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March 27, 2000

Chief, Rules and Directives Branch
U.S. Nuclear Regulatory Commission
Washington, DC 20555

RE: NUREG-1718, "Standard Review Plan for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility"

The following news articles and Greenpeace International report entitled "Fundamental Deficiencies in the Quality Control of Mixed-Oxide Nuclear Fuel" are hereby being submitted for the official record. Quality control guidelines for fuel fabrication and fuel inspection at any U.S. MOX facility must be included in the final SRP.

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# Pressure grows to sack Sellafield chiefs over false nuclear safety records

*By Severin Carrell*

*23 February 2000*

The Government is under pressure to sack executives at Sellafield and overhaul its safety regime after six European governments protested yesterday over the falsification of nuclear fuel safety records.

Five Scandinavian countries in the Nordic Council demanded that Britain stop all radioactive discharges into the Irish Sea from Sellafield after last Friday's damning report on standards at the British Nuclear Fuels plant.

Environment ministers from Sweden, Denmark, Finland, Norway and Iceland said the council viewed the nuclear installations inspectorate report with "great concern". Svend Auken, the Danish minister, called for urgent talks with Britain. He said it was "unpleasant to have a report which shows how poorly the safety work at Sellafield functions".

The council warned it would force Britain to meet its promise to stop Sellafield's radioactive waste discharges into the sea by 2020 at the Ospar Convention marine pollution conference in Copenhagen this June.

"The lack of safety controls poses serious questions about reprocessing used nuclear fuels and strengthens demands for drastic and immediate improvements at Sellafield," the council said.

Their remarks will alarm ministers. The Irish government, which sent officials for talks with nuclear safety officials in London, have stepped up demands for Sellafield to be closed. BNFL is also caught in an embarrassing row over its mishandling of safety data with the German federal environment minister, Jurgen Trittin, and a German nuclear power company, PreussenElektra.

The company said yesterday it was "surprised and annoyed" by admissions from BNFL that data for four nuclear fuel rods it supplied had been "falsified'. A technician had mistakenly deleted safety data and replaced it by copying earlier data to save repeating the work.

PreussenElektra had been alerted to the error, which did not affect the quality of the fuel, but it had believed the documentation was simply "deficient". It claimed BNFL did not say the data had been falsified.

A spokesman for Mr Trittin, a senior Green Party minister in Germany's SPD/Green coalition who wants Germany's nuclear power stations closed, talked of "a systematic neglect of safety standards". Iceland's Foreign Minister, Halldór Asgrímsson, will warn Robin Cook, the Foreign Secretary, when they meet in London on Friday of his government's fears that radioactive discharges into the Irish Sea could cripple Iceland's fishing industries.

A spokesman for Mr Asgrímsson said: "If something happened at Sellafield it could devastate our economy in two or three years. The Icelandic authorities expect that information concerning this situation is correct, forthcoming and reliable."

A Department of Trade and Industry spokesman insisted the concerns would be addressed by the new inquiry into the data scandal, and said ministers shared the anger over the events at Sellafield.

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# BNFL hit by second false data discovery

**John Hooper in Berlin and Paul Brown**

**Wednesday February 23, 2000**

A German nuclear company was "surprised and angry" yesterday to discover that documents accompanying fuel supplied by British Nuclear Fuels more than three years ago had been falsified. Officials at the company will decide today whether to shut down a nuclear plant the size of Sizewell B.

Sources at BNFL admitted last night the questionable fuel - up to 4,000 pellets of reprocessed mixed oxide - had been inside the German reactor since 1996.

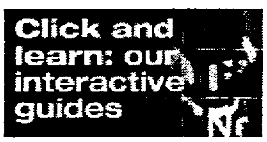
This is another severe blow for the UK company, which has already lost its biggest customer in Japan by supplying fuel with falsified documents. Germany is its other main potential market.

This second example of falsified data is a separate incident and underlines the lax management at the plant, which was heavily criticised by the nuclear installations inspectorate in three reports last Friday.

A spokeswoman for the German company, Preussen Elektra, which runs the power station at Unterweser near the Dutch border, said: "BNFL had always assured us that there was no indication of falsified safety documents. We are utterly astonished."

A decision on whether to shut down the plant for checks will be made at a meeting in Hanover of representatives of the national and regional environment ministries, a federal environment ministry spokesman said in Berlin.

The Unterweser plant, a boiling water

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reactor, generates up to 1,255 megawatts of electricity. Shutting it down during one of the coldest months of the year would cause widespread disruption to power supplies in Germany.

But the discovery that questionable fuel has been in a German reactor for more than three years is of itself an immense embarrassment both to BNFL and the German nuclear industry.

BNFL said yesterday that workers at the mixed oxide plant had measured the batch of pellets as required and were sure they were safe and to specification, but the computer had crashed and the data had been lost. Rather than do the work again, they falsified the data, copying from a previous batch. The fuel was then made into rods, delivered to the German company and placed in the reactor.

BNFL said this was an isolated example. The Japanese falsification had happened much later, when workers had routinely falsified papers rather than laboriously check samples by hand.

Whatever the circumstances, the discovery that BNFL had also sent false papers on plutonium fuel pellets to Germany poses a further clear threat to its commercial relationship. It must set back further the company's prospects for partial privatisation.

BNFL has to justify the commercial prospects for its new £300m mixed oxide plant to the government before it can get a licence to run it - a task which looks virtually impossible since there are no customers.

The revelation comes at a supremely awkward moment for the German power utilities. Gerhard Schröder's coalition government, which includes the Greens, is committed to a phased withdrawal from nuclear energy.

The environment minister, Jürgen Trittin, a Green, on Monday called on the electricity companies to consider whether they should continue their relationship with a trading partner "which has shown itself to be unreliable".

BNFL has now been given two months by the nuclear installations inspectorate to come up with management plans to improve safety or face having some of its operations shut down.

## U.K.'S NII FAULTS SAFETY CULTURE FOR PROBLEMS AT BNFL'S MOX PLANT

Evidence of falsification of quality control (QC) data at British Nuclear Fuels plc's (BNFL) 8-metric-ton/year mixed-oxide (MOX) Demonstration Facility (MDF) dates back to 1996 and would not have occurred had there been a proper safety culture within the plant, the U.K.'s Nuclear Installations Inspectorate (NII) has found.

A total of 31 lots of MOX fuel fabricated between the end of 1997 and September 1999 for Japan's Kansai Electric Power Co. are affected by faulty pellet diameter QC data, NII reported Feb. 18.

This is roughly a third more than the 22 lots originally reported in Takahama-3 fuel by Kansai Sept. 21, 1999 after an investigatory trip to BNFL's Sellafield complex by the Japanese utility officials. They concluded at that time, erroneously as later demonstrated, that the faulty QC was restricted to the eight Takahama-3 assemblies.

BNFL will only be allowed to restart MDF after it has implemented 15 recommendations given in NII's Friday report "to our satisfaction," said NII Chief Inspector Laurence Williams. "In particular, the deficiencies found in the quality checking process will have to be rectified, the management of the plant improved, and operators either replaced or retrained to bring the safety culture in the plant up to the standard" required, he said.

**NII also said that BNFL needs to investigate why its** senior management allowed the MDF situation to develop. BNFL then needs to report back to NII on how it intends to prevent a recurrence.

Said NII of MDF, "It is clear that various individuals were engaged in falsification of important records but a systematic failure allowed it to happen." NII said it found it impossible to establish a motive for the falsification, "but the poor ergonomic design of this part of the plant and the tedium of the job seem to have been contributory factors," as was the ease with which the computer data logging system could be manipulated. A lack of adequate supervision "provided the opportunity," it added.

NII concluded, "There can be no excuse for process workers not following procedures and deliberately falsifying records to avoid doing a tedious task. These people need to be identified and disciplined."

But MDF managers must also share the blame, said NII, because they "allowed this to happen" over a period of three years.

NII's findings in its report covered the pellet diameter data falsification and the effect this had on the safety of MOX fuel in use. Despite faulty QC, the MOX fuel produced for Japan "will be safe" if used, it said. NII based this view on "the totality of the fuel manufacturing quality checks." It said automated primary diameter checks were made on "100% of the pellets used in each fuel rod." Any undersized or oversized pellets were automatically rejected.

The data falsification was carried during a confirmatory second measuring of diameters of a sampling of pellets, which entailed the use of a laser micrometer but with a process worker typing each measured diameter into a computer spreadsheet.

On Aug. 20, 1999, a member of the MDF QC Team identified similarities in the sampling QC data for successive batches of pellets and on Sept. 10, BNFL reported to NII that pellet diameter data appeared to have been falsely copied from certain spreadsheets to others. That prompted NII's investigation into the extent of such falsification and the reasons behind it. Any non-compliance with a nuclear site license requirement is considered a serious matter, said NII.

MDF construction started in 1991 and plutonium active commissioning began in late 1993. The first MOX fuel produced went to a Swiss utility. Fuel of a different design was fabricated throughout 1996 for a German utility. This was followed by further Swiss fuel campaigns during 1997 and, at the end of that year, the Kansai fuel started its manufacture.

NII's report is concentrated on the Kansai fuel QC data falsifications. It does not give any evidence of faulty QC data covering either the Swiss or German fuel, except to say that "one example of falsification has been found dating back to 1996."

At the new Sellafield MOX plant, currently being commissioned, the inspection processes for MOX pellets, rods and assemblies are designed to be almost fully automated, said NII. "This should prevent the falsification of data of the kind described in this report."

NII said that though BNFL initially identified only one shift of process workers as being responsible for the falsifications—three workers out of that shift were fired Oct. 1—an analysis of the data together with staffing records showed that four of the five shifts were involved to varying degrees.

Not only were certain process workers involved, but also some of the "workers who carried the QC stamps," said NII. They were either party to the falsification or were not checking that measurements were being taken. As for the shift team managers, said NII, they tended to spend more time in the area where MOX fuel pellets were being produced, because of "bottleneck" problems, rather than in the fuel rod fabrication area where the secondary measurements were done. "From interviews," said NII, it "learned that little supervision of this task took place other than to simply do ad hoc checks on progress.

"The general view amongst managers was that the secondary check on pellet diameters was considered to be a low-risk job not requiring supervision," said NII. "It was clear that the level of control and supervision of fuel pellet diameter inspection had been virtually non-existent. This may have sent out entirely the wrong message to the process workers and QC inspectors regarding the importance of the task, and acted as a de-motivator."

### Tedious Task

NII particularly faults the tedious nature of the secondary inspection of the sample pellets. "A system where one operator places a pellet in a laser micrometer, calls out the diameter reading and another operator enters this manually into a computer spreadsheet is clearly far from ideal," it said. Indeed, it could prove "more than a minor nuisance to anyone who has to perform (it) on a repetitive basis for any extended period of time," it said.

