The Kobe Steel Group Supply Chain to the Nuclear Industry And Safety Implications

24 October 2017
Greenpeace Japan Briefing Paper
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Overview

The Kobe Steel Company and associated companies are major suppliers to the nuclear industry in Japan and overseas. Their products have been supplied across the nuclear power industry from reactor components, nuclear fuel manufacture and reprocessing plants and nuclear waste storage and spent fuel transport casks.[2] The disclosures that Kobe Steel has deliberately falsified certification and inspection reports on thousands of components supplied to at least 500 companies in Japan and overseas raises serious questions on Kobe Steel components installed in reactors and other nuclear plants in Japan and worldwide. The falsification is reported to extend back over decades and includes the possibility of violating Japanese Industrial Standards.[3]

It was during this same time period that Kobe Steel was a major supplier to the nuclear industry in Japan dating back to the early days of the nations nuclear power program in the late 1960's. The scale of their supply is immense. The sixty power reactors built and operated in Japan since 1966, together with reprocessing plants at Tokai and Rokkasho-mura were all built with supplies provided by specialized steel component manufacturers. Kobe Steel and associated companies were one of the principal suppliers. Kobe Steel also became a major supplier to the global nuclear industry, in particular to the U.S. as well as Europe.

The scale and extent of Kobe Steel's nuclear supply chain is however not in the public record. For every nuclear reactor in Japan, the precise quantity of Kobe Steel products is not publicly available. Equally the quality assurance and quality control records of the Kobe Steel components, comprehensive inspection records for those components and inspection reports of evidence of degradation, corrosion or embrittlement are not in the public record. This is a major public safety issue and the citizens of Japan must have access to all of the above information.

The quality of Kobe Steel components installed in Japanese and overseas nuclear plants are a vital safety issue. Steel pipes and nuclear fuel cladding supplied by Kobe Steel installed in nuclear plants are highly vulnerable to failure. They operate in severely corrosive environments under extreme pressures and temperatures and are subject to neutron irradiation. The nuclear industry worldwide has experienced such failures throughout its history.[4] In particular in Japan, pipe components are vulnerable to major seismic events, many of the older reactors in Japan and worldwide were constructed when seismic loading regulations for pipework were even weaker than they are today or barely applied at all.[5] The Kobe Steel pipework was manufactured and installed in Japanese reactors which until after the 2011 Fukushima Daiichi accident were considered at low or zero risk of major seismic damage. Japanese reactors since 2013 have all had their design base ground motion (the earthquake ground acceleration measured in Gal) revised upwards, but in nearly all cases replacement of the reactor pipework has not taken place. For example, in one extreme example, the Kashiwazaki Kariwa reactors owned by TEPCO have had their design basis ground motion revised from 450 Gal to 2300.[6]

Greenpeace has reviewed many hundreds of documents and thousands of pages of nuclear industry technical and engineering documents, nuclear regulator reviews and inspection reports dating back to the early 1980's in an attempt to piece together the Kobe Steel supply chain. This is an initial overview of the wide ranging components supplied by Kobe Steel and it is certainly not comprehensive due in large part to the lack of transparency in the nuclear supply chain. At minimum there needs to be a comprehensive investigation into the manufacturing records of components, the specifications set by nuclear industry customers, and inspection reports. However, given the complexity and location of many of the components inside nuclear reactors, physical inspection in many cases is extremely challenging and in some cases not possible while the part remains in situ. As a consequence therefore reliable assurance that the many thousands of Kobe Steel components installed in nuclear plans in Japan (and overseas) are safe to operate remains unattainable. At minimum there must be a commitment to transparency and disclosure of all relevant data which will at least permit a deeper understanding of the Kobe Steel nuclear supply chain.

The Kobe Steel scandal raises fundamental questions about the reliability and condition of installed components in Japanese reactors, fuel facilities and plutonium MOX and spent fuel casks. It also raises serious questions over the effectiveness of nuclear regulation, inspection and oversight. The majority of the components installed in Japanese reactors supplied by Kobe

Steel were made during the late 1970's to mid 1990's. The weakness of Japanese nuclear regulation at that time is now widely acknowledged.[7]

It is clear Japan's nuclear safety regulator does not effectively oversee Quality Assurance of the components installed in nuclear facilities. There is a hands-off approach, deferring to the manufacturer and customer, relying on assurances that the component meets industrial and safety specifications. This was clearly exposed in 2016, when the NRA conducted a superficial investigation into the JCFC and Japan Steel Works carbon steel crisis. The NRA was shown to be repeating the mistakes of past regulators by ineffectively overseeing the supply chain of the nuclear industry. There are no simple solutions to this problem – its scale is immense. Over decades Japanese nuclear regulators, along with their equivalents around the world, have endorsed the procurement of nuclear components critical to the safety of plants in a self regulating international nuclear supermarket. That is a recipe for disaster.

It has now been recommended by the European Union's Aviation Safety Agency that aircraft operators and manufacturers suspend the use of Kobe Steel components and switch where possible to alternative suppliers.[8] At very minimum, this should be the first step taken by the NRA with an instruction to all nuclear operators in Japan to suspend the use of Kobe Steel products.

For the operating nuclear reactors in Japan, Kyushu Electric's Sendai-1&2; Kansai Electric's Takahama-3&4, and Shikoku Electric's Ikata-3 (currently offline for maintenance) the issue is urgent. These companies must immediately disclose the Kobe Steel components installed in their reactors and release all relevant quality control and inspection data. Where there are Kobe steel components the reactors must be immediately shutdown and a comprehensive inspection regime conducted.

For reactors scheduled to restart in the coming months, Kyushu Electric's Genkai-3&4, and Kansai Electric's Ohi-3&4, all relevant information should be disclosed, and plans for restart suspended prior to a robust and transparent inspection of all Kobe steel components.

For TEPCO's Kashiwazaki Kariwa-6&7 reactors that are advanced in the NRA safety compliance review, the company should disclose details on all Kobe Steel components installed in the reactors. The NRA should suspend approval of safety compliance of the Kashiwazaki Kariwa reactors pending full disclosure and inspection of all components.

Equally, the Kobe Steel components installed in the Rokkasho-mura plutonium reprocessing plant must be put under urgent review and inspection.

