as aging plants faced large-scale equipment replacements, performance by the fleet as a whole continued the upward trend that had begun in the early 1980s: The median three-year capacity factor continued to rise. Also, in 1995, the NRC had put in place a system for the renewal of operating licenses at existing plants. The prospect of an extra 20 years of operation, for a reactor that would otherwise be in the last half of its license term, made it conceivable that a new set of steam generators or turbine internals might pay for themselves and presented a viable alternative to premature closure. The first license renewal applications started arriving at the NRC in 1998.

For some reactor owners, however, the thought of 20 more years of operation might not have seemed pleasant. Fortunately, where some owners may have seen liabilities, other companies saw potential assets. In one way, the extent of federal regulation could be seen in a positive light: It ensured that every licensed reactor had in place the hardware, and to some extent the personnel, that was available to every other reactor—and so, in theory, every power reactor in the United States could be a top performer, given the proper resources.

Continued

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

Rank	Plant	Factor	Operator	Rank	Plant	Factor	Operator
1.	Braidwood	97.55	Exelon	19.	Turkey Point	89.47	FP&L
2.	Byron	96.63	Exelon	20.	Millstone	89.34	Dominion
3.	ANO	96.54	Entergy	21.	Susquehanna	89.10	PPL
4.	St. Lucie	93.54	FP&L	22.	McGuire	88.90	Duke
5.	Peach Bottom	93.48	Exelon	23.	North Anna	88.57	Dominion
6.	Indian Point	93.34	Entergy	24.	Nine Mile Point	88.49	Constellation
7.	Limerick	92.94	Exelon	25.	Comanche Peak	88.24	TXU
8.	Catawba	92.46	Duke	26.	Point Beach	88.04	NMC
9.	Surry	92.18	Dominion	27.	Dresden	87.75	Exelon
10.	Beaver Valley	91.48	FENOC	28.	Palo Verde	87.07	APS
11.	Prairie Island	91.39	NMC	29.	Sequoyah	86.82	TVA
12.	Hatch	91.30	Southern	30.	Quad Cities	86.25	Exelon
13.	LaSalle	91.19	Exelon	31.	South Texas	85.53	STP
14.	San Onofre	90.92	SCE	32.	Oconee	83.67	Duke
15.	Farley	90.81	Southern	33.	Diablo Canyon	83.66	PG&E
16.	Calvert Cliffs	90.75	Constellation	34.	Cook	82.67	AEP
17.	Brunswick	90.71	Progress	35.	Salem/Hope Creek	82.26	PSEG
18.	Vogtle	90.31	Southern	36.	Browns Ferry	62.52	TVA

[1] Because Nine Mile Point and FitzPatrick have different owners, Nine Mile Point is counted here as a multi-unit 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 2002–2004 factor of 86.27. Salem and Hope Creek are treated as a single site, because they are adjacent and have the same owner; the two-unit Salem had a 2002–2004 factor of 84.40. The figure given for Browns Ferry is for all three units, although Unit 1 has been out of service since 1985; the 2002–2004 factor for Units 2 and 3 only is 92.25.

The NRC decided that a license transfer to an established power reactor operator was feasible, so there emerged a marketplace not just for nuclear electricity, but for reactors themselves. The formation of AmerGen, a company set up specifically to acquire and operate reactors, more or less fit in with the nuclear operating company model proposed decades earlier. What really made it clear that an altogether different era had begun was the 1999 acquisition by Entergy, based in the south-central United States, of Pilgrim, in Massachusetts.

The key question to be addressed here is whether a change in owner and/or operator organization makes a difference, for good or ill, in a reactor's performance. What probably cannot be denied, however, is that the combination of license renewal and a market for used (or "pre-owned," if you prefer) power reactors has made a difference in some reactors' continued operation. As will be shown below, not every reactor needs to be owned by a deep-pocketed, multiregional nuclear specialist, but the option to let otherwise unwanted reactors migrate to new owners or operators may be the reason that Nine Mile Point-1, Oyster Creek, and other reactors with past problems are still producing electricity and proving their worth. Also, the fact that virtually every reactor is now a major success suggests that this could have been possible also for the prematurely closed plants had the same options been available—extending back even to those closed earlier, such as Trojan and Rancho Seco.

No way to go but up?