"The failure to recognize and redesign this during the years of operation is another example of BNFL's failure to manage MDF properly," said NII. With the benefit of hindsight, it said, "the occurrence of non-compliant behavior is not at all surprising.

"Automation of the laser readout straight to the computer would have eliminated one tedious task, reduced the likelihood of errors and allowed the sharing of the remaining task of placing the pellets in the micrometer for measurement," it said. In fact, its first recommendation is for BNFL to do just that.

Copies of the report, "An investigation into the falsification of pellet diameter data in the MOX Demonstration Facility at the BNFL Sellafield site and the effect of this on the safety of MOX fuel in use," are available from the U.K. Health & Safety Executive's Nuclear Safety Directorate Information Center, Room 004, St. Peter's House, Balliol Road, Bootle, Merseyside L20 3LZ. Tel: 44 151 951 4103. Fax: 44 151 951 4004. Or by e-mail (nsd.infocentre@hse.gov.uk). The Internet address for the report is (http://www.hse.gov.uk/nsd/mox1.htm).

*—Pearl Marshall, London*

## BNFL'S TAYLOR, THORP DIRECTOR MEET WITH KANSAI ON DATA FALSIFICATION

British Nuclear Fuels plc (BNFL) CEO John Taylor and Thorp director Chris Loughlin met with top managers of Kansai Electric Power Co. in Osaka on Feb. 18 to discuss BNFL's own 21-page account of the falsification of quality control (QC) data governing mixed-oxide (MOX) fuel fabricated for the Japanese utility and to try to re-establish a client relationship, according to BNFL officials in the U.K. and Japan.

BNFL's report blamed the QC data falsifications on "poor employee work ethic amongst certain MDF (MOX Demonstration Facility) employees; inadequate compliance with and implementation of quality assurance systems; and failure of QC processes."

Taylor told his Kansai counterparts those problems were compounded by weak and inadequate supervision and management. He explained that the impact of the event was exacerbated by a three-week delay between the discovery of data irregularities and the notification to BNFL executives, the customer, and the regulators.

Taylor outlined BNFL's overall strategy for a new start for MOX, including a detailed "Action Plan" to recover from the situation and to prevent a recurrence. This constitutes the second part of BNFL's report, which BNFL issued in the U.K. on Feb. 18.

Taylor's team went to Japan one week after a similar visit by a high-level delegation of U.K. government officials from the Department of Trade & Industry (DTI) who discussed problems related to the data falsifications with Japan's Ministry of International Trade & Industry (MITI) and other organizations. That team left Japan with key issues still unresolved, including the question of what to do with the QC-tainted fuel already fabricated and delivered to Kansai for use in Takahama-4, a PWR. The eight assemblies are stored in a pond at the reactor site.

It was the discovery of the Takahama-4 MOX fuel irregularities that prompted Kansai and MITI to reject the MOX in December.

Last week's meeting in Japan marked the first time Taylor has met with Japanese officials on the subject of the MOX fuel since Kansai decided not to load the fuel. Sources in Japan said Taylor last met with Japanese officials on the issue in October, after the U.K. Nuclear Installations Inspectorate (NII) confirmed that QC data for Takahama-3 fuel had been falsified. That occurred before BNFL, NII, Kansai Electric, or MITI acknowledged that data for Takahama-4 fuel, which arrived in Japan on Oct. 1, also were falsified.

During the intergovernmental meetings the second week of February, diplomatic sources in Japan said, MITI pressed DTI and the U.K. government to take back the fuel soon. Japan's Ministry of Foreign Affairs was less insistent, sources said, noting that there are yet-to-be resolved "contractual and legal problems" that would constrain any near-term schedule for the return of the MOX to Britain, including the need for U.S. approval.

**"Would the U.S. like something this controversial** coming up during an election year?" asked one source. Another issue might arise concerning the classification of the returned fuel, especially because it is unlikely to be recycled for return to Japan. BNFL's contract bars the retention of foreign nuclear "waste" in the U.K.

The Takahama-4 MOX fuel transport was 10 years in the planning by the time it left Europe in July. Some believe that an early return of that fuel, possibly in six to nine months, would be "totally unrealistic," even though the DTI team promised to look at all the options, including sending the fuel back to the U.K. "as soon as possible."

Japanese sources said that Kansai and MITI want to move the fuel to Britain largely for political reasons. Both are under fire from Japanese politicians and the public following the late determination that QC data were falsified. In addition, Kansai is paying for safeguards and physical protection of the fresh MOX at the Takahama site and, sources said, may be squeezed by local authorities to pay additional fees to indefinitely store the MOX.

BNFL officials would not comment on whether the company would suggest to the U.K. government, in preparation for additional meetings with the Japanese in coming weeks, that the MOX be moved from Takahama to another site in Japan. The move would be aimed at relieving pressure on Kansai and at giving BNFL and the U.K. government more time to prepare for the eventual return of the MOX to Britain.—*Pearl Marshall, London; Mark Hibbs, Bonn*

## PETTEN OPERATORS SEEKING FUNDS TO SEND DUTCH SPENT FUEL TO U.S.

Operators of the High Flux Reactor (HFR) at Petten, the Netherlands say they are ready to send spent fuel to the U.S. instead of storing it in the country, provided the Dutch government pays the extra cost of the U.S. sendback option.

The sendback option is favored by the Dutch environment minister, Jan Pronk, as well as by Greenpeace, which doesn't want to see the fuel stored temporarily in waste agency Covra's low- and medium-level waste building at Vlissingen, near Borssele.

A senior official responsible for nuclear issues in the environment ministry, Hans Van Halem, said Feb. 17 he had transmitted the request for funding from Petten to the minister and was awaiting a response.

Pronk last week issued two revised transport licenses, one to move the spent fuel from Petten to Vlissingen and the other to move spent fuel from the shuttered Dodewaard BWR to a commercial port near Vlissingen for shipment to British Nuclear Fuels plc's Sellafield site. The original licenses, challenged by Greenpeace, were annulled Nov. 29 by the Dutch supreme administrative court on grounds of both procedure and content.

The European Commission's Joint Research Center (JRC) earlier had said the HFR fuel couldn't be brought from the reactor site to port in time for a planned shipment of spent fuel from European research reactors to DOE's Savannah River site. But the spring 2000 shipment has now been reprogrammed for this fall. Petten officials say there is just enough time to arrange for the HFR fuel to make that schedule, provided the environment ministry agrees to pay the 14-million-guilder ($6.27-million) cost of the transport.

Andre Versteegh, managing director of the Dutch nuclear engineering company NRG, which operates HFR for the JRC, said the European Commission (EC) has already paid for storage of the fuel at Covra, so it doesn't think it should have to bear the cost of the shipment to the U.S.

In a recent exchange of diplomatic notes, the U.S. government agreed to take back the Petten fuel and supply new high-enriched uranium (HEU) fuel for the HFR if needed, and the EC agreed to study conversion of the reactor's core to low-enriched uranium and to convert if the project proved technically and economically feasible.

The Petten fuel was loaded last year into two cast iron MTR-2 casks in preparation for the shipment to Covra. The MTR-2 doesn't have a valid license in the U.S., observed Covra director Hans Codee, saying, "That's going to be a problem" if the fuel is to be shipped to the U.S. in the near future.

Versteegh said operators of HFR were in the U.S. two weeks ago to discuss practical aspects of the potential transport.

Versteegh said he had informed Pronk this week that JRC is ready to consider the U.S. sendback, avoiding temporary storage of the spent fuel at Borssele, if the government supports the financial consequences. He said he also asked, however, that the ministry support a backup solution of storage at Covra should the transport not prove possible.

The Dutch operators have not been able to move any spent fuel since 1997. NRG had to unload the fuel from HFR to make room in the reactor's spent fuel pool.

Versteegh said that if the fuel can be moved off site, the next transport from Petten won't be needed until 2003, when Covra expects to have completed its HABOG vault facility for long-term storage of high-level waste. Under the JRC's contract with Covra, the spent fuel can be stored in HABOG along with vitrified high-level waste expected to come back from reprocessing in England and France. Versteegh said that some fuel will have to be stored at Covra in any case, since not all Petten fuel is of U.S. origin.

Asked whether Petten is interested in sending its fuel to Cogema for reprocessing, as other research reactor operators have done, Versteegh observed that "Greenpeace wouldn't like that."

Samsom said the HFR Petten spent fuel issue is a difficult one for Greenpeace. "All scenarios are bad," he said. "Petten is too full, Covra hasn't a bunker for high-level waste, and the U.S. is very, very far away. But the least unattractive scenario is the U.S. takeback." Samsom said Greenpeace "has to face" the reality that the HFR is essentially used to produce medical isotopes and thus its further operation is justified.

**Reprocessing?**

Opposition to reprocessing of Dutch power reactor spent fuel is also increasing, since it's not clear where the resulting plutonium and/or uranium would be used.

The Dutch parliament is scheduled to debate in June whether it's possible to recycle plutonium coming from reprocessing of fuel from Dodewaard and the Borssele PWR spent fuel as mixed-oxide fuel in Borssele, the country's only remaining power reactor. Borssele's operator, EPZ, wants to extend the reactor's life beyond the current legislative limit of 2004. However, one nuclear official said that even if Borssele operated for 11 more years, it could recycle only 500 kilograms of separated plutonium, leaving 1,500 kg of potential Dutch plutonium without an end use.

Greenpeace is strictly opposed to shipment of the Dodewaard fuel to Sellafield, said the environmental organization's Diederik Samsom. He said that if the new license gives reprocessing as justification of the transport to Sellafield, Greenpeace will attack it once again in court.

The licenses, issued Feb. 15, don't take effect for six weeks, to allow time for public comment and legal challenge.

GKN needs to conduct some 20 Dodewaard spent fuel uranium concentrates to Kazakhstan. According to the application filed by Global Nuclear Fuel, the General Electric, Hitachi, and Toshiba joint venture, "the uranium concentrates are in the form of dry, non-irradiated uranium compounds that have the general consistency of coarse powder. These concentrates are a byproduct of normal nuclear fuel fabrication and are not currently suitable for fuel fabrication without further processing. The concentrates will be processed into the form of ceramic-grade UO2 powder and the entire quantity of uranium, less a small process loss will be returned to Global Nuclear Fuel for use in the fabrication of nuclear fuel." The processing in Kazakhstan will be done at the Ulba Metallurgical Plant. Global Nuclear fuel said the shipments to Kazakhstan will be made over the next 23 months.

**In The Market . . .**

There has been little change over the past two weeks in the generally bearish outlook of most uranium analysts. Supply still seems abundant, and demand, especially in the spot market, is weaker this year so far than some analysts had expected. "I see nothing on the horizon to push prices up," said one analyst.