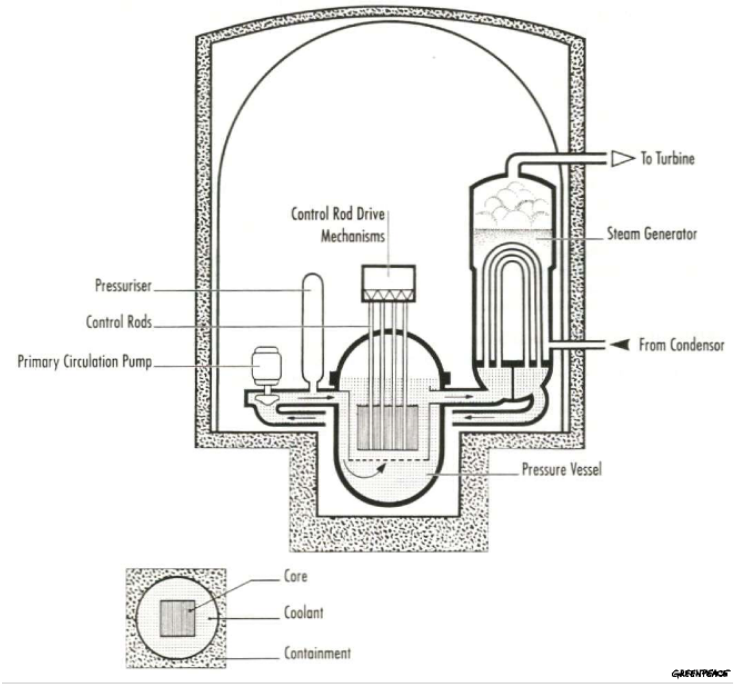
It is likely that suspect parts from Kobe Steel installed in motor vehicles, aircraft and trains will be replaced.[9] The risks and consequences of a catastrophic failure of a Kobe Steel component in a nuclear reactor would be severe, and where there is suspicion of the parts they should be replaced.

The failure of the NRA to effectively investigate the faulty manufacture of major steel components by Japan Casting and Forging Company (JCFC) and Japan Steel (JSW) to the French and Japanese nuclear industry cannot be repeated.[10]

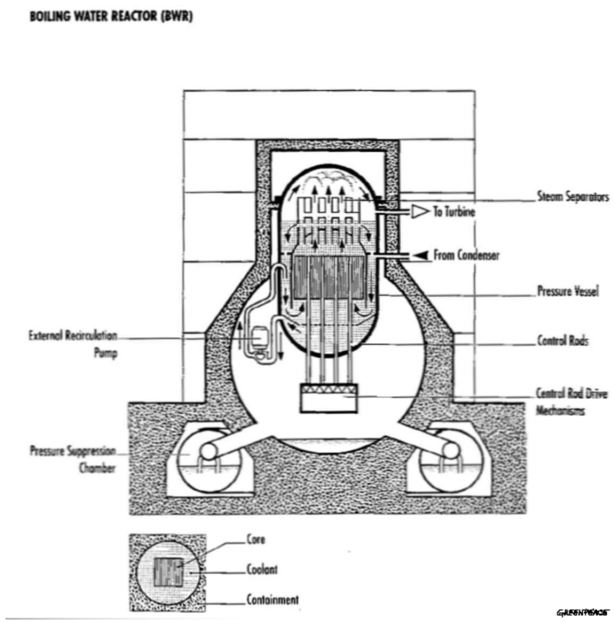
The challenge to the Nuclear Regulation Authority (NRA) in Japan is that they must demonstrate that they take these issues seriously and not conduct a superficial review of manufacturing data supplied by the very company, Kobe Steel, which is at the centre of the on-going crisis.

In conclusion, and given the scale of the nuclear supply chain, it is clearly beyond the NRA's current capacity and competence to effectively oversee the Quality Assurance of manufactured components installed in Japan's nuclear reactors and fuel cycle facilities. As Japan's aging nuclear plants are at increasing risk of catastrophic failure, the Kobe Steel scandal further challenges the operation of those reactors and nuclear fuel cycle facilities.

Pressurized Water Reactor



Boiling Water Reactor



KOBE STEEL SUPPLY CHAIN TO THE NUCLEAR INDUSTRY

Company	Product	Nuclear Equipment	Customer	Function	Safety Implications
Kobe Steel Ltd./ KOBELCO	BWR Fuel Outer Channels Kobe, Japan Kobe Steel Sheet forming, machining, welding.[11]	BWR Box Fuel Channels	Majority of Boiling Water Reactors in Japan[12] - TEPCO (Fukushima Daiichi and Daini and Kashiwazaki Kariwa) Tohohoku Electric (Onagawa), Chubu Electric (Hamaoka), Hokuriku Electric (Shika), Chugoku Electric (Shimane) Overseas customers – United States / Europe.	Permits operational control of reactor core and in emergency situation reactor control rod insertion for safe shutdown. In order to maintain the most stable neutronics in the reactor core and to add structural mechanical stability, each BWR fuel bundle is surrounded by a thin-walled-core-length square box, the BWR channel.	Essential that the fuel channels function as specified, including in seismic events. Vulnerable to distortion, bulging and corrosion.[13] Fuel channel distortion is a significant problem for BWR reactor operators,[14] increasing the risk of safety-related disruptions,[15] including decrease of thermal margins (dry-out and Loss of Cooling Accident, LOCA). Twisting of the fuel channel may result from relaxation of residual stresses from a non-optimized channel manufacturing process; however, good fabrication methods should include stress relief annealing. This includes affecting control blade insertion and withdrawal times. When channel distortion is excessive, the size of the control blade path is decreased, thus increasing friction between the control blades and the tube channels.
Kobe Special Tubes Company.	Seamless stainless steel low finned tubes.[16]	Moisture-reheater separator heater tubes in BWR[17] and PWRs.[18]	Widespread use across Japanese nuclear power plant sector.	Moisture separator-reheater components (MSRs) are used to dry and superheat the exhaust steam from the high pressure turbine.	MSRs have experienced numerous problems The most serious being the progressive failure of the U-tubes, which has necessitated replacement of MSR tube bundles at several plants.[19]
Zirco Products Co. Ltd. at its Amagasaki plant (a jointly owned company of Kobe Special Tube Co., Ltd. and Sumitomo Metal Industries, Ltd. (Sumitomo Metals); in 2009 CEZUS (AREVA)[20] purchased 33% share in Zirco.	Zirconium (2&4) cladding tube – 350 tons per year.[21]	Zirco has a 75% market share of all fuel cladding in Japan.[22] Supplied to nuclear reactor operators by Toshiba, Hitachi, Mitsubishi Nuclear Fuel/MHI and Nuclear Fuel Industries (NFI). Cladding is the outer layer of the fuel rods between the reactor coolant and the nuclear fuel.	Since the 1970's Kobe Steel has supplied Zr-2 tube cladding for the nuclear industry.[23] Zirco is Japan's largest supplier of Zircalloy to the nuclear industry. It is likely that all reactors in Japan have used and are using Zirconium fuel cladding supplied by Kobe Steel, including through supplier Zirco.	Cladding prevents radioactive fission fragments from escaping the fuel into the coolant and contaminating it. Nuclear reactor fuel rods are made of thousands of small fuel pellets of enriched uranium which are inserted end-to-end inside hollow tubes of zircaloy. There are between 91 and 96 rods per fuel assembly in a BWR, with between 300 and 800 assemblies per reactor core; for PWR's there are 180-264 rods per assembly and between 121-193 assemblies per reactor core. The tubes are filled with inert helium gas to improve the heat conduction from the pellets to cladding that is cooled by the water that circulates outside the tubes.	Fuel 'failure' refers to a situation when the cladding has been breached and radioactive material leaks from the fuel ceramic (pellet) into the reactor coolant water. The radioactive materials with most tendency to leak through a cladding breach into the reactor coolant are fission-product gases and volatile elements, notably; krypton, xenon, iodine and cesium. The most serious risks from cladding failure are in the event of a Loss of Coolant Accident (LOCA).[24] If cooling of fuel is not effective the cladding metal and reactor core can melt.