Before 1999, only two operating reactors had ever changed hands. Entergy took over River Bend when that company merged with Gulf States Utilities Company in 1994, and in 1998, FirstEnergy Nuclear Operating Company (FENOC) formally added Davis-Besse to its existing nuclear asset, Perry—although in previous years there had been some convergence of the two through the short-lived Centerior Energy. It seems reasonable to consider FENOC as something of a continuation of Centerior and not look at Davis-Besse's performance as a measure of the consequences of an acquisition.

As for River Bend, let the record show that in its first two three-year periods, 1987–1989 and 1990–1992, its factors were 69.04 percent and 61.10 percent. In 1993–1995, which included the transition to Entergy, the factor was 73.48 percent. Since then, under full Entergy control, River Bend has had factors of 87.39, 84.76, and 92.69. In short, performance has gone from at or below the median before Entergy took over to above, slightly below, and well above the median since then, suggesting that the change was worthwhile.

Of greater interest, however, are the reactor acquisitions or license transfers that began in earnest in 1999. Because this survey involves three-year factors, only those changes that took place before the end of 2001 are included so that a full three-year period of operation can be examined. This excludes Entergy's purchase of Vermont Yankee (in 2002), Seabrook's switch to FPL Energy (2002), the merger that produced Progress Energy (2003), and Constellation Energy's acquisition of Ginna (2004). Nonetheless, the database covers about one-third of the reactor fleet, because the Exelon merger and the formation of Nuclear Management Company are included.

In 1996–1998, before any of the license transfers took place, the 35 reactors that later changed hands had a median factor of 75.79 percent, and the other 69 reactors had a median factor of 86.64 percent. In 1999–2001, the 35 reactors being transferred had a median factor of 87.21, and the median of the other 69 was 88.50. In 2002–2004, the transferees, with a median factor of 90.57, actually pulled slightly ahead of the larger group, which had a median factor of 89.32. If averages are used instead of medians, the results are similar, showing a bigger deficit for the transferees in the first period (65.61 vs. 79.93), a small lead in the middle period (87.52 vs. 85.70), and a bigger lead in the latest (91.53 vs. 86.74).

On the face of it, this indicates that a change in owner/operator contributed to bringing some reactors up to the performance level of the rest of the industry, and as an extremely general statement, that may be valid. But it probably does not apply across the board. For instance, Braidwood and Byron were already on the way to reaching the highest performance level in the fleet before the Exelon merger took hold. Millstone had moved past its most severe operational and regulatory problems before it was bought by Dominion Energy. The bargain-basement price AmerGen paid for Oyster Creek belies the fact that the reactor has performed well consistently since the early 1990s. Culture change and personnel turnover do not happen the instant that the paperwork is signed on the license transfer, and whatever reassurance might come from a new owner's resources and a promise of license renewal may not be expressed clearly in performance statistics. That said, those statistics will be explored here anyway.

In Table V, the factors of the 35 units are shown for the three periods listed above and compared with the median factors of the group of unaffected reactors. In an effort to make the comparison more meaningful, a new statistical value is being created: Ceiling Level Eventual Achievement Ratio (CLEAR). This is based on a 100 percent factor's being the best that a reactor can achieve (ANO-2 notwithstanding). If a reactor had a factor of 80 percent in one period, and 95 percent in the next period, it gained 15 of the 20 points it could have picked up, for a CLEAR of 0.75. This is intended to put some of the gains in perspective; a 20-point gain from 60 to 80 percent (CLEAR=0.50) is probably less difficult to achieve than a 10-point gain from 85 to 95 (CLEAR=0.67).

Table V shows that the medians of the unaffected group have a CLEAR of 0.2006 when 1996–1998 is compared with 2002–2004, entirely before the change period to entirely after it. The CLEAR for the medians of 1999–2001 and 2002–2004 is 0.0713. For the averages, the comparable

CLEARs are 0.3393 and 0.0727. Presuming that a higher CLEAR means better performance, all 35 of the affected reactors did better than the unaffected group's median CLEAR from 1996–1998 to 2002–2004, and 27 of 35 did better than the unaffected group's median CLEAR from 1999–2001 to 2002–2004. (If averages are used instead of medians, the comparable figures are 31 of 35 and 27 of 35.) So, even though the affected reactors had more room for improvement, they still exceeded the rest of the industry's upward trend.