Energy Northwest is again looking for enriched uranium product for WNP-2. And once again the utility has specified how much money it wants to spend (about $26-million), which at today's prices, roughly equates to about 900,000 lb U3O8 equivalent and about 210,000 SWU.

Pacific Gas & Electric is out looking for 10,000 SWU for delivery by Dec. 1. Bids were due last Friday.

The Netherlands EPZ is said to have selected a supplier for over 365,000 lb U3O8 contained in UF6 for delivery over this year and next.

Korea Electric Power Co. is looking for about 6.5-million lb U3O8 for delivery between 2001 and 2005. Bids are due Feb. 29. The utility is said to want only half the uranium to be of CIS origin.

Japan's Hokkaido Electric Power Co. is said to be out looking for about 800,000 lb of U3O8 for delivery in 2000-2001. Bids are due March 1.

In NuclearFuel's judgment, significant open-market transactions in the U.S. during the forward two-week period could be concluded within the range of $8.90-$9.40, the same range reported two weeks ago. So-called unrestricted buyers could probably conclude a deal within the range of $7.20-$7.70/lb, the same range reported two weeks ago.

USEC Inc. said that it has won additional enrichment business in South Korea. In an announcement last week, USEC said that Korea Electric power Corp. had agreed to extend its current enrichment contract with USEC from 2007 through 2009 and to buy additional quantities between 2004 and 2007. The new business, USEC said, amounts to about $150-million. But to get that new business, some analysts said, USEC most likely had to offer very attractive prices that could very well be below today's estimated long-term enrichment services price of $85/SWU.—*Michael Knapik, Washington*

## U.K. ENERGY MINISTER SAYS CHANGES IN BNFL MANAGEMENT ARE NEEDED

U.K. Energy Minister Helen Liddell has called for a thorough review of management at British Nuclear Fuels plc (BNFL) following publication of a Nuclear Installations Inspectorate's (NII) report that said safety performance had deteriorated at the company's Sellafield reprocessing and waste management complex.

NII pinpointed "weaknesses in control and supervision" at the site that had caused an apparent increase in the number of "incidents" detected during the first half of 1999. The site lacks a high-quality safety management system, the report said. NII's management report was issued at the same time as its account of mixed-oxide (MOX) data falsifications at one of Sellafield's plants.

Liddell said Feb. 18 that NII's reports had documented "serious management failures." She said she had asked BNFL Chairman Hugh Collum for "comprehensive and radical suggestions" for changes over the next two months aimed at delivering "the management the company needs." The review "should regard no one and no level in the organization as out of bounds," she said. "I know that Hugh Collum shares my view of the need for change."

Liddell's strong statement did not go as far as calling for senior heads to roll as some industry observers had expected. Rumors have been rife in U.K. government corridors the past week that a BNFL senior manager would be "required to fall on his sword" over the Japanese mixed-oxide (MOX) fuel data falsification scandal and NII's disturbing analysis of the Sellafield management and safety culture.

The rumors have been, in part, sparked by U.K. Trade Secretary Stephen Byers' comment earlier last week that the falsifications arose because of a "fundamental flaw in the management at BNFL," He told the all-party Trade & Industry Select Committee on Feb. 15 that the situation "has got to change."

Liddell started making similar statements as early as Dec. 16, after she had conveyed to BNFL executives the U.K. government's "very grave concerns" about the faulty quality control exercised at BNFL's MOX Demonstration Facility (MDF) for fuel being made for Kansai Electric Power Co. Liddell reportedly said last week that BNFL's sackings "would not end" with the five fairly junior MDF employees that have so far been let go.

In her Feb. 18 statement, Liddell said she wrote to Collum at the beginning of the month that "there needed to be a root and branch review of the company."

Collum became BNFL Chairman Oct.1, 1999 with a clear remit to inject private sector disciplines into BNFL management, according to DTI sources. A couple of years earlier, BNFL had instituted a business driven cost-cutting program known as "Beyond 2000" as part of its efforts toward eventual privatization. Figures produced by BNFL show Sellafield employment rolls have already dropped by

1,000 since 1995, from 7,500 to 6,500. Companywide, the reduction went from 16,000 in 1993 to 13,000 in 1999, but this latter 1999 figure does not include BNFL Magnox Generation staffers.

NII Chief Inspector Laurence Williams referred to the Sellafield cuts when he addressed a London press conference marking the release of the reports Feb.18. "In terms of the middle management that is carrying out the control and supervision, we believe that the cuts there have gone too far," he said. "Those managers do not have sufficient time to actually monitor and control what I believe are key safety-related operations.

"We want that to be addressed. We want those managers to have their numbers increased; we want them to be given more time to actually spend on the plant talking to their staff, watching what's going on. Changes will have to be made. That's for sure," he stressed.

Williams said NII would use its regulatory powers to ensure that BNFL implemented 28 recommendations listed in its management review. These were aimed at reversing the decline in the Sellafield site's safety performance. BNFL needed to "fully meet the standards that are expected of a nuclear site licensee," he said.

NII gave BNFL two months to produce a program responding to the recommendations.

"Sellafield is not unsafe," NII stressed, "but strong management action is needed to ensure that it both remains safe into the future and that BNFL makes the practicable improvements which can reasonably be expected."

NII carried out a three-week on-site investigation in September 1999 into the apparent increase in incidents at Sellafield. The team had 11 NII inspectors, an additional two from another regulatory division, and some administrative backup. It focused on three areas: management, control and supervision of operations; adequacy of resources and staffing; and incidents.

When inspectors were on-site, an enforcement notice had to be served on BNFL requiring improvements to the company's system for controlling risks to persons working at heights.

NII said BNFL had recognized a number of shortcomings identified by the regulatory inspection and had started to make improvements. A "program of initiatives intended to improve safety in a number of areas" had been put in place, it said, and BNFL had agreed to undertake a systematic assessment of the resources required by its current activities before making any further change to its organizational structure.

NII said there were three key conclusions from its inspection. The first was the lack of a high quality safety management system across the site which was compounded by an overly complex management structure. The second was that there were insufficient resources to implement even the existing safety management system. The third was a lack of an effective independent inspection, auditing and review system within BNFL.

Without a vigorous independent checking procedure, said NII, it did not see how BNFL could "make acceptable and timely progress in delivering a high quality safety management system.—*Pearl Marshall, London*

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# Sellafield told 'clean up your act or close down'

More about the British nuclear industry

**Paul Brown, Environment Correspondent**
**Saturday February 19, 2000**

Government safety watchdogs yesterday threatened to shut down commercial activities at Britain's biggest nuclear site, at Sellafield, after damning reports set out a catalogue of "systematic management failures" which allowed workers to routinely falsify quality assurance records.

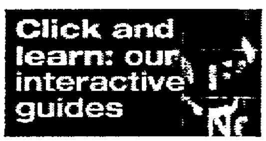
Three highly critical reports from the nuclear installations inspectorate (NII) demanded that senior management of British Nuclear Fuels (BNFL) be held responsible for the comprehensive failure of safety culture at the site, in Cumbria.

Laurence Williams, NII chief inspector, said: "It's no use sacking a few production workers. Responsibility must start at the top."

But the government decided to take no immediate action, instead giving Hugh Collum, the new BNFL chairman, two months to come up with sweeping management changes to restore confidence in the company.

A Downing Street spokesman said: "This is serious, it is unacceptable and something needs to be done about it. Something will be done about it."

Number 10 issued a statement supporting the actions of energy minister



Sellafield safety 'only just tolerable'

Mirror duo sacked after share scandal

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Quitting Europe 'would not bring big job losses'

Halifax plans begging letters to clients

Science Museum in talks with Smith as crisis threatens jobs

Gang of four guilty of drowning student

Criticised Lawrence case officer retires

Anger as Shipman escapes trial over 23 deaths

Power grid put at risk by solar eruption

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Three questioned over stabbing of traffic warden

Executed soldiers honoured

British GP drowns in Australia

Hijack Afghans moved

Helen Liddell. "I have asked Mr Collum for comprehensive and radical suggestions for change, which will deliver the management that the company needs, within two months," she said. "The review should regard no one at no level in the organisation as out of bounds. I know that Hugh Collum shares my view of the need for change."

The reports follow a series of safety incidents at Sellafield which prompted the inspection. At the same time, a set of falsified data was found involving mixed plutonium and uranium fuel (Mox) which was being manufactured at Sellafield for use in Japanese reactors.

The Japanese discovered they had been misled just before the fuel was loaded into their reactors in December and said they could no longer "trust" the company. They are demanding that Britain sends armed ships to Japan to bring the suspect fuel home.

The section of the plant where the falsification occurred is shut down and will not be allowed to restart until the NII is satisfied that the recommendations have been implemented.

This has placed in jeopardy government plans to sell off 49% of BNFL, which have been postponed until after the election. It has also made it near impossible for BNFL to justify opening its £300m Mox plant which needs ministerial approval. The company must prove it has orders for the fuel, but its main customer is Japan.

Poor design of the plant, the tedium of the job. and the ease with which the computer dating logging system was manipulated were all blamed for the falsification problem

Five production workers had been sacked but despite the NII's conclusions that management was to blame no other action has been taken. The report says the site is safe but "the standard of achievement was only just tolerable".

Individual workers were blamed for safety incidents when "there was a trail of poor standards tolerated by management". The attitude of blaming workers for management failures had hit morale, the report said.

Mr Williams said unless the company comes up with solutions within two months he will order the closure of

Star find by amateur astronomer

'Blunder' over naval vetting

Table talk Hussein Chalayan named fashion designer of the year

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Village fights to save heart of community - its school

Food for thought and Freud

A creator of life, but not as we know it

The Observer

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"commercial operations from which the company makes its money."

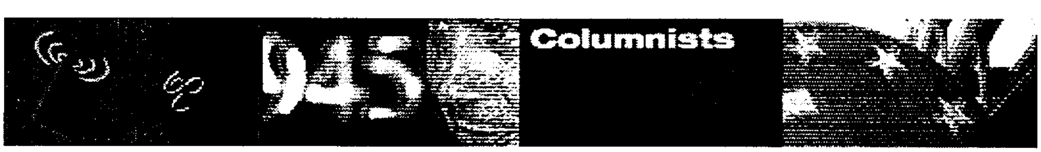
BNFL chief executive John Taylor and Chris Loughlin, the BNFL board director responsible for Mox business, both of whom could lose their jobs, were yesterday in Japan trying to convince customers that Mox was safe and they should buy some after all.

Mr Taylor said: "We deeply regret these events and the problems they have caused for our customers. We now need to get on with implementing the action plan and restoring our credibility."

Brian Watson, head of the Sellafield site, said: "This has been a shock for us all. It is not good news for our Mox business. We have to drive forward and change the [safety] culture. We have to remember that nobody is saying that Sellafield is unsafe. Safety is, and will always be, our number one priority."

