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## CORRECTED - SPECIAL REPORT - Mistakes, misfortune, meltdown: Japan's quake

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(Corrects distance from Tokyo)

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By Kevin Krolicki

TOKYO (Reuters) - By Thursday morning the last line of defense came down to this: a police water cannon, a helicopter maneuver designed for wildfires and a race against time to get the Fukushima Daiichi nuclear power plant rewired to the grid.

As a crew of about 100 Japanese workers and soldiers battled to keep a string of six nuclear reactors from meltdown just short of a week into Japan's nuclear crisis, the arsenal of weapons at their disposal remained improvised, low-tech and underpowered.

A police riot control truck was hauled in over uneven roads to keep a spray of water on the No. 3 and No. 4 reactors. In the air above, Japan Self-Defense Forces helicopters made runs with baskets of water in a desperate attempt to cool exposed fuel rods believed to have already partly melted down.

Meanwhile, technicians were dashing to complete what amounts to the world's largest extension cord: an electric cable to connect the stricken plant from the north and allow Tokyo Electric Power Company (TEPCO), which runs the plant, to restart critical water pumps taken out by the massive earthquake and tsunami that hit Japan on the afternoon of Friday, March 11.

An examination by Reuters of Japan's effort to contain its escalating nuclear disaster reveals a series of missteps, bad luck and desperate improvisation. What also emerges is a country that has begun to question some of its oldest values. Japanese have long revered the country's bureaucratic competence, especially when it is contrasted with its political dysfunction. Japan has also proudly often chosen to go its own way and turn down outside assistance. But what happens when competence begins to break down? And what happens when a disaster is so overwhelming that outside help is vital?

The Fukushima plant was designed to withstand a violent earthquake. But the massive tsunami that followed knocked out both the plant's electric-powered cooling system and its diesel-powered backup generators.

As the first pictures of the destruction around the northern town of Sendai were beamed across Japan and around the world in the hours after the quake, authorities initially said they had safely shut down the four nuclear plants closest to the earthquake and tsunami zone.

It wasn't true. With no power to the plant's cooling system, the water that circulates around the fuel rods inside the six reactors at Fukushima had already begun to boil off. Within a few hours authorities declared a "nuclear emergency situation" at the plant. While no radiation release had been detected, they said, residents around the plant should evacuate.

It was the beginning of a new nightmare. Over the ensuing days, as Japan has struggled to come to terms with what could be more than 10,000 dead and raced to bring food and clean water to more than 500,000 people who lost their homes in the quake and tsunami, rapidly deteriorating conditions inside Fukushima have threatened a meltdown with the potential to spread radioactive particles across the country and beyond.

"They might have been prepared for an earthquake. They might have been prepared for a tsunami. They might have been prepared for a nuclear emergency, but it was unlikely that they were prepared for all three," said Ellen Vancko, an electric power expert with the Union of Concerned Scientists.

### FIRST TROUBLE

Before last week, Japan's 55 nuclear reactors had provided about 30 percent of the nation's electric power. That percentage had been expected to rise to 50 percent by 2030 with a boom in new plant construction.

But nuclear power plants stop if they don't have enough power. Stranded nuclear reactors cannot circulate water to cool their fuel rods. When the existing water boils off, the nuclear fuel begins to heat, a process that can set fire to surrounding materials and touch off powerful hydrogen blasts.



"Power is the lifeblood for a power plant," said Harold Denton, who headed the U.S. Nuclear Regulatory Commission team that handled the 1979 Three Mile Island crisis in the United States. "If you've got power, you can do a lot, but if you don't have any power, the water in the reactor vessels heats up and boils away and the fuel begins to melt. It's a problem they've gotten into now."

The threat for the Fukushima plant, 240 km (150 miles) northeast of Tokyo, is compounded, experts say, by the design of its 40-year-old reactors, known in the industry as the General Electric Mark 1.

Unlike newer models, the Tokyo Electric reactors in Fukushima each contain an upper chamber for storing spent fuel rods in a pool of water housed together in the same concrete shell as the active core of the reactor. A failure in one can lead to problems in the other.