For a closer look, the affected reactors will now be grouped by the general circumstances of their owner and/or operator change: merger, acquisition, and delegation.

Exelon and AmerGen

The conventional wisdom in the industry appears to hold that PECo Energy had the most to offer in the merger that created Exelon, and Commonwealth Edison had the greatest need. Because PECo's four reactors at the time had better recent histories than ComEd's 10, it would be easy to attribute the turnaround of the Illinois reactors to help from Pennsylvania. As noted above, however, Braidwood and Byron were already hitting their stride, and as the only PWRs owned by either PECo or ComEd, PECo's experience might not have provided much specific help. It also appears that as bad as LaSalle had been in 1996–1998, it had recovered by the time of the merger, and the numbers for 1999–2001 suggest that Dresden and Quad Cities had also gotten better mainly through ComEd's own efforts, spearheaded by Oliver Kingsley, who ComEd brought in to take charge of its nuclear program in October 1997.

A stronger case can be made for PECo's favorable effect on Clinton, where PECo came on as management contractor in early 1998. Even though Clinton eventually came to be owned by AmerGen (a partnership of Exelon and BNFL Inc., which was bought out entirely by Exelon in 2004), it is PECo oversight that led to its best performance ever, in the past two three-year periods.

As noted above, Oyster Creek was doing well before AmerGen took over, and TMI-1 has almost always been a solid performer. The original PECo plants have remained among the industry's leaders. Because of various legal reasons, AmerGen (originally formed by PECo with BNFL, with the PECo share later taken over by Exelon) will continue to have a separate identity for a while, but the AmerGen and Exelon nuclear plants work under a single overall organization.

Exelon's management has clearly been successful since the merger, even if the company cannot be given much of the credit for the turnaround of the old ComEd fleet. The management is valued so highly that when Exelon and PSEG announced merger plans late last year (*NN*, Jan. 2005, p. 17), the companies signed a separate deal installing Exelon as operations contractor at Salem and Hope Creek as of January 17 so that those nuclear plants would not have to wait for the merger to go into effect (perhaps late this year) to receive the benefits of having Exelon in charge.

Entergy and other buyers

The most vigorous participant in nuclear power's version of the new utility era has been Entergy, which in short order acquired as many reactors in the Northeast (five) as it already owned in its traditional mid-south service area. The prospects for culture shock, from management groomed in one region working with plant staffers schooled in another, have been largely averted by the formation of somewhat autonomous divi-

TABLE V.
CAPACITY FACTOR CHANGE AND CEILING LEVEL EVENTUAL ACHIEVEMENT RATIO (CLEAR) FOR REACTORS DIRECTLY AFFECTED BY OWNER AND/OR OPERATOR CHANGE, 1996–1998 AND 1999–2001 TO 2002–2004[1]

