failure to mention Canadian gas was taken by some diplomatic observers as tacit endorsement of the Alcan plan.

Increasingly, Canadian officials speak of the Alcan proposal as a "land bridge" across Canada that would allow the United States to move gas to the Midwest without forcing Canada into a major development decision. Because the route follows the Alcan Highway corridor, both native claims and environmental problems would be minimized, they say.

The National Energy Board has been in session on the Arctic Gas case for almost 2 years, hearing evidence on reserves, economics, geology, financing, and pipeline construction. The nominally dry hearings became a national cause célèbre when the chairman of the NEB was disqualified for conflict of interest, and the proceedings were forced by the Supreme Court to start all over again. Now under an expedited schedule, the hearings should be completed before May. However, conservationists and other parties argue that two of the companies exploring in the delta will not have time to do adequate reserves estimates before the hearings close. The NEB says it will make a recommendation without that information.

Even so, a senior energy official says that "as of today, Canada does not have enough gas in the delta to fill its part of the pipeline." Canada, he says, would not encourage "speculation" through the pipeline. "We would not commit ourselves to a pipeline for purposes of delineating frontier reserves."

However, the government is caught in a dilemma partially of its own making. Whereas official policy still supports construction of a Mackenzie valley pipeline (presumably the Arctic Gas project), such a pipeline would have a major, and many say a deleterious, impact on the people and the delta region.

The Canadian north—almost all of it Crown land owned by the government—stretches from the lower provinces to the North Pole. In the past, the natives who inhabit this vast wilderness, numbering only several tens of thousands, have had little political voice. Most Canadians live along the U.S. border and, so to speak, face south. That there should be a growing interest among Canadians in their Arctic region and northern people was unexpected by most Canadian leaders.

One person who may have anticipated the surge of interest in the north, though, is Thomas Rodney Berger, a 43-year-old justice of the British Columbia Supreme Court. The hearings that he conducted for the government in 1975 and 1976 allowed Canadians to see the northern people as human beings rather than as anthropological curiosities (see box).

The Berger inquiry, for the first time, has humanized both the government's decision-making process and the inhabitants of the north. Rarely in the past has there been such an injection of the human element into an energy decision. Berger's final report is due in the spring, but observers feel that it will add little after the drama of the hearings.

The last time a Liberal Party government lost a national election in Canada was 1956. The issue that carried it to defeat was the charge that it had rammed legislation through Parliament to subsidize construction of the trans-Canada pipeline by American oilmen. The analogy with the current situation is not lost on Liberal Party strategists, whose defeat in the Quebec provincial elections last November makes the party even more vulnerable in national elections planned for next year. With a congressionally mandated deadline of 1 December 1977 for a presidential route decision, Canada may be forced to meet the U.S. timetable and make a decision before election time.

Backers of both the Alcan project and the El Paso LNG proposal see the steadily building, and increasingly contradictory, pressures on the Canadian government working to their benefit. "If I were a bureaucrat looking into that Arctic Gas project I'd just throw up my hands and run," says an El Paso executive. "There are just too many other things they can do that are less risky and less expensive."

But Arctic Gas officials are optimistic, saying that they have the best organized, best designed project that will move the most gas for the least cost.

An official in the Canadian embassy in Washington says, in a masterpiece of understatement, "things aren't as simple as they once were."—MARK PANITCH

The author is Washington correspondent for four newspapers in Alaska. He covered some of the Berger hearings in the Canadian Northwest Territories.

Nuclear Power Plants: Why Do Some Work Better than Others?

A snow-covered two-lane road, winding through the gray-green Connecticut countryside, ends in a parking lot before a cluster of trim white buildings dominated by a gleaming dome and a huge barnlike building. The building is a power plant complex surrounded by a chain link fence; to enter it, a visitor is first shown through a metal detector and subjected to a baggage search by uniformed Pinkerton guards. Once inside the fence, it is a short way to the offices of the power plant and that of the plant supervisor, which look out over the blue-white Connecticut River, a portion of whose waters enter the power plant through an intake channel directly below.

This, the Connecticut Yankee plant in Haddam, Connecticut, which is operated by Northeast Utilities, Inc., looks like many other nuclear power generating stations in the country. But Connecticut Yankee is distinctive: since it began operating in 1968, the 630-megawatt plant has been one of the most reliable performers in the nuclear industry.