On Saturday morning, Japanese officials reported increased pressure inside number 1 reactor. A few hours later, there was an explosion in one of the reactors.

TEPCO, the plant operator, said it had detected increased radioactivity levels around the plant but that the reactor's primary containment vessel had not been breached and no major leakage had occurred.

The company said it was about to begin pumping sea water into the reactors. They didn't explain it, but experts watching overseas immediately understood what it meant: the situation was so dire that the plants would never be saved. The priority now was to prevent a runaway meltdown.

As the level of radiation around the Fukushima complex topped safe levels, Japanese authorities began making preparations to hand out iodine -- used to protect the thyroid against radioactive exposure -- in the affected areas.

The following day, Sunday, Japan's nuclear safety agency said the Fukushima incident ranked as a 4 under the International Nuclear and Radiological Event Scale. By comparison, Three Mile Island was a 5 while Chernobyl was a 7 on the 1 to 7 scale.

Authorities were worried, but still optimistic that they could bring the plant back under control.

"SHUTTERS ROLLED"

The drama in Japan began just a day after the International Atomic Energy Agency's 35-nation Board of Governors had wrapped up its quarterly meeting in Vienna. Set up to "promote safe, secure and peaceful nuclear technologies" the IAEA has on staff some of the world's leading experts on nuclear safety.

But it quickly became apparent that the agency was struggling to keep up with what was unfolding on the other side of the world. The IAEA put out a series of short statements over the weekend, though at one point its website crashed and for several hours the press department had to refer journalists to statements posted on its Facebook page. It took three days for Director General Yukiya Amano, himself Japanese, to hold a news conference to address the emergency.

"Atomic contamination is threatening from Japan and what do you hear from the Vienna-based IAEA: dignified silence," a popular Austrian tabloid wrote. "The shutters are rolled down, just like for a weekend off."

When the markets in Tokyo opened on Monday, the response was inevitable: Japanese stocks fell more than six percent. On Tuesday, they would finish another 10 percent lower. The yen has spiked against the dollar this week as traders unwind their positions and Japanese investors pull out of foreign markets because they'll need the money at home.

On Monday a second hydrogen blast rocked the plant. TEPCO again said the explosion had not damaged the primary containment vessel. But by this stage even the stoic Japanese had begun to question the information they were receiving.

"They don't tell the truth. It's in their DNA," said Taro Kono, a member of the Liberal Democratic party and a long-time opponent of nuclear power.

Nuclear power analysts, officials and executives said they had seen nothing in the response to suggest that mistakes on the ground had compounded the crisis that now threatens a wide swath of Japan including Tokyo's nearly 13 million residents.

But the speed with which the crisis spun out of control has exposed a fundamental flaw in the risk planning that still governs much of the nuclear industry in Japan and elsewhere.

In diplomatic cables acquired by WikiLeaks and seen by Reuters, U.S. diplomats said a top Japanese official at the International Atomic Energy Agency had neglected safety in Japan.

Tomihoro Taniguchi, a Japanese official who headed the IAEA's department of Nuclear Safety and Security, hindered progress for years, according to a Dec. 2009 cable to Washington from the U.S. embassy in Vienna.

"Taniguchi has been a weak manager and advocate, particularly with respect to confronting Japan's own safety practices, and he is a particular disappointment to the United States for his unloved-step-child treatment of the Office of Nuclear Security," said another cable, sent on July 7, 2009.

Marin Kostov, an earthquake engineering expert in Bulgaria and a member of the IAEA expert team sent to Japan after the 2007 quake that hit the Kashiwazaki-Kariwa plant, said one of the main problems is not how plants are built but where they are built.

"Selecting where these nuclear power plants have to (be) built is a crucially important task," he said. Nuclear engineers had too "much belief that they are going to cope with these external events with making the buildings very strong, very safe."

"At the same time you have a situation like what has happened (in Japan) where although the building is safe -- nothing has happened after the tremor, after the shaking everything is there -- but then you do not have infrastructure, you do not have water, you do not have power, you have nothing."