Pete Roche, a Greenpeace nuclear campaigner, said "These reports are a shocking expose of Sellafield's plutonium business. This is a company dealing with one of the most hazardous materials known to mankind and they have been shown to be guilty of lax management and falsifying records.

"The government must act decisively to end nuclear reprocessing and also refuse BNFL the go-ahead to start commercial production of Mox fuel. A mere management reshuffle would be like re-arranging the chairs on the Titanic. Plutonium, once thought to be more valuable than gold, is now worse than useless. This is a dangerous, dirty trade that should be confined to the dustbin of history."



# Critical Sellafield report blames management failure

*By Andrea Babbington*

*18 February 2000*

British Nuclear Fuels management has been strongly criticised in an official report into falsification of fuel data at its huge Sellafield site.

As expected, the report from the Nuclear Installations Inspectorate (NII) said that "systematic management failure" at the Cumbria plant allowed individual workers to falsify quality assurance records in a problem that began in 1996.

Poor design, the tedium of the job and the simplicity with which computer dating logging systems could be manipulated were all blamed for the problem.

But the report said that although data was falsified it would have no effect on the safety of fuel in a nuclear reactor.

Chief Inspector of Nuclear Installations Laurence Williams said: "The deficiencies found in the quality checking process will have to rectified, the management of the plant improved and operators either replaced or retrained to bring the safety culture in the plant up to the standard HSE requires for a nuclear installation."

The plant – which manufactures uranium and plutonium mixed oxide (MOX) fuel rods – is now shut down. It will not be allowed to restart until the report's recommendations have been implemented.

Five process workers have been sacked and BNFL today accepted its responsibilities following the report – although it is not expected to sack any executives.

Today's report said that several process workers had not been following quality control procedures.

"There is no doubt that data falsification took place and MOX fuel assemblies have been produced and in some cases delivered to the customer with quality assurance documentation which included falsified data," it said.

The 40–page report concludes: "The events which have been revealed in the course of this investigation could not have occurred had there been a proper safety culture within this plant.

"There can be no excuse for process workers not following procedures and deliberately falsifying records to avoid doing a tedious task. These people need to be identified and disciplined.

"However the management on the plant allowed this to happen and since it had been going on for over three years must share responsibility."

In a separate report the HSE said Sellafield lacked a high quality safety management system.

Union officials described the reports as "devastating" and called for changes in the safety culture at Sellafield.

Jack Dromey, National Officer of the Transport and General Workers' Union, warned that a failure to act on the reports threatened the future of the state–owned company which employs 20,000 workers.

"Old habits at Sellafield die hard. The company must bear the brunt of the blame for the fragmentation of the management and irresponsible cuts to manning levels."

Brian Strutton, National Officer of the General, Municipal and Boilermakers, said the company must now demonstrate that all safety and quality systems were "totally robust".

Environmental campaign group Greenpeace said it was time for the Government to end nuclear re–processing at Sellafield.

"The whole plutonium business is rotten to the core," said spokesman Peter Roche.

BNFL said it fully accepted the reports and their recommendations and said actions were already under way to improve the safety culture.

news | UK | Environment Up

# Ministers step in over BNFL safety scandal

*By Michael Harrison, Business Editor*

*17 February 2000*

A damning report into the falsification of plutonium data at BNFL's Sellafield plant will show that it took place on a much wider scale and for much longer than thought. Ministers are demanding a boardroom sacking at the company.

The report, to be published tomorrow by the chief inspector of Nuclear Installations, Laurence Williams, will reveal that falsification of safety data at the mixed oxide fuel facility has been going on secretly since 1996. The report will state that there was a management culture at Sellafield that allowed the falsification of safety records to take place.

BNFL insiders said last night that John Taylor, the chief executive, and Chris Loughlin, the board member responsible for the facility, were both fighting for their jobs. One of themis likely to be asked to resign. A third board member, David Bonsor, who runs the company's American business, BNFL Inc, is on standby to be drafted in as acting chief executive if Mr Taylor is forced out.

Ministers are understood to have demanded a scalp following the disclosure in *The Independent* last year that safety records relating to shipments of uranium and plutonium mixed oxide (Mox) fuel bound for Japan were systematically falsified. The Mox demonstrator plant where the falsification took place began operations in 1994. It is thought that safety data began to befalsified two years later.

The chief inspector's findings are almost certain to sound the death knell for hopes of part-privatising BNFL during this parliament, a move that would have raised £1bn-£1.5bn for the Government through the sale of a 49 per cent stake. Hugh Collum, the chairman of BNFL, is thought to have advised ministers last Friday that they should delay turning BNFL into a Public Private Partnership until after the next election.

So far only five BNFL employees, all of them process workers, have been fired over the falsified safety records. But ministers have become slowly more alarmed and angry as the scale of the problems has emerged.

Helen Liddell, the Energy minister, is understood to have met Mr Collum 10 days before Christmas and told him that heads were likely to roll at a senior level.

On Tuesday Stephen Byers, Secretary of State for Trade and Industry, told a Commons select committee: "The events [at

Sellafield] show a fundamental flaw in the management at BNFL and that has to change."

Last night a senior Whitehall source said: "It is public knowledge that the Nuclear Installations report is being published on Friday and it is becoming clear that it is pretty serious stuff. You heard what Stephen said on Tuesday. You will have to draw your own conclusions from that."

Mr Taylor and Mr Loughlin are in Tokyo, attempting to reassure Japanese customers and the country's nuclear regulators, that the problems at Sellafield have been overcome. They are expected to be out of the country when the report is published.

Mr Taylor is understood to have told the Japanese in good faith that the falsification of data did not involve the Mox fuel already en route. It was only later, after the inspectors went in, that it became clear this was not the case.

Mr Taylor was brought into BNFL from the oil giant Exxon in 1996 and has overseen its expansion into nuclear fuel manufacturing and waste clean-up through the takeovers of Westinghouse's nuclear operations in the US and those of ABB in Europe. His supporters say that attempts to improve the operation of the company have been resisted by the "Windscale man" culture that still permeates BNFL. Mr Loughlin, the director responsible both for Mox and the £2.6bn Thorp reprocessing facility at Sellafield, has been with BNFL for 19 years.

One source said: "The instinct of the company will be to protect Sellafield, which means that Taylor's position could be undermined. If he goes, it will be a triumph for Windscale man and that would be a tragedy."

# FUNDAMENTAL DEFICIENCIES IN THE QUALITY CONTROL OF MIXED-OXIDE NUCLEAR FUEL

Dr Frank Barnaby/Shaun Burnie
Greenpeace International
Fukushima City, Japan, March 27th 2000

## INTRODUCTION

In September 1999 it was revealed that British Nuclear Fuels (BNFL) had falsified quality control data during the production of plutonium Mixed Oxide fuel (MOX) for a Japanese client. In subsequent months further details have emerged on the quality assurance standards applied by BNFL, as well as their Belgium competitors, Belgonucleaire. Just prior to the release of this report, it has been revealed that French plutonium company Cogema has falsified quality control data for MOX fuel being used in a German nuclear power plant. The scandals have shaken public confidence in Japanese industry plans to use MOX fuel, as well as industry confidence in the reliability of BNFL as a fuel supplier. The majority of reports, including from the UK governments Nuclear Installations Inspectorate (NII), have tended to define the problem as being due to worker boredom, poor ergonomic design of the MOX plant, and inadequate management supervision during MOX production. However this Greenpeace assessment, based upon the publicly available literature points to a far more serious problem: that current MOX quality control standards are low. In addition, it is suggested that the actual production technology currently utilized cannot guarantee a reliable product in important areas vital for the safe operation of a reactor using MOX fuel. Without rigorous quality control standards, the reliability and safety of MOX fuel cannot be guaranteed, with major implications for nuclear reactor safety and public health.

The quality assurance data that has so far been disclosed has given independent analysts a unique opportunity to assess both the standards applied by BNFL and Belgonuclaire, as well as an insight into the quality of the actual production. However, BNFL, Belgonucleaire (and the French plutonium company, Cogema) never intended to make public the data that has now been released, and they continue to withhold extensive and important data on the production standards applied and quality assurance. Citing commercial confidentiality, they are rightly under intense pressure to release all relevant data. This report is the first attempt to assess what information they have released to-date. It has enabled us to reach some preliminary conclusions, but raises many more important questions that remain to be answered.

## MEANING OF QUALITY CONTROL

Quality control involves a system of inspection, analysis and action applied to a manufacturing procedure in which a small fraction of the product produced is inspected to make an estimate of the overall quality of the product. The changes, if any, which must be made in the manufacturing operation to achieve or maintain the required level of quality are then determined. Normally, each of the items produced has a set of specifications, which must be satisfied to meet the needs of the customer. The specifications may be set by the customer, with reference to the intended use of the product, by the relevant manufacturing organization, according to its understanding of the customer's intended use, or they may be legally defined. Quality control is then the set of activities in manufacturing the item, which has the aim of ensuring that the specifications of the finished product are satisfied.

The term quality assurance includes all the technical and management aspects of product quality and safety during the entire manufacturing process - design, specification, research and development, manufacturing and use stages. In other words, quality control refers to the technical aspects of the inspection procedures, including analysis and action, while quality assurance involves actions by, and is the responsibility of, the relevant managers of the manufacturing firm, including the active supervision of the staff doing the quality control operations.

From time to time, quality standards must be reviewed and quality operations undertaken to ensure products remain satisfactory to the customer. Because manufacturers generally want to make a profit, they aim to perform quality control with minimum costs, to obtain the specified product quality at the lowest feasible cost.

Inspection and testing of the product are, for cost reasons, normally performed at various points in the production process, so that it can be seen if the specifications are being conformed with at all stages of production. This avoids waste; it can be costly if non-conformity is determined at the final stage of production. Usually, therefore, there are key points in the production process at which inspection and checking are essential. If they are to be effective, quality control operations should be incorporated into the overall organization. Moreover, the manager in charge of quality control should report to the most senior manager responsible for manufacturing the product (typically, the works manager), who should be responsible for both the quantity and quality of production.

The range of characteristics of the product checked, the frequency of checks, and their thoroughness, should be determined by the consequences of the use of a faulty product. If, for example, the safety of people would be jeopardized by a faulty product, the quality control and quality assurance must be particularly stringent. Where relevant, the type, range and frequency of checks should be based on estimates of the degree of risk to people that is acceptable. Faulty mixed-oxide (MOX) nuclear fuel pellets - containing large agglomerates of plutonium, for example - could produce hot spots, which could damage the cladding of fuel rods and threaten the safety of the reactor using the MOX fuel. The quality control of MOX pellets should, therefore, be determined by estimates of the risk to reactor safety of defective MOX pellets.