Richard H. Graves, the 43-year-old plant superintendent, proudly tells his guest that the plant holds the world's record for the number of kilowatt-hours generated from a single reactor and that, at that very moment, the plant is breaking its previous record of having run for 143 days without a shutdown. It has won several industrial safety awards. In 1975, for example, it was one of four nuclear plants to win the industry's Edison Award for "distinguished contribution to the development of electric light and power." Although it has occasionally been shutdown for maintenance, repair, and minor mishaps, Connecticut Yankee has operated very safely.

Plants like Connecticut Yankee are getting more and more attention these days from people engaged in the nuclear controversy. Critics are asking why most plants are not operating 80 percent of the

time, as was claimed years ago. Utility managers, burdened by the soaring prices of fossil fuels, are more and more anxious to get maximum, continuous performance from their nuclear plants.

The people who design reactors, and who build and regulate them, are aware that there are a series of older, smaller plants like Connecticut Yankee, which have performed more reliably than many of the newer, bigger ones. This fact has stirred up a debate, within the industry and among nuclear critics, as to whether in nuclear power plant design, indeed, small is beautiful.

The point is a sensitive one, since the nuclear power industry, with the assent of its utility customers, has been engaged in a rapid escalation of plant size since the late 1960's and stopped building plants the size of Connecticut Yankee years ago. The justification for this escalation was mainly the supposed economies of scale which would come with building first 1000-megawatt, then 1500- and 2000-megawatt nuclear power plants. But partly because the Atomic Energy Commission, concerned over the lack of operating experience with larger plants, put a ceiling on plants above 1300 megawatts a few years ago, and partly because the supposed economies of further size growth have all but vanished, the nuclear power plants under construction today are in the 1000-megawatt range. Today, only 16 percent of the 58 reactors in operation are of this size; according to the Edison Electric Institute, by 1986, fully 90 percent of the 153 reactors then in operation will be in the 1000-megawatt range. The thorny question remains, however, as to why plants like Connecticut Yankee have been more reliable.

Another reason for concern with plant reliability is the better-publicized issue of nuclear plant safety. Many experts argue that there is little correlation between the reliable plant and the safe plant. As one said in a more mundane analogy, "Your car can have four sets of brakes and still be in the shop all the time for transmission repair." On the other hand, other people whose views count think there is a connection. The Director of Nuclear Power Regulation of the Nuclear Regulatory Commission (NRC), Ben C. Rusche, says: "The plant that has to be shut down often has not achieved the degree of maturity, of uniformity of experience, of insight into operation, which is needed for the complete assurance that it will also operate safely." This does not mean that plants that are frequently shut down are unsafe, adds Rusche, but rather that they are "developing a higher level of maturity."

Graves, the superintendent of Connecticut Yankee, has few doubts as to why his power plant has served as a model to the industry. "I'm biased, but I believe that the Westinghouse 600-megawatt pressurized water reactor (PWR) is a beautiful machine. . . . I feel that if the country stopped at the 600-megawatt size and built only those PWR's, we would have 100 percent acceptance of nuclear power in this country."

Interviews with more than a dozen experts, at Northeast Utilities and other power companies, at the NRC and the Federal Energy Administration, indicate that despite his self-confessed chauvinism, Graves has a point: Connecticut Yankee is one of a series of older, smaller PWR's built by Westinghouse that have performed above average by the key indicator of capacity factor, or CF, which is the percentage of actual, as opposed to possible, time a plant is in operation.* Nuclear power plants have an average CF of approximately 60 percent. Fossil fuel plants have an average CF of about 75 percent; Connecticut Yankee has a lifetime, cumulative CF of 80.7 percent.

Experts on nuclear power plant design and operation are loath to draw conclusions about size—or generalize about the other factors which could be responsible for superior plant performance. The industry has not standardized, they will say; every nuclear power plant is different from every other one; besides, there are too many variables: four reactor manufacturing firms, several architect-engineering firms, and literally dozens of utility purchasers. Nonetheless, when pressed, some do offer explanations why some reactors have performed better than others, such as the conservatism of the engineering which goes into the system and its components, the caliber of the utility's engineering staff, and even, some will add, the absence in the old days of myriad government-required add-ons which are making plants increasingly complex and liable to malfunction.

