



**Union of
Concerned
Scientists**

Citizens and Scientists for Environmental Solutions

Nuclear Plant Steam Generators: “a ‘loaded gun,’ an accident waiting to happen”*

David Lochbaum
Nuclear Safety Engineer
dlochbaum@ucsusa.org
August 16, 2001

* NRC Commissioner Kenneth C. Rogers speech at the International Symposium on Nuclear Power Plant Aging, August 30, 1988



**Union of
Concerned
Scientists**

Citizens and Scientists for Environmental Solutions

Synopsis

Nearly 13 years ago, NRC Commissioner Rogers spoke about steam generators being a loaded gun, an accident waiting to happen.

Since Commissioner Rogers gave his warning, the NRC has relicensed 5 nuclear reactors with hundreds (if not thousands) of cracked steam generator tubes for 20 more years and certified the designs for 3 new nuclear reactors.

The guns are still loaded.

Last year, the guns fired at the Indian Point 2 nuclear plant when a cracked steam generator tube broke. Luckily, no one was hit.

It would be really swell if the NRC would unload the guns at its earliest convenience.

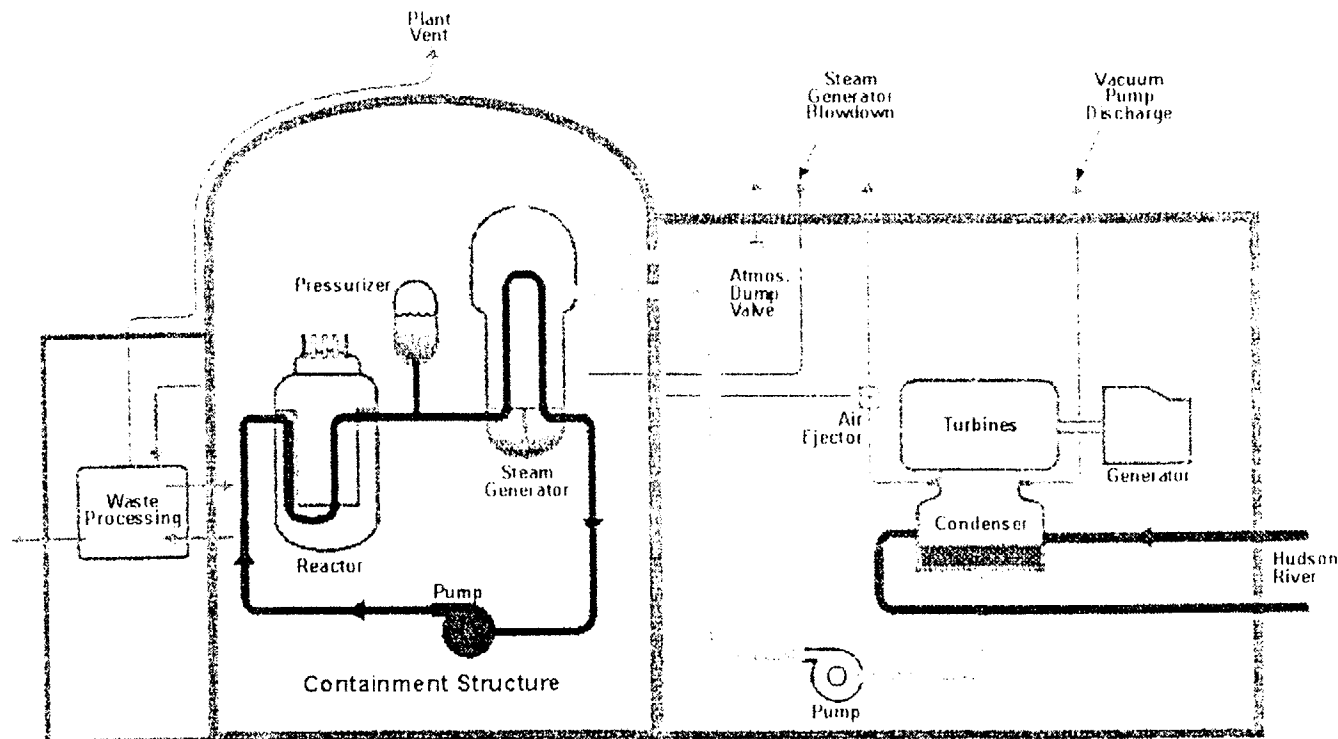


Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

Pressurized Water Reactor

INDIAN POINT 2

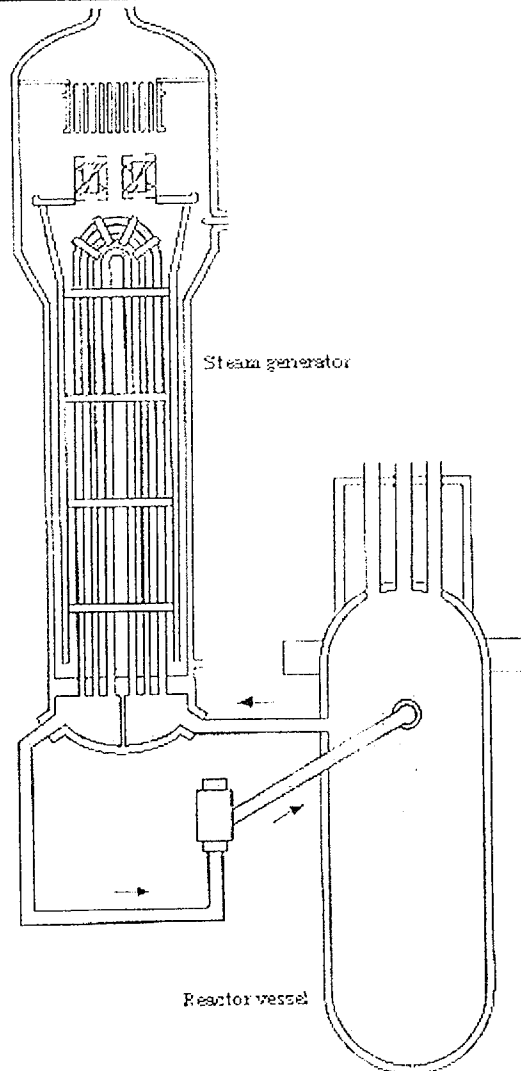




Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

Steam Generator Tubes: Vital Barrier



"Steam generators constitute more than 50% of the surface area of the primary pressure boundary in a pressurized water reactor."

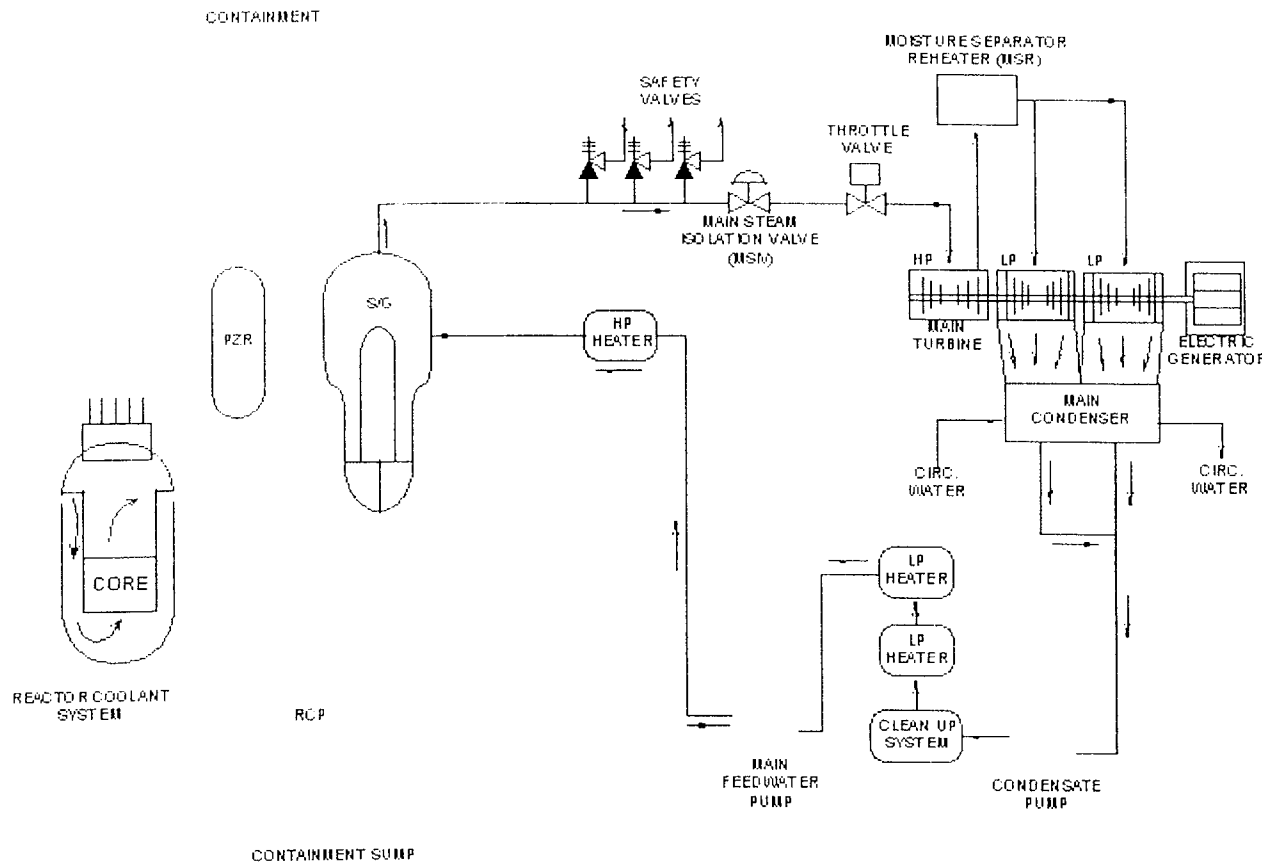
**NRC's Advisory Committee on
Reactor Safeguards (ACRS),
February 2001**



Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

Steam Generator Tubes: NO Backup



"Unlike other parts of the reactor pressure boundary, the barrier to fission product release provided by the steam generator tubes is not reinforced by the reactor containment as an additional barrier."

ACRS, February 2001



Union of
Concerned
Scientists

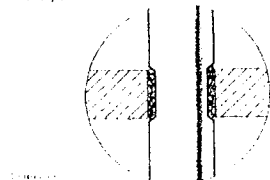
Citizens and Scientists for Environmental Solutions

Steam Generator Tubes: Failure Modes

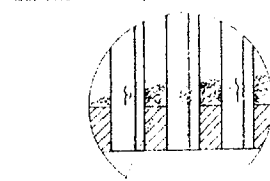
Unbond primary side stress corrosion cracking
Low cycle fatigue cracks in the primary side stress corrosion cracking (SCC) are initiated by the primary side stress corrosion cracking (SCC) and propagate along the tube wall.



Tube denting
The denting of the tube wall is caused by the impact of the primary side fluid on the tube wall.



Wastage, thinning, and pitting
The wastage, thinning, and pitting of the tube wall is caused by the primary side fluid on the tube wall.

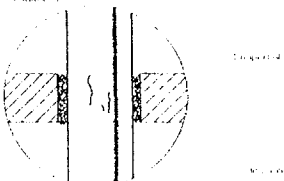


Primary side corrosion

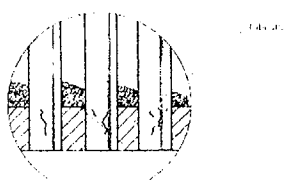
Antivibration bar wear
The antivibration bar wear is caused by the primary side fluid on the tube wall.



Secondary side stress corrosion cracking
The secondary side stress corrosion cracking (SCC) is initiated by the secondary side stress corrosion cracking (SCC) and propagate along the tube wall.



Secondary side intergranular attack
The secondary side intergranular attack is caused by the secondary side fluid on the tube wall.



Secondary side corrosion

"The techniques [used to look for cracked steam generator tubes] are not nearly so reliable for determining the depth of a crack, and in particular, whether a crack penetrates through 40% of the tube wall thickness."

"The NRC staff acknowledged that there would be some possibility that cracks of objectionable depth might be overlooked and left in the steam generator for an additional operating cycle."

ACRS, February 2001

DEGRADATION FORMS AND LOCATIONS Since they were first introduced, steam generators have experienced various forms of damage, most involving some kind of corrosion. Some of these problems have been virtually eliminated, others are being successfully managed, and a few have not yet been brought under control.



Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

Steam Generator Tubes: Humpity Dumpity!

“The tube repair criterion for each defect type should be 40% of the nominal tube wall thickness.”

NRC, December 1998

“Tubes with degradation less than 40% through wall may be left in service or removed from service depending on the observed growth rate of the degradation.”