This should be done separately for each type of check made on the pellets. In other words, the fundamental principle of quality control (particularly the detail of characteristics checked and the frequency of the checks) and quality assurance of a product like MOX fuel should always be based on risk assessment and not on cost. The evidence, described below, suggests that this is not happening in the production of MOX fuel. Quality control and assurance procedures are not based on acceptable risk analysis; they are determined instead by cost considerations. If they were based on safety rather than cost, MOX production may well prove to be not viable economically.

## THE MOX PRODUCERS

European commercial MOX fabrication plants are operated by: British Nuclear Fuel Limited (BNFL) at Sellafield, England; Belgonucleaire at Dessel, Belgium; and Cogema at Marcoule and Cadarache, France. The Belgian MOX production plant at Dessel, PO, is operated by Belgonucleaire, started commercial operation in January 1985. It can produce 35 tons of heavy metal (LWR) MOX pellets and rods per year (tHM/y). Final assembly of the fuel is conducted at the nearby Franco-Belge de Fabrication de Combustible International (FBFC) site. The French plant at Marcoule, MELLOX, started commercial operation in 1995. It has a current operating capacity of 100 (tHM/y), though Cogema plan that it eventually produces 250 tHM/y. Cogema's other MOX plant is located at Cadarache, and started operating in 1969. It has a nominal capacity of 40 tHM/y but produces significantly less than this. It can produce MOX for fast breeder reactors, using the COCA process, and MOX for LWRs, using the MIMAS process (see below).
The MOX Demonstration Facility (MDF) at Sellafield operated by BNFL, originally a fast breeder reactor (FBR) fuel manufacturing plant during the 1970's and 1980's. After 1989, its capacity was increased and converted to LWR MOX production, which began in October 1993. It has a capacity of 8 tHM/y and is a pilot (demonstration) plant devoted to LWR MOX fuel. The Sellafield MOX Plant (SMP) was completed in 1997, but has not yet been fully licensed to operate. Owned by BNFL, it has a capacity of 120 tHM/y.

## MOX PRODUCTION TECHNOLOGIES

Two different processes are used to produce MOX fuel in European plants. BNFL uses the Short Binderless Route (SBR) process; Belgonucleaire and Cogema use the Micronized MASter Blend (MIMAS) process. SBR was developed by BNFL as a result of its experience in developing and fabricating MOX fuel for fast breeder reactors. BNFL claims that, by the nature of the process, the MOX fuel pellets produced by the SBR are more homogenous than those produced by MIMAS.

SBR uses an attritor mill to blend the uranium dioxide (UO2) and plutonium dioxide (PuO2) powders and a spheroidiser to condition the blended mixed oxide (MOX) powder to convert it into a suitable feed for a press. The attritor mill is a high energy stirred ball mill, using a static mill pot with a stirred ball charge, that breaks down powder agglomerates and is supposed to produce intimately mixed, finely divided micronised (particles of micron size) MOX powder. The size of PuO2 particles is reduced to that of UO2 particles. Milling times are less than one hour, very much (up to ten times) shorter than in a conventional tumbling ball mill. The milled powder from the attritor is passed to the spheroidiser that is also static and operates at a much slower speed, gently tumbling the powder. The spheroidiser is a vertical disc-shaped chamber fitted with a rotating blade driven from a central axis. The powder tumbles between the blade and the outside wall of the disc. This tumbling process causes the finely divided powder particles to agglomerate, and is supposed to produce a granular material that flows well, a good free-flowing powder feed for the press.

After the MOX powder is pressed into a cylindrical shape it is sintered to produce the ceramic MOX pellet that is then precision ground to specified dimensions. During the sintering process the finely divided particles inter-diffuse to form what amounts to a near-solid solution of uranium-plutonium dioxide. After pressing, the pellets, green in colour, are passed on a conveyor belt to a furnace 'boat load station' where they are loaded into furnace 'boats' and taken to the furnace where they are sintered in a cycle of about 24 hours in an atmosphere of argon and hydrogen. Conveyors then transfer the pellets to the grinding and inspection stations. They are dry ground using a center-less grinding machine. Suitable pellets are put into a pellet store until they are required for the production of reactor fuel rods. Unsuitable pellets are recycled.

In BNFL's MOX Demonstration Facility (MDF), a 25-kilogram mixture of MOX powder is produced in an attritor mill. It is then blended with two other 25-kilogram batches in a blender to produce a 75-kilogram batch of MOX powder of uniform composition. This MOX powder is then divided into three 25-kilogram batches. Each of these is processed through an attritor mill and spheroidiser to produce the feed for the press. In the planned Sellafield MOX Plant (SMP), the SBR process has been scaled up using larger batches. In SMP, the MOX powder is to be processed through one of two separate attritor mills and spheroidoisers. The first attritor mill will prepare a 50-kilogram batch that will be blended with two other 50-kilogram batches to form a 150-kilogram batch of MOX powder. This will be processed in three 50-kilogram batches through the second attritor and spheroidiser [1]. Because each attritor and spheroidoiser can be used separately, a batch of MOX pellets could be produced for a PWR and another produced for a BWR simultaneously.

The MIMAS process was developed by Belgonuclaire to replace the former process used at Dessel that directly blended the UO2 and PuO2 powders. MIMAS is also used by Cogema to produce MOX at the Cadarache and MELLOX plants. The main reason for developing MIMAS was to produce MOX fuel soluble enough for the further reprocessing of spent MOX fuel.

Whereas SBR uses one blender step, MIMAS uses two blending steps to produce a solid solution of UO2 and PuO2 homogeneously dispersed in a UO2 matrix. The primary, or master, blend is obtained by ball milling. This so-called micronization stage produces MOX powder of high plutonium content (30 to 40 per cent Pu). The required plutonium content (5 per cent, for example) is obtained in the second blending step. The MOX is than compacted, sintered and precision ground.[2] A feature of the MIMAS process is that re-introducing THEM at the primary or secondary blending steps easily recycles rejected pellets, grinding powder, and other scrap. It should be borne in mind that ease of recycling might influence quality control.

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[1] BNFL, 'Special feature - Sellafield MOX Plant (SMP)', Engineer, No. 8, Spring 1996.

[2] Vliet, J. van, Haas, D., Vanderborck, Y., Lippens, M., and Vandenberg, Cl., 'MIMAS MOX fuel fabrication and irradiation performance', paper presented to International Seminar on MOX Fuel, Institute of Nuclear Engineers, Windermere, England, 4 June 1996.

If it is harder to recycle, as it is in the SBR process, there may be a pressure not to reject pellets on inspection in the first place. There may, therefore, be a direct connection between rejection (failure) rates and ease and cost of production, an example of how commercial considerations may affect quality control.

MIMAS proponents also claim that because of the double blending there is good isotopic homogeneity of the Pu in the product, even with Pu from different origins - light water or gas cooled reactors - or Pu of various forms, including MOX produced in Japan. Also, the micronization step uses only about 15 per cent of the powder. SBR advocates, however, argue that with ball milling it is difficult to achieve a plutonium agglomerate specification of 400 microns maximum. SBR, they claim, offers a 100 microns maximum and, in practice, there are few agglomerates even as large as 20 - 30 microns. BNFL claim that it: "has successfully demonstrated that SBR MOX fuel has no significant plutonium-rich regions of more than 20 microns diameter containing more than 30 percent plutonium". Comments on measurements of plutonium homogeneity in MOX fuel pellets are made in the section below on autoradiography.

MOX fuel rods are produced by placing MOX pellets end to end in sealed tubes, typically made from zircalloy, filled with argon. The fuel rods are held in geometric array by spacers to form a fuel assembly for a nuclear-power reactor. A typical MOX fuel assembly consists of a square array of rods (17 x 17): each 3-metre long rod contains about 300 MOX pellets.

**QUALITY CONTROL AND ASSURANCE OF MOX FUEL**

It has already been mentioned that, for the safe operation of a reactor using MOX nuclear fuel, the quality control and quality assurance of the fuel pellets and rods are a matter of considerable importance. The MOX fuel pellets must be produced to very demanding tolerances. This is more important for MOX fuel than for ordinary UO2 fuel; the fact that MOX fuel pellets are constructed from two actinide oxides rather than one makes fabrication considerably more difficult for MOX compared with uranium oxide fuel.

The production of MOX fuel involves the use of an advanced powder technology requiring the mixing, micronizing, pressing, sintering and grinding of two actinide oxides. Experience in other powder processing industries, such as the pharmaceutical industry, suggests that technologies dependent on powder technology are not very reliable. Small changes in parameters such as humidity, binder concentration and particle size distribution can effect the powder rheology and result in changes in flow rate, poor mixing or powder jams. Such problems are likely to be more severe and more frequent when, as in MOX fuel pellet fabrication, relatively small batches and variable formulations are pelletised. Variations of flow are likely to affect the density and dimensions of pellets and the homogeneity of Pu distribution in the pellets. For this reason, quality control of MOX pellets should be more stringent than for uranium oxide pellets.

Linear dimensions, density, bulk composition and homogeneity of MOX pellets should all be assured to within very narrow limits. A lapse in quality in any one of these parameters may have extremely serious safety implications and may have consequences which are time consuming and costly to rectify.

Recent revelations of the deliberate and consistent falsification of quality control and assurance data at BNFL's MOX Demonstration Facility (MDF) are therefore of considerable concern. But these represent only part of the problem of assuring the quality of MOX fuel. The quality control procedures themselves as well as their implementation are at fault. The very nature of the fuel pellets and the way they are made preclude adequate quality control procedures capable of being implemented at economic costs.

The advanced powder processing technologies used at MDF are not reliable; particularly so when more than one constituent is mixed together. Faults can occur when a total or partial blockage of the flow of powder occurs or when the components - uranium dioxide and plutonium dioxide in the case of MOX - are incompletely mixed. If the attritor mill at the MOX plant is operating correctly it should produce fine, uniformly mixed "micronized" (micron-sized) particles which can be made to flow like a liquid through subsequent processing stages until they are pressed and heated to form the final sintered (heat fused) cylindrical pellet. Experience in other industries, such as the pharmaceutical industry, however, indicates that processes that depend on the flow of powders are far from totally reliable, particularly when these involve the mixing of different constituents.

A crucial question is: Given the potential problems inherent in the production process of MOX fuel pellets, are the quality control and quality assurance procedures sufficiently effective to give confidence that MOX fuel is no threat to reactor safety? The information available so far suggests that current MOX production techniques and quality control are indeed a threat to the 'safe' operation of a reactor.