Company	Product	Nuclear Equipment	Customer	Function	Safety Implications
Shinko Metal Products Company.[25]	Copper-nickel tubes, Ferroco tubes (heat exchanger tube with iron-hydroxide protective film), KC tubes and heat exchanger Duplex tubes.[26]	The heat exchanger tubes are incorporated into nuclear reactor condensers and associated pipework.	Condensers and condensate circuit piping are used in all Japan's PWR and BWRs, with Shinko Steel and Kobe Steel Tube Company one of the principal suppliers.	The condenser is a large heat exchanger designed to cool exhaust steam from a turbine below the boiling point so that it can be returned to the heat source as water. In a PWR, the water is returned to the steam generator. In a BWR it returns to the reactor core. The heat removed from the steam by the condenser is transferred to a circulating water system and is exhausted to the environment.	The quality and reliability of the condenser and associated feed pipes is essential for reactor operation,[27] and in the event of an emergency shutdown. Operating under intense pressure and temperature, condenser tube rupture is a major risk in a nuclear power plant. Five workers were killed at the Mihama 3 nuclear power plant on 9th August 2004 following the rupture of main condensate pipe.[28] Tube thickness is a critical issue for integrity of condenser pipes. The Mihama-3 pipe had not been inspected since it was installed 28 years earlier. The principal risks of condenser failure is it will contribute to a LOCA, with the potential for reactor core melt.
The Kobe Steel Group Kakogawa Works.[29]	Largest hydraulic press of 13,000 tons supplies steel ingots and and steel plate.	Reactor pressure vessel components (eg. closure head) and steel plate for steam generators.	Unclear the extent to which Kobe Steel has supplied Japanese and overseas industry. Likely contractor to MHI and others but no public dislcosure.[30]	The heart of a nuclear plant, the reactor pressure vessel retains the reactor fuel core; steam generators in PWR's converts high temperature water to steam to power turbine.	Class 1 components not permitted to fail to severe consequences. Vulnerable to embrittlement, corrosion, reduced toughness (including due to excess carbon content). Quality control and assurance and inspection essential.
KOBELCO Steel Tube Company.[31]	Stainless steel tubes.	Feed water systems in Japanese PWRs and BWRs.	Kobe Steel Tube widely used in Main Feed water systems in PWRs and BWRs in Japan, and in auxiliary feed water systems.	The major secondary systems of a Pressurized Water Reactors are the main steam system and the Main condensate/feed water system, which transfer heat from the primary circuit to the steam generators. The auxiliary feed water system and the steam dump system (turbine bypass valves) are essential when trying to remove residual decay heat from a shutdown reactor core.[32] In the case of BWRs, the condensate/feed water system provides water directly to the reactor pressure vessel, which then is heated to steam which passes through the reactor turbine, then condensers before passing through the low pressure feed water heaters and feed water pumps before returning to the reactor pressure vessel. In emergency situations, the BWR reactor core isolation cooling system relies on the auxiliary feed water pump and piping to maintain water levels above the reactor core fuel and to avoid fuel melt.	Degradation of main and auxiliary feed water pipes, including thinning, can have catastrophic consequences leading to the failure to cool the reactor core, including in emergency situations, such as Station Blackout. See US NRC.[33] Pipes less than the minimum necessary thickness are non-compliant with the technical standards.[34] Pipes vulnerable Stress Corrosion Cracking SCC in steam generator feed water piping of PWR's, in carbon steel piping of BWRs[35] and in feed water tanks of nuclear reactors, also Strain-induced Corrosion Cracking; Erosion-corrosion has reduced pipe wall thickness in PWR's; and Intergranular stress corrosion cracking. The feed water pipes are vulnerable to to Flow Accelerated Corrosion (FAC), in addition to general risks due to aging, Japanese plants are highly vulnerable to seismic induced damage.[36] Questions over the frequency and effectiveness of inspections in Japanese nuclear reactors.[37]