Reactor	Change, 1996–1998 to 2002–2004	Change, 1999–2001 to 2002–2004	CLEAR, 1996–1998 to 2002–2004	CLEAR, 1999–2001 to 2002–2004
Arnold	+4.07	+4.03	+0.2596	+0.2577
Beaver Valley-1	+32.47	+7.62	+0.7553	+0.4201
Beaver Valley-2	+35.81	+6.27	+0.8460	+0.4902
Braidwood-1	+18.73	+0.23	+0.8919	+0.0920
Braidwood-2	+9.35	+1.77	+0.7805	+0.4023
Byron-1	+22.30	+0.37	+0.8919	+0.0909
Byron-2	+10.36	-0.89	+0.7737	-0.4159
Clinton	+67.03	+9.34	+0.8555	+0.4521
Dresden-2	+24.41	-3.36	+0.6769	-0.4053
Dresden-3	+23.92	-3.57	+0.6503	-0.3843
FitzPatrick	+14.78	+1.56	+0.6868	+0.1880
Indian Point-2	+38.09	+27.97	+0.7924	+0.7370
Indian Point-3	+26.33	+5.52	+0.8892	+0.6273
Kewaunee	+21.25	+3.87	+0.6188	+0.2282
LaSalle-1	+67.90	-2.38	+0.8865	-0.3772
LaSalle-2	+71.17	+5.03	+0.8885	+0.3603
Limerick-1	+7.13	-4.17	+0.4860	-1.1488
Limerick-2	+3.10	+1.28	+0.3291	+0.1684
Millstone-2	+82.16	+8.14	+0.8600	+0.3783
Millstone-3	+72.52	+3.90	+0.8940	+0.3120
Monticello	+13.04	+11.87	+0.6436	+0.6218
Nine Mile Point-1	+12.61	+10.10	+0.5209	+0.4654
Nine Mile Point-2	+5.78	+3.38	+0.3353	+0.2278
Oyster Creek	+8.32	+3.58	+0.4202	+0.2377
Palisades	+6.45	+21.92	+0.2926	+0.5844
Peach Bottom-2	+6.02	-2.36	+0.3896	-0.3338
Peach Bottom-3	+8.69	+5.88	+0.7065	+0.6196
Pilgrim	+4.64	+7.96	+0.4218	+0.5559
Point Beach-1	+30.91	+3.09	+0.7120	+0.1982
Point Beach-2	+35.97	+3.63	+0.7590	+0.2412
Prairie Island-1	+6.95	+2.31	+0.3909	+0.1758
Prairie Island-2	+11.45	+1.06	+0.6415	+0.1421
Quad Cities-1	+30.88	-6.83	+0.6844	-0.9217
Quad Cities-2	+33.18	-5.26	+0.7143	-0.6567
Three Mile Island-1	+3.31	+16.85	+0.4868	+0.8284
all others (median)	+2.64	+0.82	+0.2006	+0.0713
all others (average)	+6.81	+1.04	+0.3393	+0.0727

[1] The numbers above probably need some more explanation. The newly invented statistic called CLEAR is intended as a way to compare improvement at different reactors; it is much less meaningful for reactors that have declined slightly. Limerick-1, which went from a factor of 96.37 in 1999–2001 to a still excellent factor of 92.20 in 2002–2004, is shown in the far right column to have the worst CLEAR on the list, which says nothing whatsoever about the performance of this reactor. The intent is to see whether performance changed specifically because of owner/operator change. The third column shows CLEAR from entirely before the change to entirely after; the fourth column shows CLEAR from (to varying extents) during the change to entirely after. The bottom two lines give the percentage point changes and CLEARs for the medians and averages of the other 69 reactors that were not affected.

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

Rank	Owner/Operator	Factor
1.	Entergy Nuclear (all divisions)	94.13
2.	Exelon (including AmerGen)	92.48
3.	Florida Power & Light	91.65
4.	Southern Nuclear Operating	90.76
5.	Progress Energy	90.34
6.	Dominion Energy	89.91
7.	Constellation Energy	89.60
8.	Nuclear Management Company	88.71
9.	Duke Power	88.11
10.	Tennessee Valley Authority	75.59
11.	FirstEnergy Nuclear Operating	74.98

[1] The factors for some smaller divisions of the organizations listed above are as follows: Entergy South, 94.63; Entergy Northeast, 93.38; AmerGen, 91.19; Exelon without AmerGen, 92.69; TVA without Browns Ferry-1, 89.69.

sions within Entergy for the Northeast (and a separate one for Vermont Yankee, not examined here because the acquisition took place after the end of 2001). The result is that the reactors that were doing well already (FitzPatrick and Pilgrim) continued to do so, while Indian Point-2 and -3—brought under single management for the first time ever—clearly were improved a great deal.

Compared with Entergy, other acquirers seem almost timid. Constellation, Dominion, and FENOC have each added one two-unit plant. Nine Mile Point was already in good shape before Constellation arrived, with solid performance since the mid-1990s. Both units have posted CLEARs above the industry median since Constellation took charge, but not far beyond what the reactors might have achieved without having been sold.

As dire as the situation was at Millstone in the late 1990s, and as helpful as Dominion's acquisition of the plant may have been, the surviving two units were back at steady operation by the time Dominion bought them. The new owner can be credited with building on the gains made after restart, and with (apparently) overcoming the plant's long-standing management and safety culture problems. (Similar problems had plagued the plant in the early 1990s and were supposed to have been addressed by revamped management with greater corporate authority, but in a few years, regulatory and operational issues cropped up again.) But it was under the old Northeast Utilities regime that Millstone-2 and -3 became productive again.