BNFL claims that "the data obtained on the key quality characteristics during the fabrication of several tons of MOX fuel pellets" in its MDF plant shows that:

- "No difficulties have been experienced controlling the pellet dimensions, the density, surface finish or thermal stability of the fuels made in MDF. The standard deviation on pellet diameter is 0.004 millimeters and on geometric density is 0.032 grams per cubic centimeter. The surface roughness of pellets produced in the plant averages 0.43 micro-radians with a standard deviation of 0.159 micro-radians."
- "The hydrogen content of the pellets produced was low (with a mean value of 0.27 parts per million and a standard deviation of the mean of 0.14) and tests showed that pellets produced do not pick up hydrogen or moisture when stored in air. The oxygen/metal ratio was consistently close to 2.000".
- "No manufacturing difficulties have been experienced controlling the fissile material content of the fuel within the specified enrichment tolerances"
- "The grain size averages 7.4 microns with a standard deviation of 0.54 microns. For pores with a diameters greater than 5 microns the median pore size has never exceeded 15.4 microns during the production to date (1996)" [3].

The raw data on which these conclusions are drawn are not publicly available and therefore no independent analysis can be done. But there is some data from other sources showing that the BNFL statement about its ability to control pellet dimensions is inaccurate. On 1 March 2000, the Japanese utility Kansai Electric (KEPCO) released a report on the falsification by BNFL of MOX fuel pellets inspections. The report questions the competence of NII in investigating the falsification scandal. According to KEPCO, in 1995 Mitsubishi Heavy Industries (MHI), acting on behalf of KEPCO, questioned the ability of BNFL to make pellets with accurate diameters. It was also found that the MDF was incapable of conducting the preferred method of quality assurance due to insufficient performance of the pellet grinder. Moreover, random sampling for the Japanese fuel was not conducted properly at BNFL. BNFL intentionally passed pellets that should have failed the quality control inspection. Pellet diameter measurements were not conducted according to the agreed procedure. When inspectors found that a diameter measurement of a pellet was not within specification, rather than rejecting the pellet which was the agreed procedure, they turned the pellet 90 degrees in order to find a measurement that would be within the specification and therefore allow the pellet to pass inspection. This raises the suspicion that there was pressure from management to pass these inspections to avoid having to re-fabricate pellets and lose time and money.

Further questions about the reliability of the MOX pellet production process was raised recently when it was reported that many pellets were emerging from the grinding process out of shape. The problem dates back to the early operation of the plant and confirms the doubts expressed by MHI around the same time. Large numbers of pellets that should have been cylindrical had instead one end significantly wider. When the automatic laser micrometer measured "top", "bottom" and "middle", it rejected many pellets as being outside the tolerance range in safety specifications. Unable to correct the problem, BNFL instead altered the measuring technique, by moving the "top" and "bottom" readings from the pellets to within two millimeters of the center reading, so that pellets that would have failed were passed.[4] BNFL claims that the explanation that it is normal for the pellets to be "plant-pot" shaped, but that following grinding the pellets are "not flowerpot shaped" is not credible. Automatic laser inspection takes place after grinding. Questions over the effectiveness of both the sintering technology and the grinding tools arise out of this information. BNFL claimed that the micrometer was rejecting the pellets because it was measuring the chamfer edge, again this does not appear credible. The measurement points are set to give assurance on the pellet size.

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[3] Edwards, J and Brennan, J., 'MOX Fuel Manufacture at Sellafield', paper presented to International Seminar on MOX Fuel, Institute of Nuclear Engineers, Windermere, England, 4 June 1996.

[4] "BNFL lowered safety standard to boost output", The Independent, March 7th 2000

The chamfer, or rim, is important to check separately, but it is not a factor that should effect the diameter measurements of the pellet, and it certainly is not a justification for measuring only the central diameter of the pellet.

## PARAMETERS CHECKED DURING MOX PRODUCTION

A number of characteristics of the MOX pellets produced by BNFL are, of course, checked before they are put into store until required for loading into fuel rods. The rods also go through a quality control procedure. Some information about the quality control procedures is in the open literature,[5] but not nearly enough to comprehensively review the effectiveness of quality control. The rationale given for this lack of information is 'customer confidentiality'. The BNFL MOX pellet specification, according to which the pellets are produced, is 'developed in conjunction with' BNFL's customers and 'the details of this specification are confidential'.

Some information about quality control is given in the report of the British Nuclear Installations Inspectorate (NII) of its investigation of the falsification by BNFL of MOX pellet data.[6] However, although more information is available than previously it is still insufficient for a full independent assessment to be made of the effectiveness of the quality control of MOX pellet production.[7] There are questions about the independence of the NII, including concerns that the "nuclear safety watchdog may have become too close to BNFL to regulate it effectively"[8]. The NII failed to identify the problem about the falsification of data on MOX pellet inspections at BNFL for three years, and has still not adequately addressed fundamental issues, such as the underlying motives for the falsification.

According to the NII report, the types of inspections of pellet characteristics performed by BNFL are: chemical composition; visual inspection; pellet length; geometric density; re-sinter behavior; end squareness; dish and chamfer dimensions; surface roughness; plutonium homogeneity; and grain size. The inspection of the fuel rods includes: visual inspection; x-ray inspection; weld metallography; helium leak detection; rod surface contamination; rod length; rod straightness; weld region diameter check; helium pressure test; end plug seal corrosion resistance; and wrong enrichment detection.

Fuel Rod Parameter - The weight of each fuel rod is an important measurement to ensure that the correct number of correctly sized pellets, have been introduced into the fuel rod. It would also monitor for the illicit replacement of fuel pellets with blanks of a similar size. The latter is of considerable importance, for safeguards reasons, to ensure that all the plutonium entering the MOX fabrication process can be accounted for in the completed fuel assemblies. Unless this is accurately done it will not be known whether plutonium has been lost or stolen in the MOX fabrication plant, a serious consideration for this fissile and highly toxic element. The NII report does not say whether or not all MOX rods are weighed.

The entire length of each rod is X-rayed. This will, however, not detect a uranium oxide pellet that has been inserted into the rod to replace a MOX pellet. MOX fuel assemblies are inspected for: dimensional envelope; channel spacings; cleanliness; control rod withdrawal force; and surface finish.

Pellet Content Analysis - The NII report states that pellet samples are taken for physical and chemical analysis. The check of chemical composition includes the ratio of Pu isotopes to U isotopes, Pu enrichment, metal content ratio, oxygen to metal ratio, impurities, gas content, and solubility. The measurements are carried out in a laboratory that is NAMAS accredited. But no indication is given of how frequently the measurements are done. Without this information it is not possible to comment on how effective the checks are.

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5 opcit, BNFL, 'Special feature - Sellafield MOX Plant (SMP)', Engineer, No. 8, Spring 1996.

6 The Nuclear Installations Inspectorate of the Health and Safety Executive, 'An Investigation into the Falsification of Pellet Diameter Data in the MOX Demonstration Facility at the BNFL Sellafield Site and the Effect of this on the Safety of MOX Fuel in Use', 18 February 2000.

7 opcit, BNFL, Special feature.

8 Morgan, O., 'Safety Chiefs too close to BNFL', The Observer, Business Section, 5 March 2000.

The measurements of the metal (plutonium and uranium) content of the pellets and the pellet's oxide-to-metal ratio are important because they give further information about the plutonium content of the pellets. The bulk composition (the masses of plutonium and uranium dioxides in the pellet) is also an important parameter. Too little plutonium in the pellets and the purchasers are not getting value for money; too much and serious local overheating could result. Indeed, it has been recognized that the production process does produce MOX pellets with variable plutonium content.

Variable plutonium content can adversely affect core neutronics, the effects of which have been modeled using a computer simulation.[9] The need to check the composition of individual MOX fuel pellets is further heightened by the requirement to produce MOX assemblies with a range of plutonium contents. The plutonium content of each fuel pellet must also be determined as part of the accountancy procedure, used for safeguards purposes, for this material. Too many impurities in a pellet could lead to the corrosion of the cladding of the rod and produce unwanted gases. The gas content of the pellets is important; too much gas in the pellet could cause the rupture on heating.

Pellet Size - MOX pellets are visually inspected for defects on the surface. The lengths of pellets in a random sample are measured using a micrometer with an accuracy of 1 micron. The length must be within a specified range, not given in the report, with a 95 per cent confidence level. The sample consists of 20 pellets taken from a 'lot' of 4,000 pellets, or 0.5 per cent of the total.

The diameter of the MOX pellets is checked using an automated inspection system. The system uses a laser micrometer to make three separate measurements of the diameter of a pellet. A pellet for which one or more of the measurements is out of specification (given by the customer) is supposed to be automatically rejected by a gate mechanism. The specification range for diameters of Kansai pellets is plus or minus 0.0125 millimetre. BNFL claims that the accuracy of the laser micrometres is plus or minus 0.002 millimetres. However, recent reports have revealed that BNFL altered the measuring points to one central diameter check, following the rejection of an undisclosed quantity of MOX pellets when measuring the top, bottom and middle of pellet.[10]

The diameters of 200 pellets out of a 'lot' of about 4,000 pellets (about 5 percent) are also measured manually - top, middle and bottom diameters are measures on each of the 200 pellets. Two operators are involved in this check; it takes them about two hours to measure the 200 pellets. This statistic indicates the man-hours, and therefore high cost, of checking large numbers of MOX pellets. The numbers involved are very high indeed. The eight MOX assemblies sent from Sellafield to Japan in 1999, for example, contained a total of about 614,000 MOX pellets (17 x 17 rods; 300 pellets per rod, and 8 assemblies = 614,000 pellets).

The size of pellets is important because a pellet, which is too small, may rattle about within the fuel rod and cause serious wear in the fuel cladding. On the other hand the swelling of a pellet to a size which is too large as a consequence of neutron irradiation or heat may also cause damage to the fuel cladding. Apart from visual inspection, looking for chips, cracks, defects in the surface, and distortions of shape, the diameter measurement is the only check done on all the pellets. All other checks are done on samples, often representing only a very small percentage of pellets.

The initial visual check inspects only one side of the pellet (the pellets are on trays). A second visual check is done on a sample of pellets. The NII report fails to address the question of whether these visual checks are adequate.

Weight And Density - The weight of the pellets in a random sample - 20 pellets out of 4,000 (0.5 per cent) is measured using an electronic balance. From this and the measurements, using a micrometer, of outer diameter and length, the density of the pellet is calculated. The measurement of weight will be very

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[9] Willermoz, G., Bethoux, P., Bruna, G. B., Castelli, R. and Serant, D., 'Modeling of manufacturing fuel heterogeneity's in a PWR via a stochastic - perturbative method', Prog. Nuc. Energy, Vol. 33, pp. 265-278, 1998.

[10] opcit, The Independent, March 7th 2000.

accurate but the other measurements will be less so. The density, according to the NII report, must be within the specification range with a 95 per cent confidence level. This is not a very strict level - 99 per cent would be more reassuring. A high or low density could indicate faults in pellet fabrication. High-density pellets may swell excessively; pellets with low density might split. The fact that it has now emerged that BNFL falsified density data for MOX pellets supplied to German client, PreussenElektra raises further questions about the reliability of BNFL production and quality control standards.