Engineering Conservatism

Connecticut Yankee, like many of the early PWR's, is designed on the basis of a technology which received extensive operational testing in the naval nuclear propulsion program. Vice-Admiral Hyman G. Rickover, who is known as the "father" of today's nuclear navy, in begetting it in the 1950's, opted early on for the PWR over other reactor types. A parallel backlog of operational system and component testing does not exist for the other main reactor type, the boiling water reactor (BWR), which is built by General Electric Corporation. Some BWR's have been among the best performers in the industry, such as the Monticello plant in Minnesota, a 545 BWR with a lifetime CF of 67 percent; nonetheless experts admit that the BWR still has some generic problems, such as salt water intrusions into the reactor containment due to leaky condenser tubes—in fact, Northeast has experienced such problems in its 830-megawatt BWR plant known as Millstone 1.

Plant superintendent Graves says that a similar conservatism, a reliance on proven components also has characterized Connecticut Yankee's operation. For example, when other nuclear power plants changed the type of cladding used to enclose their fuel pellets, from stainless steel to zircalloy, a new material which was believed to be longer-lived, Connecticut Yankee continued to use stainless steel. Later, when the zircalloy started bowing and stretching during use in the other reactors' cores, Connecticut Yankee was spared the resulting repair problems.

Connecticut Yankee and other older plants like it are simpler than the newer, more complex, 1000-megawatt BWR and PWR plants, which statistics have shown have experienced more performance problems. The engineering explanation for this argument is that the fewer and simpler the parts of a machine, the less chance there is of malfunction—a principle also known in engineers' jargon as KISS, or Keep It Simple, Stupid.

Experts offer yet another reason why plants such as Connecticut Yankee have performed better; it is the greater experience which comes with a whole series of reactors of a similar size, type, and configuration. Problems have tended to occur in one-of-a-kind or first-of-a-kind designs, components, configuration, or repair procedures. For example, the first 1000-megawatt plant in the country, a BWR at Brown's Ferry, Alabama, experienced a disastrous fire in 1975, only months after it first started operation. These same experts agree that this constitutes a powerful argument against continuing the one-of-a-kind trends in the nuclear power industry and in favor of standardization. In fact, to some extent the industry is trying to standardize its 1000-megawatt designs.

For example, Walter Fee, Northeast's vice president for system engineering, says, by the time Millstone 3 becomes operational in 1982, there will be no less than 19 other 1000-megawatt PRW's

*These include Yankee Rowe (start-up 1961, lifetime CF 71 percent); San Onofre (start-up 1968, lifetime CF 73 percent); Ginna (start-up 1970, lifetime CF 65 percent); Point Beach 1 (start-up 1970, lifetime CF 72 percent); Robinson 2 (start-up 1971, lifetime CF 73 percent); Turkey Point 3 (start-up 1972, lifetime CF 67 percent); Point Beach 2 (start-up 1973, lifetime CF 70 percent); Turkey Point 4 (start-up 1973, lifetime CF 68 percent). CF figures are from Nuclear Regulatory Commission Gray Book, August 1976.

operating elsewhere in the country, and Fee plans to have his engineers studying the performance of every one. "Millstone 3 will perform as well as Connecticut Yankee," Fee pledges.

Are there other reasons some plants perform better than others? Those familiar with Connecticut Yankee and other successful plants claim the caliber of the people matter as much as the machines themselves. Northeast, for example, has a very large inhouse engineering staff, which numbers about 180, including five Ph.D.'s and 35 holders of the master's degree. Moreover, the engineering expertise of the team that built Connecticut Yankee is well established.

The plant was designed by the Yankee Atomic Electric Company, an unusual organization formed in the late 1950's under the auspices of a group of New England utilities. Yankee Atomic's sole purpose was to design, build, and operate New England's first nuclear station, built Yankee Rowe, a small PWR which became operational in 1960. After this team had operated Yankee Rowe successfully for 2 years (now 17 years old, it has a lifetime CF of 71 percent), the Yankee Atomic team went to work designing Connecticut Yankee. Each of Connecticut Yankee's three plant superintendents, as well as some members of Northeast's current engineering staff, are alumni of the unusually selective Yankee Atomic program, which has no exact parallel elsewhere in the civilian nuclear power industry.

Glenn Reed, of the Wisconsin Electric Power Co., who was a key figure in the Yankee Atomic program, says that often when a utility has lacked its own experts to ride herd on the manufacturer and the architect-engineer, the result has been a poorly performing nuclear power plant. "Only the utility knows what it wants," Reed says. "The manufacturers don't know; they'll sell their reactors to Timbuctoo."