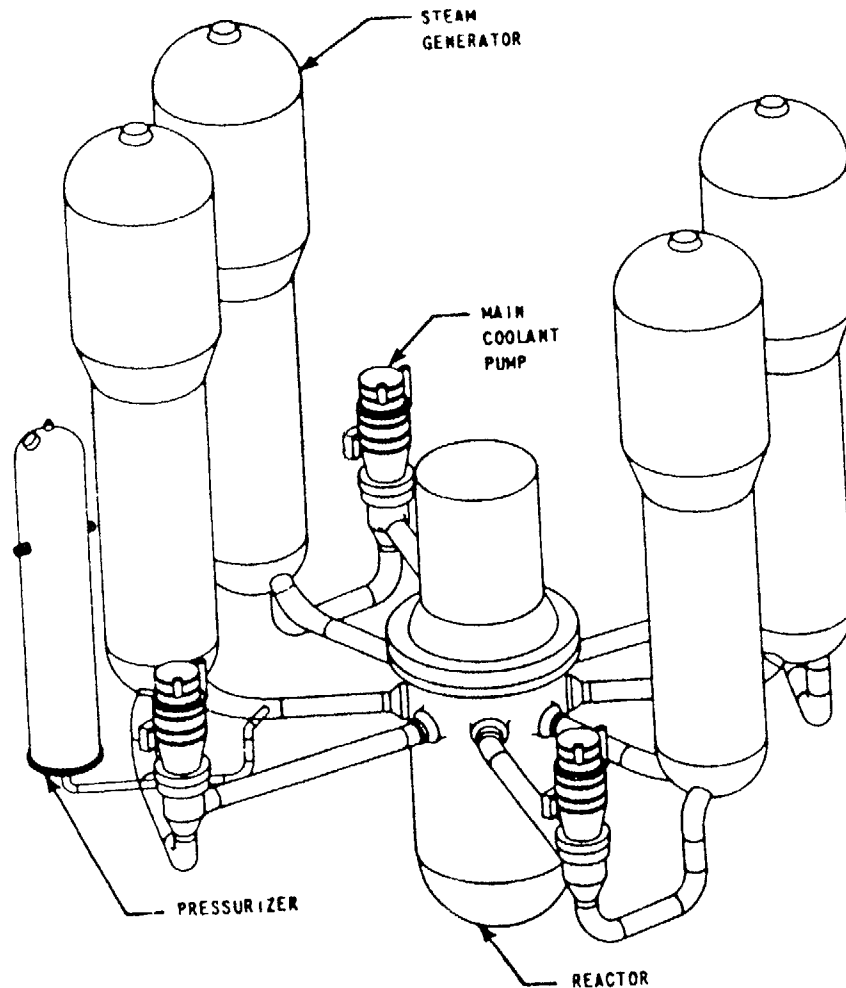
PSEG Nuclear, February 2001



Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

4-Loop Westinghouse PWR Salem Generating Station



Salem Unit 1 Tube Plugging:

SG 11: 3 tubes (<0.1%)

SG 12: 3 tubes (<0.1%)

SG 13: 13 tubes (<0.1%)

SG 14: 4 tubes (<0.1%)

Salem Unit 2 Tube Plugging:

SG 21: 197 tubes (5.81%)

SG 22: 216 tubes (6.38%)

SG 23: 161 tubes (4.75%)

SG 24: 297 tubes (8.76%)



Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

And furthermore...

"This seems to be a plausible contention [that an accident at a nuclear plant with cracked steam generator tubes could widen the cracks and result in larger leakage], and the staff has not produced analyses or test results to refute it."

"The [ACRS] found that the [NRC] staff did not have a technically defensible understanding of these processes to assess adequately the potential for progression of damage to steam generator tubes."

"The [NRC] staff has not developed persuasive arguments to show that steam generator tubes will remain intact under conditions of risk-important accidents in which the reactor coolant system remains pressurized. The current analyses dealing with loop seals in the coolant system are not yet adequate risk assessments."

"The [ACRS] concluded that the issue of the possible evolution of severe accident to involve gross failure of steam generator tubes and bypass of the containment is not yet resolved."

ACRS, February 2001



Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

The Bad News

FACT: Steam generator tubes are cracking for reasons and at speeds that continually surprise the industry and the NRC.

FACT: Methods used to inspect steam generator tubes for cracks are notoriously unreliable.

FACT: ACRS concluded that NRC lacks a sound basis for its faith that one tube and only one tube will break during an accident.

FACT: The reactor coolant system water pouring out of multiple steam generator tube breaks can exceed the maximum makeup rate.

FACT: If the reactor core is not adequately cooled, it can meltdown.

FACT: If a meltdown occurs when one or more steam generator tubes are broken, the radioactivity may have a direct pathway through the containment to the atmosphere.