Thermal Stability - The thermal stability of the pellets is measured following the exposure of the pellets to a high temperature. The report says, "ten pellets samples are taken at regular intervals agreed by the customer. All pellets must meet specification limit on geometric density following high temperature, extended sintering." The question of how frequent a "regular" interval is not answered. No figures are given as to the percentage of pellets checked and the NII report does not explain if the dimensions of the pellets are measured with the density. Thermal stability is a very important property of reactor fuel and more details about the measurement should be given.

The dish dimension (the punch used to produce the pellet produces a dish-like indentation at each end of the pellet) and the chamfer dimension are checked but only on samples. Random samples of six pellets per lot of 4,000 are taken. The chamfer height and length are measured using image processing with a precision of 0.01 millimeters. Dish depth is measured using a depth gauge with a precision of 1 micron.
After press tools are changed a random sample of 20 pellets is taken and end squareness measured with a gauge with a precision of 1 micron. The measurement must be less than the specified limit. Taking a random sample of five pellets at 'regular intervals' checks surface roughness. The surface roughness is measured using a proprietary gauge with a precision of 0.02 micron. Surface roughness must be within the specified limit. The frequency of the check is not stated.

**PLUTONIUM CONTENT OF PELLETS**

One of the most important properties of a MOX pellet, from the point of view of reactor operation, is the plutonium content - the weight of plutonium in the pellet as the percentage of the total weight. Inadequate mixing of the oxide powder before feeding it to the attritor could result in variations of plutonium content from pellet to pellet. Too much plutonium could produce excessive local heating and affect the core neutronics with adverse safety consequences. More seriously, inadequate mixing of the powder fed into the attritor or inadequate mixing in the attritor may result in inhomogeneous distribution of plutonium within a pellet. Plutonium 'spots' could then arise.

A whole series of variables such as the water content, composition and initial size of the particles used to make the pellets, wear of the attritor mill, and so on, could account for faults in mixing. Variations in them could cause inadequate mixing or even partial or total clogging of the mill. There is little information in the open literature on the efficiency of operation of the attritor mill - how often it jams, how rapidly the mechanism wears, and so on. Without this information it is not possible to estimate the effectiveness of quality control.

The NII report implies that achieving the specified plutonium content depends on the accuracy at which the quantities of $PuO_2$ and $UO_2$ powders milled in the attritor are weighed. No information is provided as to how the correct weight is determined, how many personnel are involved in checking measurements, whether inputs and outputs are checked, and how a powder jam in the attritor is dealt with.

The homogeneity of BNFL's MOX pellets is measured using colour alpha autoradiography. Two pellets are sampled at regular intervals for the measurements of $PuO_2$ particle size and Pu concentration - again, the NII report does not say how frequently measurements are done, a crucial piece of information to judge the effectiveness of the check. Colour alpha autoradiography is not a commonly used technique and there is some question about its validity for routine measurements. It appears that BNFL examines plutonium 'spots' with diameters up to 400 microns. A thin section (slice) is cut from a sample pellet and then polished. It is then placed in contact in the dark with a photographic film for some days, developed and examined and the size and number of clumps of silver grains in the film assessed. If colour film is used, plutonium shows up as red, so that plutonium particles appear as red dots.

Grain size is measured on the same samples as Pu spot size. Apparently, a polished surface of the pellet is photographed in a microscope, with surface illumination. No information is provided as to how the uniformity of grain size and the size of $PuO_2$ particles are measured across the surface of the polished slice of the pellet. There is also no way of knowing if the particular polished surface examined is representative of conditions throughout the pellet. This is equally true for the autoradiography check for Pu homogeneity. This, plus the extremely low frequency of all the pellet checks, except for diameter, means that quality control on MOX fuel pellets is fundamentally inadequate. Assurance that the MOX fuel is therefore safe cannot be given with any confidence.

## THE IMPORTANCE OF PLUTONIUM HOT SPOTS

The way in which the powder flows during the various stages of MOX pellet fabrication will determine the degree of in-homogeneity in the fuel pellets. The unpredictability of variations in homogeneity has serious implications for quality control procedures. Brief fluctuations in the efficiency of mixing would not be detected unless substantially all of the pellets were inspected; even extended fluctuations would be missed if the samples taken for inspection were not large enough. The uniform distribution of plutonium and uranium oxides in the pellets is extremely important for safety. The cladding of MOX reactor fuel rods could be damaged by local hot spots produced by larger than average plutonium oxide particles on the surface of pellets. Such large particles could accumulate to produce aggregates. Inhomogeneity of MOX fuel pellets is acknowledged in the open scientific literature to be a serious problem.

For example, Gouffon and Merle point out: "The size of the aggregate obtained after micronizing (crushing and blending) determines the criterion regarding the energy contained in the oxide pellet during an accident of the control rod ejection type"[11]. According to Schmitz and Papin, "Accumulations of large plutonium dioxide particles on the surface of the pellet could create hot spots when the fuel is in the reactor and damage the cladding of the fuel rod... Equally important is the evidence that transient, dynamic fission gas effects resulting from the close to adiabatic heating introduces a new explosive loading mechanism which may lead to clad rupture under RIA [accident] conditions, especially in the case of heterogeneous MOX fuel".[12]

Damage to fuel cladding is made worse by the fact that much more fission and hence more heating occurs at the surface of the pellet than at its center. The risk of serious damage to the cladding is increased for fuels with high plutonium contents and when the fuel is subject to high burn-up.

## INADEQUACIES OF AUTORADIOGRPHY

Alpha autoradiography is a labor-intensive method of testing a pellet for the homogeneity of Pu throughout its volume. It is destructive to the pellet and time consuming. This may account for the fact that BNFL apparently only routinely inspects a single pellet taken from about 40,000 pellets. Of the pellets inspected about 20 per cent typically fail.

Not only are very few pellets sampled but also only a thin slice is taken from a pellet for testing. We argue that, from the point of view of reactor safety, testing for homogeneity is by far the most important of all the checks. And even this one is totally inadequate in its scope. Because only a thin slice of a pellet is tested it is assumed that the result is representative of the whole pellet, this assumption is not robust.

## SELLAFIELD MOX PLANT – NO SIGNIFICANT IMPROVEMENTS WITH AUTOMATION

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[11] Gouffon, A. and Merle, J. P., 'Safety problems related to the use of MOX assemblies in PWRs', paper for International Working Group on Water Reactor Fuel Performance, International Atomic Energy Agency, Vienna, 1990.

[12] Schmitz, F. and Papin, J., 'High burn-up effects on fuel behavior under accident conditions: the tests', CABRI REP-Na., J. Nuc. Materials, Vol. 270, pp. 55-64, 1999.

BNFL often claim that because SMP is an automated plant the quality control of the MOX pellets will be much superior to that in the MDF plant. The situation is that in the SMP plant three of the 15 pellet checks in the BNFL quality control list will be automated - the diameter check, a check of the circumference, and inspection of the ends of the pellets. The last two checks look for damage to the surface of the ceramic pellet - chips, and so on. The other 12 checks will be carried out by taking samples in a way similar to that at MDF.

Since the specification of pellet quality will presumably be the same for SMP and MDF pellets, as it is the same SBR technology, the frequency with which the 12 non-automated checks are performed will be similar. The concerns about the inadequacy of important quality control checks (particularly checks for inhomogeneity) of MDF MOX pellets will therefore apply equally to SMP MOX pellets. BNFL's claim that the quality control of SMP MOX pellets will be much superior to the quality control of MDF MOX pellets, just because the plant is automated, cannot be substantiated. We, therefore, strongly disagree with the statement that: "The optimized SBR process (in SMP) reduces the number of quality control samples required and results in a larger quantity of fuel with uniform Pu isotopic composition."[13]

## QUALITY CONTROL AT BELGONUCLEAIRE

As described above, we do not know many details of the quality control and assurance at BNFL remain unknown. Considerably less is known about these operations at Belgonucleaire. But from the little that is known, it appears that quality control at Belgonucleaire is even less stringent than that at BNFL, mainly because checks are done with considerably less frequency (see table 1,) and there are fewer total checks.

Tokyo Electric Power Company (TEPCO) which received 32 assemblies of MOX fuel from Belgonucleaire in 1999 has added confusion and contradictory statements to this lack of transparency. When the falsification scandal first broke in September 1999, Tokyo Electric stated that BN had produced MOX for Fukushima-I-3 using both production lines at the PO plant. For one of these lines, an automatic laser micrometer did not cover 40% of the production line, and instead one out of every hundred is inspected manually. However, by February 2000 Tokyo Electric had changed its explanation: it claimed that all MOX produced for them had been made in one production line, which is 100% covered by automatic laser. To complicate the issue further, it has been confirmed by Tokyo Electric and the Ministry of Trade and Industry, MITI, that no data exists from the automated laser inspection, as it is overwritten, or deleted. As of March 24th, TEPCO had failed to clarify this issue, citing the commercial confidentiality of Belgonucleaire as the reason why data could not be released publicly. It may in fact not be the case that the automated fuel data is deleted, but if so, there remains the question as to why such data, important in the even of liability for example was deleted in the first place. Even BNFL did not delete their automated data on mass.

It also appears from an assessment of the graph data released by Tokyo Electric on February 24th for MOX pellets produced at BN, that the range of pellet diameter for the pellets manually inspected is too similar to be representative of a random sample.[14] The same Japanese citizens groups that challenged Kansai Electric in the Osaka District Court over BNFL falsification have now questioned this. The question arises as to whether workers at Belgonucleaire act similarly to those at BNFL, by repeatedly revolving the pellet through 90 degrees until they obtain the diameter measurement required to pass. If this is the case, the quality control process fails not only on grounds of falsification, but also on grounds of deliberate manipulation. Again only full transparency, including release of all data will answer this important question.

As far as the important check for homogeneity, there is still a great lack of clarity. The February 24th TEPCO report indicates 32 pellets selected (out of 430,000 total for Fukushima-I-3 reactor fuel) were

[13] Bairiot, H., van Vliet, J., Chiarelli, G., Edwards, J., Nagai, Sh., and Reshetnikov, F., 'Overview on MOX fuel fabrication achievements', International Symposium on MOX fuel cycle technologies for medium and long term deployment: experience, advances, trends', International Atomic Energy Agency, Vienna, 17-21 May 1999.

[14] "Reconfirmation result on quality control of MOX fuel for Fukushima-I-3 and Kashiwazaki-3", issued on February 24th, 2000, Tokyo Electric Power Company.

checked for homogeneity, a slightly higher check fraction than BNFL. This may be confirmation that MIMAS technology is inferior to BNFL MOX fuel in terms of the efficiency of the blending of uranium and plutonium powders, giving rise to concern over the homogeneity of the fuel. The frequency of other tests, such as isotopic abundance and impurities (carbon, fluorine and nitrogen), is about one pellet in 20,000; hydrogen content is checked in one pellet in 420; heavy metal content in one pellet in 2,100 in practice is inadequate, oxygen to metal ratio in one in about 2,500.