The extent to which FENOC's ownership can be credited with improvement at Beaver Valley may be open to debate. Clearly, both units were in the doldrums in 1996–1998, and the FENOC takeover in 1999 would have been early enough to affect most of 1999–2001, when both units did well. But can a company be credited with running one plant well while it was failing to notice that one of its other plants was developing an equipment problem beyond all previous experience? The vessel head erosion at Davis-Besse, and the resulting two-year outage, will remain FENOC's main identifier until it can compile several years of productive, trouble-free operation over its entire reactor fleet.

NMC's pooled expertise

It should be emphasized that while new ownership may not be entirely responsible for a reactor's improvement, there is no indication from performance statistics that new ownership has ever been bad for any U.S. reactor. On that basis alone, one can understand Dominion's continued pursuit of Kewaunee (finally approved in March by

How we did this, and how you can get even more of it

In 1983, *Nuclear News* began compiling three-year capacity factors of operating power reactors in the United States. Originally this was done to call attention to the industry's best performers and to spotlight what the personnel in charge of these reactors were doing right, so their example could be emulated by others. This sort of gathering of "good practices" was also being done far more energetically by the Institute of Nuclear Power Operations, and before long *NN* changed its focus so that reactor success stories were the subject of lengthy and frequent feature articles (the magazine also added a news section on operations). The capacity factor survey then evolved into a more detailed exploration of the statistics themselves and called attention to what became a long-term trend: steady improvement in performance, to higher levels than the industry had ever known before.

A three-year period was chosen in order to help even out fueling cycles of different lengths and to shed light on how reactors performed over sustained periods. The survey also uses design electrical rating (DER) net capacity factor as the most reasonable indicator of whether a reactor is producing enough electricity to justify its initial, and continuing, investment. Because DER criteria do not change often (although power uprates are having an effect), it is possible to track the reactor fleet over several three-year periods (as in Figs. 1 and 2) with reasonable assurance that like is being compared with like.

The key data are the amount of electricity produced by a reactor and the reactor's power rating. The numbers for both are obtained through the monthly operating reports sent by the reactor licensees to the Nuclear Regulatory Commission, which are then corrected by Tom Smith at the Idaho National Laboratory, who again this year has assisted immensely in this survey by sharing the corrected data with us. *NN* then compiled the survey, with much of the attention going to pinning down rating changes so as to produce accurate weighting factors.

To examine groups of reactors, we use the median (rather than average) value within a group of capacity factors and compare it to the median for the same group in earlier periods. We have found that this gives a more accurate view of the development of the entire industry than an average would. In some instances, however, we compute and mention the average value to give the reader a comparison; many years ago, averages ran several points lower than medians because of a number of reactors running at very low capacity (or not at all).

In this survey, for the first time, we have set aside our now antiquated distinction of "good" and "poor" performances, which in the early 1980s were defined as three-year DER factors of more than 70 percent, and less than 50 percent, respectively. With 102 of the 104 licensed units now above 77 percent, one of the other two coming off a two-year outage, and the last in a 20-year outage scheduled to end two years from now, there no longer appears to be anything instructive or illuminating in these terms. We want to emphasize, however, that by virtually any measure (and even allowing for the extra expenditures that brought about some of the improvements), even the last few reactors in the first 102 of Table 1 are much more successful than they were originally expected to be; most of them were built in anticipation of capacity factors around 65 percent and expected to earn their keep on that basis.

To put it another way, even in an era of (partly, and inconsistently) deregulated electricity and its high-stress competitive atmosphere, it would be ludicrous to sneer at a reactor with a factor of 85 percent, when that would have been the industry's best about 20 years ago (with most of the reactors in service then still running now, much better than they ever did before). If a reactor should drop from, say, 94 percent to 91 percent, no subsequent exploration of the minutiae of this change should make anyone lose sight of the fact that the performance was, and remains, excellent.

A vast amount of data is crunched to produce this survey, and most of it would not fit this space, so this year the American Nuclear Society will resume publication of the survey in far greater detail, in book form. *U.S. Power Reactor Performance, 2002–2004* will be published in June and will include historical three-year capacity factor data (in charts and tables) for each individual reactor, each multireactor site, and each multisite operator (although this will be somewhat limited, because the mergers and acquisitions in the industry make long-term historical trending less meaningful). The book should be priced just under $20 and will be available for browsing during the ANS Annual Meeting in San Diego, June 5–9.—*E.M.B.*

the Wisconsin Public Service Commission; see *NN*, Apr. 2005, p. 17). Also, the Duane Arnold Energy Center is likely to draw interest when it goes on the market this summer. In both cases, a sale would probably mean these reactors' departure from the influence of Nuclear Management Company, which has never owned the assets it operates. The owners were content to delegate authority to NMC.