BLACK SWAN

Nassim Nicholas Taleb's 2007 book *The Black Swan* described how the commonly held views of risk exclude the truly unexpected events that shape history and markets. The book has fueled new thinking on how to manage the risk from apparently low-probability, world-shaking events such as the attacks of Sept. 11, 2001.

Nuclear experts have thought a lot about that over the past few years. In the wake of the Sept 11. attacks, U.S. regulators required plant operators to develop plans to deal with potential airline attacks.

In February last year, the IAEA posted a report on its website about the 2007 Japan quake, saying it was a "wake-up call that reverberated around the globe."

"There has been a misconception since the early days of nuclear power that human error or mechanical failure, in other words risk factors within the plant itself, are the most significant variables regarding possible radiological release to the environment," the story read. "In fact, the greatest threat to a plant's operation may lie outside its walls.

"Nuclear power plants all over the world are exposed to natural hazards, such as hurricanes, floods, fires, tsunamis, volcanoes and earthquakes. With safety always a key concern, engineers, safety specialists and architects also have to take extreme natural forces into consideration."

Avinash Nafday, a California-based researcher who consulted for the U.S. Nuclear Regulatory Commission and has written on the Black Swan effect for nuclear plants, agrees. "In doing nuclear plant designs, you have to look at the consequences of events, no matter how low the probability," Nafday said.

But Ed Lyman, a physicist and nuclear plant design expert with the Union of Concerned Scientists, said watching plant workers put their lives at risk in a bid to prevent meltdown is a good reminder that even the most thorough plans will never be enough.

"I think we need to reevaluate the realism of those plans in light of what we're seeing here, because they involve the reliance on heroic actions on the part of workers and possibly life-or-death decisions to protect (against) larger scale releases," he said.

#### A RARE ADDRESS

Tuesday brought worse news: blasts in two of the reactors and a fire in a third at Fukushima as water levels in a pool used to store spent fuel dropped sharply. Radiation levels in the plant soared so high at one point that workers were pulled out of the control room.

Little is known about the skeletal crew that has battled to bring the plant under control. Even Japanese media have not identified any of the 200 or so workers involved.

"What is clear is that those working there are receiving radiation and should be treated as heroes," Javier Dies, head of nuclear engineering at the Polytechnic University of Catalonia in Barcelona told Reuters.

The sense of dread grew almost by the hour. In Tokyo on Tuesday, radiation levels shot to 10 times normal levels, a worrying elevation if not yet a level that would cause acute radiation problems.

Prime Minister Naoto Kan appeared in a televised news briefing to urge people living up to 30 km (19 miles) from the reactor to stay indoors. The Bank of Japan pumped eight trillion yen (\$102 billion) into the jittery financial system after a record 15 trillion yen injection on Monday.

As bulldozers begin clearing an emergency route to the Fukushima nuclear plant to allow access for fire trucks, the country's reclusive Emperor Akihito delivered a rare address to the Japanese people, offering his concern about the scale of the crisis. In his televised Wednesday statement Akihito said he was deeply worried and asked people to treat each other with "compassion" during a crisis he called "unprecedented in scale."

Coming in a week of mass evacuations and dwindling food on store shelves, the emperor's address reminded older Japanese of the end of World War Two when a recorded message from Akihito's father had marked the surrender.

Though the sense of helplessness is hardly as profound as it was then, the impact of last week's disaster is already profound. After the Kobe earthquake in 1995, Japan refused offers of help from the United States. This time around, Tokyo welcomed offers of help early. On the day Akihito made his address, the government even said it might have to seek direct U.S. military intervention in the crisis.

#### A FAST CAR AND A GEIGER COUNTER

The government now planned to use helicopters to drop water onto the reactors in an attempt to cool them. Authorities had also brought in troops to help pump water at the stricken plant as part of their last-ditch efforts to prevent a meltdown.

Washington had offered help almost immediately after the quake. But its navy had also pulled back from the Japan coastline in an apparent effort to avoid any possible nuclear contamination.