It is perhaps surprising that specifications for MOX pellet quality differs between suppliers of MOX - BNFL and Belgonucleaire - for different Japanese reactors. In fact there are no agreed or consistent standards for the quality of MOX fuel. From what is known about the standard of MOX production technology, SBR versus MIMAS, as well as the frequency of quality control checks conducted by Belgonucleaire, it is highly likely that the quality of MOX fuel produced by Belgonucleaire is at least as poor as that produced by BNFL, and may be significantly worse. This has direct implications for the safe operation of Fukushima-I-3 reactor, if loading is to proceed, as well as for fuel currently awaiting shipment at Belgonucleaire, to TEPCO's Kashiwazaki-Kariwa-3 reactor.

## COGEMA QUALITY CONTROL

No significant data has been released to date on the quality control standards applied by Cogema at the two operating MOX plants, Cadarache and MELLOX. Both plants produce MOX fuel for commercial light water reactors using the MIMAS process. Together with the PO plant at Dessel, the facilities are operated under the Cogema Group MOX Platform, and all of the production is marketed by Commox, 60% of which is owned by Cogema, and 40% by Belgonucleaire. The Cadarache plant operates entirely for the production of MOX fuel for German nuclear power plants, while MELLOX produces largely for French state-utility, Electricite de France. In late 1999, Cogema began production of 8 MOX fuel assemblies for KEPCO, fuel originally intended to be loaded as the second core load of MOX fuel for Takahama-4 reactor. Due to the canceling of plans to load BNFL MOX fuel, the MELLOX fuel will be the first to be loaded by KEPCO. Production of this fuel was suspended between December 27th and February 21st due to MITI concerns over quality control standards at MELLOX, but following and as yet undisclosed investigation by KEPCO, production resumed and is due to be completed during April 2000. A second batch of 8 MOX assemblies, intended for Takahama-3 is due to is manufactured at MELLOX by December 2000.

As no data has been released on quality control standards of MOX fuel produced by Cogema, it is not possible to verify whether or not the standards applied are more or less robust than those applied by BNFL or Belgonucleaire. Only release of all relevant data would provide the answer to this question. However, it is almost certainly the case that standards applied for plutonium homogeneity will not be significantly more robust than those applied at Dessel and at Sellafield. In combination with the use of the same MIMAS technology which produces a less homogenous uranium-plutonium mix than the SBR technology of BNFL, we have grounds for saying that Cogema produced MOX is at least as poor in quality control as BNFL, perhaps more so. Production of MOX with effective plutonium homogeneity would not be economic for Cogema to produce.

The refusal by Belgonucleaire to release off-site all quality control data for fuel produced for TEPCO (intended for Fukushima-I-3 and Kashiwizaki-Kariwa-3) raises suspicions that Cogema, as a major partner in the MOX Group Platform, is not prepared to expose its quality standards to the same public scrutiny as BNFL. Though it is worth emphasizing that BNFL only did so under intense pressure from Japanese politicians and environmental groups, which led to a demand from KEPCO and the Japanese Ministry of Trade and Industry (MITI), and then finally the UK NII. This more than raises suspicion that Cogema has something to hide. Citing commercial confidentiality may be a convenient cover, but it is not a justification, especially since BNFL, Cogema's only potential competitor, has been forced to release considerably more quality control data though still insufficient for independent analysis.

Further confirmation of the inherently poor standards of MOX quality control standards has emerged as late as March 24th, when Siemens, the fuel vendor for German reactors, confirmed that MOX fuel produced at

Cadarache by Cogema contained falsified quality control data.[15] The MOX fuel was produced for the Isar-2 reactor operated by utility Isar-Ampere, which in total has loaded 48 assemblies from Cadarache. No MOX fuel from Belgonucleaire (or BNFL) has been loaded in Isar-2. Siemens stated that the problem was similar to that uncovered for MOX fuel loaded in the Unterweser reactor, produced by BNFL. According to Siemens the quality control failure related to data having been not entered on the computer for 40 out of 100 pellets selected out of 7000. Siemens have now requested Cogema to assess all previous quality control data related to MOX fuel produced at Cadarache for Germany, an enormous undertaking if it is to be done thoroughly. Cogema will rightly come under significant pressure to release all relevant MOX quality control data in the following weeks.

## CONCLUSIONS

As has been described, BNFL apparently applies 15 checks to its MOX pellets under the following headings: isotopic composition; plutonium enrichment; metal content; oxide/metal ratio; impurities; gas contents; appearance (visual check); outer diameter; height; dish dimension; chamfer dimension; end squareness; density; alpha-auto-radiography (to identify plutonium spots); solubility. Belgonucleaire conduct less total checks, but of a similar range, including homogeniety and diameter. No information is currently publicly disclosed by Cogema, however, we assume that similar quantity and range of checks are conducted as by Belogonucleaire.

On first sight, this appears to be a comprehensive set of checks. But in most cases the frequency of the checks is totally inadequate. In some checks only one sample is taken per 22,000 or 13,500 pellets (at BNFL and Belgonucleaire respectively - see Table 1 for details. The checks for pellet length and geometric density, for example, are done on random samples of 20 pellets per lot - that is one pellet in 200 or a sample size of 0.5 per cent. Such a low sampling rate will allow flawed pellets to get through the checking procedures, with serious implications for reactor safety and for the safeguarding and accountancy of plutonium. Of particular concern is the serious inadequacy of the checks to detect inhomogenieties in plutonium distribution in pellets. Because of the very low sampling rate, variations in plutonium homogeneity will not always be detected.

The inspection rate is clearly inadequate for a fabrication technology subject to the vagaries of powder flow. The high failure rate indicates that the inspection rate has not been defined as the minimum rate required for adequate quality control. Instead it appears to have been established by economic, rather than statistical considerations. Further, too little is known about the quality control procedures used to monitor MOX fuel pellets and rods. 'Commercial confidentiality' is used as a smoke screen to prevent independent scrutiny of quality control and quality assurance procedures for MOX. The safety of conventional thermal nuclear reactors fuelled by MOX is seriously compromised by two important considerations: difficulties in the fabrication and quality control of MOX fuel pellets and differences in the behavior of plutonium and uranium in the reactor. The former has received little attention but may be at least as important as the latter.

The cost of properly checking for inhomogenieties in the distribution of plutonium in a fuel pellet, by, for example, alpha-autoradiography, would be large, from a commercial point of view prohibitively so. This is compounded by the current poor economics of the MOX industry. Available estimates suggest that MOX supply will be about two times greater than MOX demand up to the year 2015. The pressure to reduce costs in such a competitive market inevitably has impacts on the extent, and therefore effectiveness, of quality control and assurance. The margins to make substantive and required improvements may not exist for the MOX manufacturer.

The inability of the industry to carry out adequate checks for inhomogeneities may have serious implications for the integrity of the fuel cladding. It is extremely irresponsible of the industry to dispense with adequate quality control and assurance procedures and, in effect, rely instead on limited research trials carried out on fuel produced by different pilot fuel fabrication plants operating under optimal conditions.

[15] Siemens press statement, March 24th, 2000.

In summary, we conclude that:

1. The amount of publicly available information is insufficient for any comprehensive analysis of the adequacy of quality control and quality assurance. The public therefore has to rely solely on the word of the industry and the discredited regulators. Given the furore about falsification the word of the industry is totally discredited.

2. The NII report has been limited in its scope and depth, and adds virtually no new information about quality control and assurance. The NII should be required to make adequate information available so that analysis and conclusions about the adequacy of quality control and quality assurance be made by independent analysts. Similarly the withholding of information by Belgonucleaire and Cogema, and the attitude of TEPCO is unacceptable, and disclosure of all relevant data should be immediately.

3. Of particular concern is the plutonium homogeneity of MOX pellets. It seems that autoradiography is done on only one BNFL pellet in about 22,000, and one pellet in 13,500 for Belgonucleaire produced MOX. Given the serious adverse consequences of plutonium hot spots for reactor safety, this level of frequency is inadequate and irresponsible.

4. The frequency of all BNFL and Belgonucleaire quality control checks, except the measurement of the diameter, of MOX pellets is so low as to be statistically unreliable.

5. The cost of adequate quality control and quality assurance would be high, which provides an explanation for the inadequacies of current practices. Autoradiography is particularly costly and labor intensive.

6. The evidence suggests that BNFL, Belgonucleaire, and probably Cogema use approximately the same specifications for the quality control and quality assurance of MOX pellets sold to foreign customers.

7. No significant analysis has been done by either MOX producers or regulatory bodies, such as the NII, into the implications of quality control and quality assurance for the risk of accidents when MOX fuel is used in reactors.

8. Even without the application of satisfactory quality control and quality assurance, MOX fuel is much more expensive than ordinary uranium oxide fuel. Adequate quality control and quality assurance would make it prohibitively costly.

9. Disclosures that BNFL and Cogema have falsified quality control data, and indications that Belgonucleaire have also done so, confirm in our minds that adequate MOX quality control is not possible.

10. Quality control checks conducted are limited, and even in so-called automated facilities, such as SMP and MELLOX, the range of checks remain small, with the most important check for homogeneity limited to a fraction of total pellets that would be required to assure safety.

Given these conclusions, it is clear that MOX producers and those few utilities committed to burning MOX fuel are putting economics before safety. Given the level of information publicly provided, it is clear that MOX fuel production fails to meet the basic principles of quality control and quality assurance and that MOX fuel cannot be guaranteed safe to use.

**Table-1 Frequency of BNFL and Belgonucleaire quality control checks on samples**

| Check type | Frequency – BNFL (for Takahama-4 reactor fuel) | Frequency - Belgonucleaire (for Fukushima-I-3 reactor fuel) |
|---|---|---|
| | | |
| Isotopic Composition | One pellet in 1600 | One pellet in 20,000 |
| Pu Enrichment | One pellet in 1600 | |
| Metal content | One pellet in 4,000 (first lot only) | One pellet in 2,100 |
| Oxide/metal ratio | One pellet in 22,000 | One pellet in 2,500 |
| Impurities | One pellet in 22,000 | One in 20,000 (hydrogen one in 420) |
| Gas contents | One pellet in 22,000 | |
| Appearance - visual inspection | One pellet in 12 | |
| Outer Diameter – manual measure | One pellet in 20 | One pellet in 220 |
| Outer Diameter – automated | All pellets | |
| Length | One pellet in 200 | |
| Dish dimension – first lot after punch change | On pellet in 700 | |
| End Squareness | One pellet in 200 – first lot after pellet change | |
| Density | One pellet in 200 | |
| Pu spot – homogeneity | One pellet in 22,000 | One pellet in 13,500 |
| Solubility | One pellet in 22,000 | |