Company	Product	Nuclear Equipment	Customer	Function	Safety Implications
Kobe Steel Company	Austenitic stainless steels.	Pipe work and tanks, remote handling, treatment and storage systems for radioactive waste channel boxes.[38]	JNFL Rokkasho-mura reprocessing plant – chemical separation facility, nuclear waste storage at the Nippon Flakin Co.,Ltd. Rokkasho-mura reprocessing plant.	Highly corrosive environment in the reprocessing plant – including boiling nitric acid requires high quality steel.[39]	The Rokkasho-mura reprocessing plant (currently non operational) is intended to separate up to 800 tons of nuclear spent fuel per year. There are multiple risks with such operations, with corrosive resistant steels essential to prevent ruptures and leaks, including of liquid high level nuclear waste. Steel pipe work is vulnerable to corrosion and fatigue, as well as poor design, installation, maintenance and inspection. Major pipe breaks have led to the leak of highly radioactive spent fuel at reprocessing plants.[40] Kobe Steel was one of the principal suppliers of austenitic steel at the Rokkasho plant, which suffers inter granular corrosion in boiling nitric acid solutions due to impurities in manufactured steel.[41] Kobe also supplies across the nuclear waste storage supply chain.
Kobe Steel Company (partnership with AREVA through Transnuclear Ltd. (TN).[42]	Design and manufacture of plutonium MOX fuel and spent fuel casks, including borated aluminum alloy[43] and neutron shielding.[44] Production at Takasago Equipment Plant.	Across the supply chain for cask manufacture, for example the alloy used as the basket material of spent fuel cask.[45]	Worldwide use, including in Japan,[46] for example casks delivered to the Fukushima Daiichi plant in 1995 and from 2013; and plutonium MOX fuel casks delivered to Takahama nuclear power plant in September 2017.	Spent fuel casks are used both for transport and storage of highly radioactive nuclear reactor spent fuel. Currently most spent fuel in Japan is stored in spent fuel pools, but increasing move to dry cask storage which reduces risks from spent fuel pools. Currently, Japan has 17000 tons of spent fuel.	As one of the principal suppliers of plutonium MOX fuel and reactor spent fuel casks, TN has decades long experience in manufacture. Over the years Kobe Steel and its suppliers have been issued non compliance and violation orders from the U.S. NRC, including related to quality assurance, questions over staff competence and inspection oversight.[47] Due to the long lived radioactive isotopes in spent fuel, essential that storage casks integrity assured. Key issues are: Preventing nuclear criticality, due to degradation of spent fuel, the canister, or neutron absorbers; Preventing unacceptable release of radioactive material (i.e., confinement), due to degradation of the seal, the canister, and spent fuel; Avoiding excessive radiation dose rates and doses (i.e., radiation shielding), due to degradation of shielding material; Maintaining the retrievability of the contents under SNF degradation. All of these are highly relevant to the quality of Kobe Steel casks.

Company	Product	Nuclear Equipment	Customer	Function	Safety Implications
Shinko Wire Company Ltd.	Pre-stressed wire and strand for use in pre stressed concrete structures.[48]	Tendon wire for nuclear reactor concrete containment vessels.	Widespread throughout Japanese nuclear reactors and overseas.[49]	The containment structure serves as the final barrier against the release of fission products to the environment under postulated design-basis accident conditions. Therefore, it is essential that its integrity be maintained. The focus on the prestressing tendon system for containment integrity is based on the vital role it plays. In addition to the issue of tendon relaxation, other aspects of the prestressing tendon system, such as controlling the material condition of the tendon galleries and maintenance of the tendon system to minimize corrosion, are also important.	Degradations, such as concrete spalling, water infiltration into tendon galleries, and concrete cracking in the containment and the containment dome, all affect the containment's ability to perform its intended function. Particularly important in aging nuclear reactors. It remains important to ensure that the cumulative effects of degradation mechanisms do not compromise the safety of the containment.[50]
Kobelco Welding and Kobelco Welding Company America Inc.	Welding metals (consumables)	Welding metals for pressurized nuclear reactor components – Reactor Pressure Vessels, Steam Generators, Condensers and Feed Water systems.	Widespread use across Japanese PWRs and BWRs, and in case of Westinghouse/Toshiba and Hitachi reactors and through Mitsubishi Heavy Industries (MHI) supplied to U.S./Europe market.	The large steel pressurized components that make up a nuclear reactor (RPV, SGs etc) as well as associated pipework all require weld metal to be applied to the base metal components, in many cases supplied by Kobe Steel.	Critical to reactor safety in routine operation and in emergency shutdown situation. Kobe Welding provides materials for Reactor Pressure Vessels and Steam Generators, which are Class 1 pressurized components and are not permitted to fail due to the severe consequences. Subject to both high pressures and temperatures, as well as neutron irradiation, the inside of reactor pressure vessels, steam generators, condensers and feed water piping is a severe corrosive environment. Exacting chemical, mechanical quality and tensile strength standards must be applied to the quality of the welding metal, including carbon content (not to increase brittleness), The Kobe Steel welding metals must not contribute to crack propagation in the main steel components, or reduce toughness. The welding consumables, must be reliable and have enough strength to withstand at elevated temperatures during operation, low temper embrittlement in case of emergency shutdown, high resistance to neutron irradiation brittleness, and good weldability.[51] Kobe Steel in recent years has supplied plate steel and welding metals to the Westinghouse/Toshiba VC Summer nuclear plant in South Carolina[52] construction of which was stopped in July 2017.[53]

1 Senior Nuclear Specialist, Greenpeace Germany, sburnie@greenpeace.org, Tokyo, Japan, October 2017

2 Nuclear Safety Network, "Summary Report of Peer Review", Nuclear Safety Network (NSnet) Otemachi Building #437 1-6-1 Ote-machi, Chiyoda-ku, Tokyo 100-0004, August 2003, see http://www.gengikyo.jp/english/topics/20031212a.pdf

3 Nikkei Asian Review, "Kobe Steel plants faked quality data for decades", 17 October 2017, see https://asia.nikkei.com/Spotlight/Kobe-Steel-data-scandal/Kobe-Steel plants-faked-quality-data-for-decades and Kyodo, "Kobe Steel allegedly passed down how-to memos detailing deceptive practice for years", 19 October 2017, see https://www.japantimes.co.jp/news/2017/10/19/business/corporate-business/kobe-steel-allegedly-passed-memos-detailing-deceptive-practice-years/ and Nikkei, "Kobe Steel fesses up to more data cheating", 21 October 2017, see https://asia.nikkei.com/Japan-Update/Kobe-Steel-fesses-up-to-more-data-cheating

4 For recent U.S. industry experience see "Nuclear Pipe Nightmares" Dave Lochbaum Director, Nuclear Safety Project l October 27, 2015, see http://allthingsnuclear.org/dlochbaum/nuclear-pipe-nightmares

5 Fauske Associates, "Nuclear Power Plant Seismic Verification of Piping Systems" 12 December 2013, see https://www.fauske.com/blog/bid/359117/nuclear-power-plant-seismic-verification-of-piping-systems

6 NRC, "Seismic Design Standards and Calculational Methods in the United States and Japan" NUREG/CR -7230NUREG/CR -7230, Office of Nuclear Regulatory Research, May 2017, see https://www.nrc.gov/docs/ML1713/ML17131A127.pdf

7 The National Diet of Japan The official report of Executive summary The Fukushima Nuclear Accident Independent Investigation Commission, 2012, see http://large.stanford.edu/courses/2013/ph241/mori1/docs/NAIIC_report_hi_res10.pdf, and more recently, "New York Times, "Japan and Utility Are Found Negligent Again in Fukushima Meltdowns" 10 October 2017, see https://www.nytimes.com/2017/10/10/world/asia/japan-fukushima-lawsuit.html