The formation of NMC was motivated more by economics than by performance. The power reactors of the upper Midwest generally have been good performers, many of them ever since startup, but because they are relatively small—with a power uprate to 600 MWe, Monticello is the largest of the original group—their ability to operate economically in the license renewal era was open to question. The pooling of some resources has provided some benefits in economy of scale, but NMC is an operator and cannot by itself change the financial picture of a reactor and its owner. For this reason, Kewaunee and Arnold, small single-unit plants that are their owners' only majority-interest nuclear assets, have gone on the market.

Nonetheless, NMC may be carrying out a valuable turnaround at another reactor, which was not included in the original group. Consumers Power Company's Palisades was a substandard performer from the time it was commissioned, and it remained that way for more than two decades (its capacity factor for its first 24 years was 45 percent). It achieved some steady operation in the late 1990s, but then spent much of 2001 out of service. During that year, NMC was brought in by Consumers, and in 2002–2004, Palisades had its best three-year factor ever—still in the bottom quartile, but at least somewhat in pace with the rest of the industry.

Should this go on?

An open market for power reactors may therefore prove worthwhile for the continued operation of reactors that might otherwise face early closure, or not pursue license renewal. Experience has shown that performance does seem to improve for merged, bought, or delegated reactors, although in many cases much of the improvement took place before the license transfer. Does this provide one more argument in favor of the trend toward a few nuclear-specific concerns owning and/or operating every power reactor in the United States?

The potential concentration of the nuclear industry need not present a problem; the old industry, tied to service-area utilities, already had monopolistic aspects, and as long as electricity from nuclear power is widely available through the transmission and distribution system, the benefits of nuclear would still be available to the general pool of customers, as required by the Atomic Energy Act. Also, while large companies would supplant smaller ones, even those "small" companies are sizeable businesses, so nobody should regret it if they decide that their best interest lies in selling their reactors.

The concern raised most recently about the reactor market is not concentration, but continued mobility. Many of the Wisconsin Public Service Commission's questions about Dominion's proposed purchase of Kewaunee had to do with whether Dominion's commitments would be carried over to another owner if Dominion sells later and how the PSC would be able to enforce compliance.

As things stand now, the used-reactor market will remain available, but there does not appear to be inexorable momentum toward nationwide concentration. South Carolina Electric and Gas Company might seem like a candidate to sell out; its Summer plant has a single power reactor, and its service area is surrounded by those of companies with much larger nuclear commitments. Summer has nearly always been a strong performer, however, and SCE&G seems to be happy the way things are. It renewed Summer's license on the reactor's 20th anniversary, the earliest date that a full 20-year extension could be provided.

What about reactors that have not done as well? Both Cook units have been unsteady performers, even more so in the mid- and late 1990s than they were earlier, but American Electric Power, parent of Cook operator Indiana Michigan Power, did not decide to bolt from the nuclear fold when times were tough, and in 2002–2004 both units performed better than they ever had previously. AEP has very deep pockets and wide-ranging interests (it is selling off its minority share of South Texas), but even the smaller and more limited Detroit Edison Company has stayed the course with Fermi-2, its only reactor. Fermi-2 has had a variety of problems, but lately has been able to keep pace with the overall industry performance trend. Detroit Edison has not shown signs of wanting to part with the reactor.

On the other side, not every major nuclear player has sought to expand its holdings. Duke Power and Southern Nuclear appear to be focusing on their existing plants. Duke's interest in more nuclear power appears to be centered on the possibility of building new capacity, not acquiring it from someone else (*NN*, Apr. 2005, p. 11).

Whether or not the used-reactor market covers the entire industry, its existence appears to be one more contributor to the overall improvement in nuclear performance. Even those reactors that never change hands operate in an environment where something like that could happen, and perhaps the desire to prevent such a change adds impetus to efforts to improve performance, even beyond what had been achieved before. NN