(Reed should know. In 1965, he was hired by the Wisconsin utility where he built and operates two of the other, highly successful, small PWR's, Point Beach 1 and 2. Reed's group at Wisconsin is known for its toughness: potential employees are subject to seven to eight tests, including psychological tests, before being hired; employees, even supervisors, who don't perform are fired. And, Point Beach's special supervisory personnel must live within 12 miles of the reactors themselves. Even the vociferous Chicago-based nuclear critic David Dismore Comey speaks respectfully of the way Point Beach 1 and 2 are managed. Comey calls Reed "the Hyman Rickover of the civilian nuclear power business.")

As for the instances Reed talks about, when utilities have paid a price for inadequate engineering know-how, experts on power plant performance usually cite Consumers' Power experience with the problem-ridden Palisades Plant. Two West Coast plants that have had CF's of 20 percent or less, Rancho Seco and Trojan, are run by the Sacramento Municipal Utility District and Portland General Electric, two utilities without prior experience with nuclear power.

Mixed Blessing of Regulation

Another argument, raised primarily by utility executives, is that government regulations, which are becoming increasingly complex, are making the newer nuclear plants operate less and less reliably. Connecticut Yankee seems to be a rather simple machine, in some ways. A visitor on a guided tour can see the main turbine generator (whose broken blades shut the plant down in 1973) housed in the big, barnlike turbine building. From a viewing porch, the four pipes carrying steam from the generator inside the reactor containment to the turbine generator can be seen, as well as the pipes circulating that steam, now condensed into water, back into the containment. Below, the Connecticut River water is being flushed out of the plant, where it has served its function as the coolant which condensed the steam back into water.

But as he shows his visitor around, Graves also points to the numerous features which the Nuclear Regulatory Commission has forced him to add. There, for example, are the metal trays separating yards and yards of electric cables—these were added after the cable fire at Brown's Ferry. And NRC will require more add-on's in the near future, he says.

Eventually, Graves makes the point which is often repeated by executives at Northeast and elsewhere: Connecticut Yankee and the other, older plants have functioned so well because they were built before government regulatory requirements became so complicated, requiring so many additional systems in violation of the KISS principle. There may come a point, the executives argue, when nuclear power plants will become less reliable, because they have to be shut down all the time to repair all these extra systems.

Such arguments seem at least partly self-serving, and are certainly not surprising, coming from the power business, which for more than half a century has lived uneasily with other forms of federal and state regulation. Nonetheless, from an engineering standpoint, even some of the officials who do the regulating admit that the utilities may have a point. Says Rusche of NRC, who as chief of nuclear plant regulation is as much a bête noire of the power industry as anyone:

"I don't doubt that you can find individual nuclear plants where a particular increment in safety required by us produced a corresponding decrease in reliability. You can add a bell or a whistle and it may not improve reliability. But we make a conscious effort not to require any step today which would invalidate safety levels achieved in the past." Rusche claims NRC has held off from imposing certain new requirements in order to find ways to achieve safety goals without compromising reliability. "And, of course, then we get criticized by the public for not doing enough," he adds.

It is not yet clear how well the utilities, the NRC, or the reactor manufacturers are absorbing the lessons of Connecticut Yankee's success. On the engineering side, there indeed has been a trend away from one-of-a-kind designs and toward standardization. More and more plant designers are studying failures of equipment in the nonnuclear portion of the plant, such as steam turbines, which are a main reason for plant outage time. Whether NRC should or would change its safety requirements to take better account of reliability, is not yet clear: Rusche says the NRC has no formal policy on the issue.

But perhaps the question of upgrading the utilities' manpower is causing the most current concern. Most utilities are not like Northeast, and do not have enlightened, ambitious executives and a technically expert staff of 180. There is genuine concern that one reason for the poor performance of some plants is simply that the companies who are responsible for them simply do not understand what is going on.

"The power business, historically, has been run by people who understood only the traditional technologies of power generation," says a student of the industry, and of plant performance at the Electric Power Research Institute. "Beginning in the mid-1960's, some had to start hiring nuclear engineers to cope with the nuclear plants they were ordering; in fact the government ordered that the utilities have such people on their staffs. But only in the last few years, since the energy crisis, when the entire industry has been transformed, have utilities started making the quantum jump in terms of expertise. Now you see them hiring more Ph.D.-level engineers; now you see more chief executives interested in understanding what's inside the nuclear black box." Whether these changes will permeate the industry enough to influence the current and future reliability of their nuclear power plants, however, remains to be seen.—DEBORAH SHAPLEY