8 European Aviation Safety Agency, "Kobe Steel Ltd. Material – Falsified Inspection Data" 17 October 2017, see https://ad.easa.europa.eu/ad/2017-17

9 Reuters "Boeing passenger jets have falsely-certified Kobe Steel products: source" 13 October 2017, see http://www.reuters.com/article/us-kobe-steel-scandal-boeing/boeing-passenger-jets-have-falsely-certified-kobe-steel-products-source-idUSKBN1CI05P, and New York Times, "Factbox: Kobe Steel's Data Fabrication Leaves Manufacturers Scrambling" Reuters, 20 October 2017, see https://www.nytimes.com/reuters/2017/10/20/business/20reuters-kobe-steel-scandal-factbox.html?_r=0

10 See "Japanese Steel At Centre Of French Nuclear Crisis – Major Questions And Implications For Japanese Reactor Safety", 25 October 2016, see http://www.greenpeace.org/japan/ja/news/press/2016/pr201610251/ and "Japanese Reactor Steel at Risk of Catastrophic Failure - JCFC, JSW and JFE Holdings under Suspicion" 13 December 2016, see http://www.greenpeace.org/japan/ja/news/press/2016/pr201612131/

11 ANT International, Fuel Design Review Handbook – 2010, see https://www.antinternational.com/docs/samples/FM/11/fdrh_examples1.pdf

12 iKOBE Steel, "Functions and Fabrication Technologies of Fuel Channel", Kobe Steel Engineering Reports/Vol. 53 No. 3（Dec. 2003）see http://www.kobelco.co.jp/technology-review/pdf/53_3/098-102.pdf (in Japanese).

13 Advanced Nuclear Technology International, "BWR Fuel Channel Distortion", Friedrich Garzarolli Fürth, Germany Ron Adamson Fremont, Pleasanton, CA, USA Peter Rudling ANT International, Mölnlycke, Sweden Alfred Strasser Sleepy Hollow, NY, USA Reviewed by Peter Rudling ANT International, Mölnlycke, Sweden, October 2011, Analysvägen 5, SE-435 33 Mölnlycke Sweden, see https://www.antinternational.com/docs/samples/FM/04/ZIRAT16_STR_ChannelDistortion_sample1.pdf.

14 See for example, AREVA supply of Kobe Steel manufactured advanced fuel channel for Grand Gulf BWR nuclear plant in the United States which suffered "unexpectedly high bowing", Fuel Performance Meeting April 8-9, 2008 Lynchburg, VA AREVA NP Inc., https://www.nrc.gov/docs/ML0814/ML081410298.pdf

15 For examples as of 2011, fifty percent of the 35 BWRs in the United States had reported channel box interference due to channel distortion, primarily channel bow - see https://www.antinternational.com/docs/samples/FM/04/ZIRAT16_STR_ChannelDistortion_sample1.pdf

16 KOBELCO, "Widely Applicable Seamless Stainless Steel Tubes and Pipe", see http://www.kobest.co.jp/english/products/01_stainless.html

17 General Electric, "General Electric Systems Technology Manual Chapter 1.4 Types of Boiling Water Reactors", 2012, see https://www.nrc.gov/docs/ML1125/ML11258A293.pdf

18i Development of Large Size Moisture Separator Reheater for Up to 1700 MW PWR Class" Issaku Fujita, Teruaki Sakata and Toshiki Kojima, 18th International Conference on Nuclear Engineering, China, May 2010, see http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1619188

19 IAEA, "Tube failures in moisture separator-reheater tube bundles due to restrained thermal expansion", Heiker WJ, Cassell DS, Combustion Engineering, 1983, https://inis.iaea.org/search/search.aspx?orig_q=RN:15047102

20 CEZUS was embroiled in a quality control scandal centered on zirconium fuel cladding in the late 1990's. For 18 months, between August 1998 and February 2000, an utrasonic scanner failed to inspect the first third of the first fuel cladding tube of each lot. All tubes are to be scanned in entirety during the principal QC check. Although the fault was discovered in February 2000, management of the plant failed to communicate the problem, to both customers and French regulators. it was only with the failure of fuel cladding in a French reactor in August of 2000 leading to a rise in radioactivity in the primary coolant, that an investigation by Framatome uncovered the problem at one of its plants. It was a further three months before the French nuclear safety regulator, DSIN, was informed, even though fuel cladding failure relates directly to the safety of fuel in reactors, see "THE CEZUS AFFAIR: A flaw in the quality control of nuclear fuel", Xavier COEYTAUX, Yves MARIGNAC, Emmanuel ROUY, Mycle SCHNEIDER, WISE-Paris, 2000, see http://www.wise-paris.org/english/ourbriefings_pdf/001220BriefCEZ1v2.pdf; and see also Greenpeace comments regarding the Nuclear Regulatory Commission's (NRC) scoping process in preparation for the completion of the Plutonium (MOX) Fuel Environmental Impact Statement (EIS), Damon Moglen, Greenpeace International, 2001, https://www.nrc.gov/docs/ML0114/ML011490317.pdf

21 Kansai, Hokkaido, Shikoku and Kyushu Electric Power Companies, the Japan Atomic Power Company, MHI, NFI, MMTL, ZP, MNF, NDC, Sumitomo Metal Industries and Kobe Special Tube) and academic institutes (Tokyo, Osaka, Tohoku and Kyoto Universities and JAEA) have jointly formed an investigation committee to develop J-AlloyTM for nuclear fuel cladding development.

22 In September 2009, CEZUS obtained a **33% share in the capital of Zircoproducts**, the Japanese tube manufacturer.SFEN Jeune Génération, "Interview with Mr Rémy Autebert, President of AREVA Japan" see http://www.sfenjg.org/IMG/article_PDF/article_a165.pdf. AREVA has long been a customer of CEZUS and is the first fuel assembly cladding manufacturer on the Japanese market, holding a market share of nearly 75%, see "AREVA in Japan The Facts", http://www.new.areva.com/EN/group-1483/japan-nuclear-power-a-major-strategic-area.html

23 Hiroshi SUZUKI , Tadatsune Okubo & Hikari Ishizaka (1982) Nonelastic Behavior of Zircaloy Fuel Cladding Tubes at 473 K, Journal of Nuclear Science and Technology, 19:2, 133-144, DOI: 10.1080/18811248.1982.9734125, see http://dx.doi.org/10.1080/18811248.1982.9734125; see also patent filing Kobe Steel, Surface-Hardenedtitaniumor Zirconium And Their Alloys And Method Of Processing Same, U.S. Patent Office, 22 March 1971.