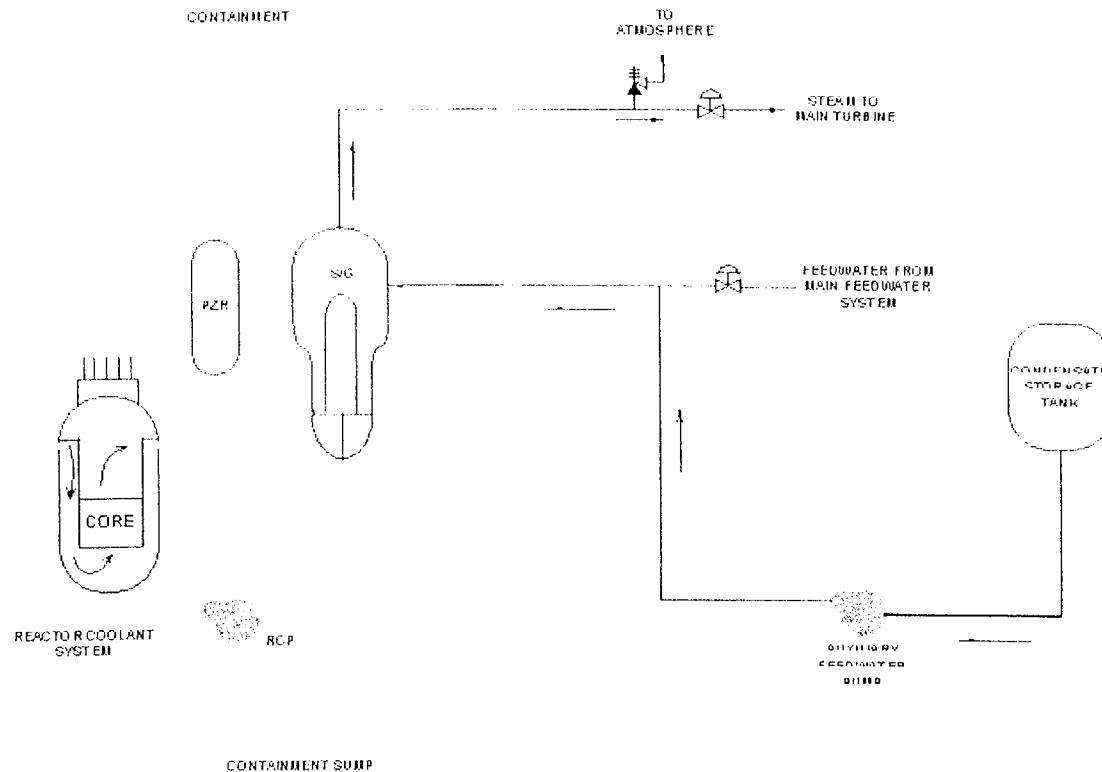
FACT that just seems like FICTION: Knowing that this is “an accident waiting to happen,” the NRC recently gave 5 nuclear reactors with cracked steam generator tubes permission to operate for 20 more years.



Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

What Could Happen?



① Main steam line could break - high pressure inside tubes and zero pressure outside tubes could break cracked, weakened tubes causing more water to leak out than can be put back: core meltdown!

② Steam generator tube(s) break allowing more reactor coolant system water to leak out than can be put back: core meltdown!

③ Steam generator tube breaks and jet flow through hole breaks adjacent cracked, weakened tubes causing more water to leak out than can be put back: core meltdown!



Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

The Good News





Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

NRC, not NRA

Public outcry can force the NRC to unload the guns, guns that are now aimed at people living around nuclear plants with cracked steam generator tubes.

The NRC's Steam Generator Action Plan is basically an IOU to the public. It affords zero protection.

People can protect themselves by contacting their Congressmen, writing letters to the editor, and e-mailing the NRC (opa@nrc.gov) demanding that the NRC stop waiting for the accident to happen and fix all of the problems described in the ACRS's February 2001 report.

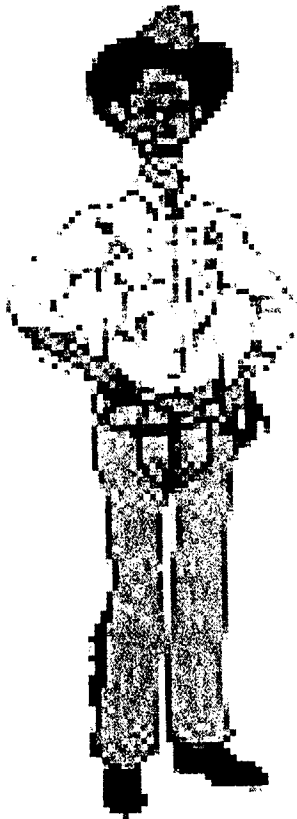
The NRC must move protection of public health and safety ahead of protecting the financial interests of the plant owners.



Union of
Concerned
Scientists

Citizens and Scientists for Environmental Solutions

Unless Outcry Forces NRC to Unload Guns



Public's Chances