U.S. Nuclear Regulatory Chairman Gregory Jaczko questioned Japan's order to evacuate citizens within a 20-km radius from the plant. Under the Japanese order, people living within 30 km are advised to stay indoors. Jaczko said U.S. citizens would be told to evacuate to an 80-km radius. By Wednesday afternoon, workers at Fukushima had resorted to taking radiation levels from a moving car as it drove past the main gate of the plant. The eight automated radiation monitoring points at Fukushima No. 1 relied on the same power that went down with the plant itself.

With gasoline reserves at the site dwindling, scientists initially decided to drive to the West Gate, stop, and then monitor radiation levels there.

Now the levels were so high that those sent in didn't stop. With only a single data point -- and a lot of noise -- it became harder to draw conclusions on what was happening at the plant.

"Readings can change with the weather and be affected by radiation in dust and other materials that accumulate," Tetsuo Ohumura of the Nuclear and Industrial Safety Agency told reporters. "We'll have to see how things change."

By Thursday morning, the cores of the No. 1, No. 2 and No. 3 reactors were believed to have partly melted. Just as worryingly, backup systems to provide water for a pool of spent fuel rods in No. 3 and No. 4 had also failed.

Japan's Air Self Defense Force had begun using Chinook helicopters to dump water on the damaged No. 3 and No. 4 reactors but with seemingly little impact.

Without water in the pools, radiation levels will spike to levels high enough to prove lethal with exposure of less than 20 seconds, according to a U.S. projection based on a 1982 incident in a plant of the same design in Connecticut.

Absent some intervention, U.S. experts predicted a wave of radiation that would drive workers back for their own safety.

#### PRESSURE GROWS

The sense of panic was now fueled by rolling blackouts in some of the country's biggest cities. ATMs stopped working, households sat in darkness.

"I don't think the situation on the ground or the psychological pressure that we're under is understood," Sakura Shoen, mayor of a small town ordered to stay indoors because of the threat of rising radiation told broadcaster NHK. Many of his residents wanted to flee but couldn't because they didn't have access to gasoline, he said. "We need the power of the central government."

Nurses at one Tokyo area hospital resorted to using sealed plastic bottles with little rocks inside when call buttons went dead. Patients would shake them for attention. Neighborhoods like Shibuya -- known around the world for its giddy excess of light and neon advertising -- blinked out.

Foreigners scrambled to get out of Japan, with the number of countries advising its nationals to consider leaving Tokyo and the area north of the capital growing. Bankers chartered private flights. Washington and other capitals said it would send in planes to rescue its nationals.

Beijing, which has ambitious plans to expand its nuclear power stations, urged Japan to disclose any developments concerning radiation risks in an "accurate and swift" way.

In Vienna, the IAEA has begun giving daily briefings, though there are still plenty of questions.

"The situation is completely unclear, there are huge questions, especially regarding unit 4. We do not know if the fuel core will melt. The focus is the battle to cool it down," said a diplomat accredited to the agency.

"We got no answer from the IAEA on detailed questions about the development of radioactivity, the changing levels. The radioactivity rose dramatically. It is very, very difficult to say why."

The diplomat also said he and others accredited to the IAEA wanted more discussions on whether the agency needed powers to enforce nuclear safety and security.

Shiro Ogawa, 75, a now-retired engineer with Toshiba, watched the developments play out with a note of sadness and regret.

Ogawa had been involved in the design of safety pumps for the No. 1 reactor in 1971 and No. 2, completed in 1974, a year after the oil shock had convinced Japan that nuclear was the power of the future.

Ogawa said he had never questioned the earthquake design standards of the reactors and never questioned the durability of back-up power plans. He never thought about a tsunami big enough to take out the generators like last week's wave of 10 meters or more.

"We had almost no experience in Japan with nuclear power at the time," Ogawa told reporters. "It's a terrible thing to say, but we were ignorant. We didn't think that we were in a position to judge the standards we were given. We were close to being ignorant."

(With additional reporting by Terril Jones in Tokyo, Fredrik Dahl and Sylvia Westall in Vienna and Bernie Woodall in Detroit; Editing by Simon Robinson and Jim Impoco)

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