24 The emergency core cooling systems must cool the fuel efficiently during all phases of the LOCA. This requirement leads to a criterion that the fuel must maintain its coolable geometry throughout the whole LOCA sequence and that the structural integrity of the fuel rods is maintained. During the LOCA event, the cladding heats up to temperatures over 1 000°C. When the temperature reaches about 800°C, zirconium starts to transform from alpha to the beta phase. Oxygen dissolves in the metal and embrittles the alpha phase. Therefore, there must be a limit on the oxygen-stabilised alpha phase, since the load bearing prior beta layer may be too thin to ensure structural integrity of the fuel during the quench phase of the LOCA. There are many other issues which must be taken into account. When the fuel rods heat up during the LOCA and the external pressure is lost, the rod internal pressure is large enough to cause plastic deformation of the cladding which leads to ballooning and burst. See OECD NEA, "Nuclear Fuel Behaviour in Loss-of-coolant Accident (LOCA) Conditions State-of-the-art Report", 2009, Nuclear Energy Agency Organisation For Economic Co-Operation And Development, see https://www.oecd-nea.org/nsd/docs/2009/csni-r2009-15.pdf

25 KOBELCO, Copper and Copper Alloy Tubes", see http://www.shinkometal.co.jp/english/products/goukinkan.html

26 KOBELCO "Challenging the Future"see http://www.kobest.co.jp/english/products/03_specialty.html

27 In March 2017, the Watts Bar 2 nuclear reactor in the United States suffered a condenser failure leading to emergency shutdown, see NRC, "Preliminary Notification Of Event Or Unusual Occurrence Pno-Ii-17-002, Subject: Shutdown Due To Condenser Failure" 23 March 2017, see https://www.nrc.gov/docs/ML1708/ML17082A621.pdf

28 The pipe in Mihama-3 contained water heated to 140 degrees Celsius under 9.5 atmospheric pressure. When the pipe ruptured, this water spewed out in the form of steam, severely scalding the unfortunate workers who happened to be in the room. The thickness of the wall of the pipe at the point where it ruptured was down to around 1mm, compared to the original thickness of 10mm and the regulatory minimum of 4.7mm. It had never been checked during the entire 28 years that the plant had been operating, see CNIC, "Five Killed in Mihama-3 Accident", Tokyo Nuke Info, October 2004, see http://www.cnic.jp/english/newsletter/pdffiles/nit102.pdf

29 KOBELCO, "Kobe Steel Nuclear Technology and Products", undated, see http://www.kobelco.co.jp/products/nuclear/npi.pdf

30 KOBELCO, "Kobe Steel Nuclear Technology and Products", undated, see http://www.kobelco.co.jp/products/nuclear/npi.pdf

31 KOBELCO, "Widely Applicable Seamless Stainless Steel Tubes and Pipe," 2016, http://www.kobest.co.jp/english/products/01_stainless.html

32 The auxiliary feed water system pumps water from the condensate storage tank to the steam generators. This water is allowed to boil to make steam. The steam can then be dumped to the main condenser through the steam dump valves. The circulating water will then condense the steam and take the heat to the environment.

33 The NRC describes Main Feed water pipes "are important to the safe operation of nuclear power plants. Past failures of feed water and other high-energy system components have resulted in complex challenges to operating staff when the released high-energy steam and water interacted with other systems, such as electrical distribution, fire protection, and security systems. Personnel injuries and fatalities have also occurred. The failure to maintain high energy piping and components within allowable thickness values can (1) increase the initiating event frequency for transients with loss of the power conversion system, main steam line breaks, and other initiating events due to system interactions with high-energy steam and water; (2) adversely affect the operability, availability, reliability, or function of systems required for safe shutdown and accident mitigation; and/or (3) impact the integrity of fission product barriers." see Information Notice 2001-09: Main Feed water System Degradation in Safety-Related ASME Code Class 2 Piping Inside the Containment of a Pressurized Water Reactor," United States Nuclear Regulatory Commission, Office Of

Nuclear Reactor Regulation, 12 June 2001, see https://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/2001/in01009.html In the case of auxiliary feed (AF) water system in PWRs they are designed to supply high-pressure feed water to the steam generators in order to maintain a water inventory for removal of heat energy from the reactor coolant system by secondary side steam release in the event of inoperability or unavailability of the main feed water system. The AF system shall automatically start and deliver adequate AF system flow to maintain adequate steam generator levels during accidents which may result in main steam safety valve opening. The AF system shall automatically start and deliver sufficient AF system flow to maintain adequate steam generator levels during accidents which require rapid reactor coolant system cool down to achieve the cold shutdown condition within the limits of the analysis. In the event of a station blackout (prolonged loss of offsite and onsite AC power) affecting both units, the AF system shall be capable of automatically supplying sufficient feed water to remove decay heat from both units without any reliance on AC power for one hour.

34 NEA OECD, "JSME Codes for Nuclear Power Generation Facilities, Rules on Design and Construction for Nuclear Power Plants 2005 (2007), CODAP Topical Report Flow Accelerated Corrosion (FAC) of Carbon Steel and Low Alloy Steel Piping in Commercial Nuclear Power Plants Nuclear Safety NEA/CSNI/R(2014)6 June 2014, see https://www.oecd-nea.org/nsd/docs/2014/csni-r2014-6.pdf

35 In a boiling-water nuclear power plant, oxygen, hydrogen peroxide, and the like produced by radiolysis of water in the radiation field exist in a state dissolved in the reactor water. It is a well-known fact that stainless steel and nickel-based alloys, which are used for reactor structural components of the nuclear power plant, generate stress corrosion cracking in the presence of oxygen and hydrogen peroxide in a high-temperature environment such as a nuclear reactor.

36 NEA OECD, "Seismic Safety Evaluation of Review Manual for Technical Evaluation of Measures for Aging Management, Codes for Nuclear Power Generation Facilities, Rules on Design and Construction for Nuclear Power Plants 2005 (2007), CODAP Topical Report Flow Accelerated Corrosion (FAC) of Carbon Steel and Low Alloy Steel Piping in CommercialNuclear Power Plants Nuclear Safety NEA/CSNI/R(2014)6 June 2014, see https://www.oecd-nea.org/nsd/docs/2014/csni-r2014-6.pdf

37 CNIC, "NISA also noted that other power companies (Hokkaido, Kyushu, Tokyo, JAPCO) had postponed changing pipes. Something that is not mentioned in NISA's report is the fact that other companies, including Tokyo Electric Power Company (TEPCO) and Tohoko Electric Power Company, measured pipe thicknesses at the straight part of pipes near elbows and recorded these as measurements of elbows, even though the elbows were never actually measured. CNIC "Final Reports on Mihama-3 Accident: Critical Facts Remain Unclear" Nuke Info Tokyo No. 106 (May/June 2005) see http://www.cnic.jp/english/newsletter/nit106/nit106articles/nit106mihama.html

38 Toshiba and its affiliated company Tran-Nuclear Co., Ltd. have recently established Aomori Technical Service Co., Ltd. in Rokkasho village, Aomori Prefecture, and started business. The company will provide technologies and services related to the operation, maintenance, management, etc. of reprocessing related facilities under construction by Nipponbara Incorporated in Rokkasho village., 19 July 2001, see http://www.kobelco.co.jp/column/topics-j/messages/119.html

39 "Corrosion Kinetics of Type 310 EHP Stainless Steel in Nitric Acid with Cr(VI)＊ Tetsunari Ebina＊, Shigeru Yamazaki and Yutaka Watanabe Japan Nuclear Fuel Limited Japan Nuclear Fuel Limited (currently Kobelco Research Institute, Inc.) Tohoku University, 2016, see https://www.jstage.jst.go.jp/article/jcorr/65/7/65_302/_pdf, see also The Japan Society of Mechanical Engineers "ICONE23-1656 Study Of The Corrosion Resistance And The Mechanical Properties Of R-SUS310ULC EHP", Imaruoka Hiroto, Japan Nuclear Fuel Limited; Okada Kiyotaka, Japan Nuclear Fuel Limited; Sugiyama Hiroshi, Japan Nuclear Fuel Limited; Ebina Tetsunari, Japan Nuclear Fuel Limited; Kano Yoichi, Japan Nuclear Fuel Limited; Soma Yasutaka, Japan Atomic Energy Agency; Kato Chiaki, Japan Atomic Energy Agency; Ueno Fumiyoshi, Japan Atomic Energy Agency; Yamamoto MasahiroJapan Atomic Energy Agency; Kato Osamu, KOBE STEEL, LTD.;Nakayama Junpei, KOBE STEEL, LTD.; Proceedings of the International Conference on Nuclear Engineering, July 2015, see http://ci.nii.ac.jp/naid/110010046410

40 See for example the leak of 22 tons (85 cubic meters) of spent fuel at the Head End at the THORP reprocessing plant in England, CORE, "THORP Leak Update No 08/05, 13 May 2005, see http://corecumbria.co.uk/briefings/thorp-leak-update-no-805/, and also Report of the investigation into the leak of dissolver product liquor at the Thermal Oxide Reprocessing Plant (THORP), Sellafield, notified to HSE on 20 April 2005, UK Health and Safety Executive, see http://www.onr.org.uk/periodic-safety-review/thorpreport.pdf

41 Effect of nitrate on corrosion of austenitic stainless steel in boiling nitric acid solution containing chromium ions", Satoshi Hasegawa,Seong-Yun Kim,Tetsunari Ebina,Haruaki Tokuda,Tatsuya Ito,Nobumichi Nagano,Keitaro Hitomi &Keizo Ishii, Journal of Nuclear Science and Technology Volume 53, 2016 - Issue 9, see http://www.tandfonline.com/doi/full/10.1080/00223131.2015.1107514?scroll=top&needAccess=true; the JNFL Rokkasho-mura plant uses steel pipe that is less resistance to corrosion than more modern steels, which will have a significant impact on the operational life of the plant as well as increasing risks of pipe rupture, see IAEA "Development of fabrication technology of the extra high purity stainless steel 'SUS310EHP" Okada, Kiyotaka; Sugiyama, Hiroshi; Ebina, Tetsunari; Kano, Yoichi; Nakayama, Junpei; Soga, Yukihiro Proceedings of the 11th annual meeting of Japan Society of Maintenology, 2014, see https://inis.iaea.org/search/search.aspx?orig_q=RN:46134721 and KOBE Steel, "Extra High Purity Stainless Steel "SUS310EHP®" with High Corrosion Resistance for Next Generation Nuclear Fuel Reprocessing Plant" April 2014, see http://www.kobelco.co.jp/technology-review/pdf/64_1/whole.pdf

42 Transnuclear Ltd provides global services for nuclear transport, from design and manufacture of transport containers to transport services, inspection and maintenance, share ownership is Kobe Steel 47.5% AREVA TN 47.5% Sojitz Corporation 5.0% see Transnuclear Tokyo, see http://www.tntokyo.co.jp/en/product.html; AREVA, The Design Specialist In Japan For Transport And Storage Casks, see http://www.new.areva.com/EN/operations-3754/tn-tokyo.html

43 Kobe Steel, Borated Aluminum Alloy Manufacturing Technology, Kobe Steel Engineering Reports/Vol. 53 No. 3（Dec. 2003）see http://www.kobelco.co.jp/technology-review/pdf/53_3/012-017.pdf (in Japanese).

44 Kobe Steel produces the Kobesh neutron shield, see Kobe Steel Engineering Reports - Vol.53, No.3 / Dec. 2003, see http://www.kobelco.co.jp/technology-review/english/vol53_3_sum.htm; Kobe Steel was subject to investigations following the disclosure in 1998 that they had falsified neutron shielding material on spent fuel casks, see Nuclear Safety Network, "Summary Report of Peer Review", Nuclear Safety Network (NSnet) Otemachi Building #437 1-6-1 Ote-machi, Chiyoda-ku, Tokyo 100-0004, August 2003, see http://www.gengikyo.jp/english/topics/20031212a.pdf; and "Neutron shielding material", Nodaka, M.; Iida, T.; Taniuchi, H.; Yosimura, K.; Nagahama, H., The 10th international symposium on the packaging and transportation of radioactive materials, 1993, see https://inis.iaea.org/search/search.aspx?orig_q=RN:25043529

45 KOBELCO "Borated aluminum alloy is used as the basket material of cask because of its light weight, thermal conductivity and superior neutron absorbing abilities. Kobe Steel has developed a unique manufacturing process for borated aluminum alloy using a vacuum induction melting method. In this process, aluminum alloy is melted and agitated at higher temperatures than common aluminum alloy fabrication methods. It is then cast into a mold in a vacuum atmosphere. The result is a high quality aluminum alloy which has a uniform boron distribution and no impurities.", see Kobe Steel Engineering Reports - Vol.53, No.3 / Dec. 2003, http://www.kobelco.co.jp/technology-review/english/vol53_3_sum.htm ; also "Development of Enriched Borated Aluminium Alloy for Basket Material of Cask for Spent Nuclear Fuel,"Katsura Kajihara, Kobe Steel, Ltd., Kobe, JapanYasuhiro Aruga, Jun Shimojo, Hiroaki Taniuchi, Tsutomu Takeda, Kobe Steel, Ltd., Takasago, Japan and Masatosi Sasaki, Nippon Koshuha Steel Company, Ltd., Tokyo, Japan Paper No. ICONE10-22025, see https://www.jstage.jst.go.jp/article/jaesj1959/39/2/39_2_156/_article/-char/ja/

46 AREVA "In Japan, Transnuclear, Ltd., the joint venture between AREVA TN in France and KOBE STEEL delivered 20 TN®24 storage casks for 37 and 52 BWR assemblies to Fukushima No.1 NPP in 1995 and in 2013. For Japanese utilities, new transport and storage casks namely, TK®69 for 69 BWR and TK®26 for 26 PWR, have been developed. They offer the highest capacity and best coverage of fuel inventory to Japanese utilities.", Metal Casks for Used Fuel Transport and Storage, See http://us.areva.com/home/liblocal/docs/Catalog/AREVA-TN/AREVA_TN24_Metal%20Casks.pdf and AREVA, "AREVA And Its Japanese Partner Kobe Steel Deliver The First Dry Storage Casks For Spent Fuels Of Fukushima Daiichi Nuclear Power Plant", 4 March 2013, see http://www.new.areva.com/EN/news-9720/areva-and-its-japanese-partner-kobe-steel-deliver-the-first-dry-storage-casks-for-spent-fuels-of-fukushima-daiichi-nuclear-power-plant.html

47 In 2003, NRC inspectors found at the Kobe Steel plant a "lack of a record identifying the welder for a temporary attachment weld, and a violation with several examples of inadequate procedure control. Additionally, one violation was identified that was common to both KSL and HZ D&E involving the lack of a procedure and records for quality control surveillances." see Nuclear Regulatory Commission (NRC) Inspection Report No. 72-1004, 72-1027/2003-201 And Notice Of Violation" March 2003, see https://www.nrc.gov/docs/ML0308/ML030840292.pdf; In July 2006, NRC to Transnuclear related to inspection at Kobe Steel, Ltd. (KSL) in Takasago, Japan, and Hitachi Zosen Mechanical Corporation (HMC) in Ariake, Japan, "Nuclear Regulatory Commission (NRC) Inspection Report No. 72-1004/2006-203 And Notice Of Violation", July 206, see https://www.nrc.gov/docs/ML0619/ML061910208.pdf. In 2012, a non confirmatory order by the U.S. NRC was issued, following a stop work order made by a U.S. client of Transnuclear during the fabrication of fuel casks at the Kobe Steel works and partner plant at Sedae Enertech (SEC), South Korea; the NRC found that "during an inspection conducted November 5-7,2012, the following non-conformances were identified by the NRC where activities affecting quality were not prescribed in docwumented procedures or drawings, or where procedures or drawings for activities affecting quality were not followed. The NRC follow up inspection focused on 1. - Review KSL's and SEC's quality management system documents. 2. Review and understand the issues that led to the May stop work order issued to KSL and SEC and subsequent corrective actions put in place by TN, KSL and SEC, see Safety Inspection Report And Compliance Inspection, 20 December 2012, see https://www.nrc.gov/docs/ML1300/ML13008A602.pdf.

48 Post Tensioning Institute "Post Tension Manual", Arizona, see http://www.imcyc.com/biblioteca/ArchivosPDF/Concreto%20Postensado/4%20Post-Tensioning%20Manual.pdf

49 "Maintenance of Prestressed Concrete Containment Vessels in a Nuclear Power Plant", Yoshihiro Yamaguchi1), Takashi Kitagawa1), Hideki Tanaka2), Yasumichi Koshiro3), Hideo Takahashi4), Shinichi Takezaki5), Masazumi Nakao6)1) Nuclear Power Division, The Kansai Electric Power Co.,Inc., Japan. 2) Nuclear Facilities Division, Obayashi Corporation, Japan. 3) Technical Research Institute, Obayashi Corporation, Japan. 4) Planning & Design Section, Nuclear Facilities Engineering II, Nuclear Facilities Division, Taisei Corporation, Japan. 5) Building System and Material Research Section, Building Engineering Research Institute, Technology Center, Taisei Corporation, Japan. 6) Wakasa Branch, The General Environmental Technos Co., Ltd., Japan, Journal of Advanced Concrete Technology Vol. 14 (2016) No. 8 p. 464-474, see https://www.jstage.jst.go.jp/article/jact/14/8/14_464/_pdf

50 Examples of aging effects on Shinko tendon wire is at the Turkey Point 3&4 nuclear reactor, "Turkey Point, Units 3 & 4, Updated Final Safety Analysis Report" NRC, 2013, see https://www.nrc.gov/docs/ML1633/ML16330A184.pdf

51 KOBELCO, "Designing High Quality Welding Consumables For Nuclear Power Reactors" Technical Highlight Vol.3, http://www.kobelco-welding.jp/education-center/technical-highlight/vol03.html

52 NRC, "Virgil C. Summer Nuclear Station Units 2 And 3 - Nrc Integrated Inspection Reports 05200027/2014003 And 05200028/2014003", 6 August 2014, United States Nuclear Regulatory Commission Region II, see https://www.nrc.gov/docs/ML1421/ML14218A414.pdf and NRC, "Virgil C. Summer Nuclear Station Units 2 AND 3 – NRC Integrated Inspection Reports 05200027/2015003, 05200028/2015003" 5 November 2015, United States Nuclear Regulatory Commission Region II, see https://www.nrc.gov/docs/ML1530/ML15309A177.pdf

53 New York Times, "U.S. Nuclear Comeback Stalls as Two Reactors Are Abandoned", 31 July 2017, https://www.nytimes.com/2017/07/31/climate/nuclear-power-project-canceled-in-south-carolina.html?_r=0