

1 molybdenum alloys, the description of the alloys
2 suggests that they are something pretty close to
3 stainless steel. Is that right?

4 WITNESS SPATARO: No, that is wrong. The
5 reason I changed it to a family is that we used a number
6 of different alloys of the same family type in order to
7 make our manufacturing. If I can elaborate on that just
8 a little, the coolers themselves are made of an alloy
9 called AL6X. It is Allegheny Ludlum's alloy. It has 6
10 percent ^{molybdenum} ~~nickel~~. It gives the maximum resistance to
11 pitting corrosion.

12 However, that alloy cannot be made in large
13 sheet or piping form because of the high ^{molybdenum} ~~nickel~~
14 content. The water boxes of the fan coolers and the
15 attendant piping are made of an alloy called alloy 20
16 modified, manufactured by ^{Cabot} ~~Cabot~~ Corporation. This
17 alloy is approved for ^{use} ~~use~~ by the ASME Boiler and Pressure
18 Vessel Code.

19 The rest of the piping system, however, is
20 made of an alloy called 904L. Both 904L and alloy 20
21 ~~mod~~ have approximately 3 and a half to 4 percent
22 ^{molybdenum} ~~nickel~~ in them. The reason for 904L, which is
23 manufactured by the ^{Uddeholm} ~~Hydrex~~ Corporation in Sweden, and
24 by Inco here in the United States, was the relative
25 availability of the material in large quantities, such

1 as elbows, tees, straight runs, or piping.

2 We could not get the ^{Cabot}~~Cabot~~ alloy in large
3 quantities quickly enough to put our systems in, so we
4 changed over to a very similar alloy, and that is the
5 reason why I mentioned them as a family of alloys.

6 Your basic question was whether or not they
7 were equivalent to stainless steel. As I understand you
8 to mean stainless steel, this would be the straight 18
9 chrome, 8 nickel alloys. The answer would be no,
10 because these have an appreciably large amount of
11 nickel, of the range of at least 23 to 28 percent. The
12 chromium is comparable, if slightly higher.

13 However, the ^{molybdenum}~~molybdenum~~ content coupled with
14 the nickel is what gives us our pitting corrosion
15 resistance.

16 JUDGE SHON: I guess the way in which I
17 thought they might be similar to stainless is, are they
18 or are they not subject to intergranular stress
19 corrosion cracking when exposed to aqueous solutions of
20 chloride ion? That is the reputation of stainless
21 steel.

22 WITNESS SPATARO: No, they are not. If I may
23 elaborate, stainless steels have that problem due to
24 something which we call sensitization. The carbon
25 content in the stainless steel during welding and heat

1 treating operations migrates to the grain boundaries,
2 where it then ties up with chromium in the neighboring
3 grains.

4 This leads to a depletion of the neighboring
5 grains from the chromium content. When that chromium
6 content drops below 11 and a half percent,
7 approximately, the alloy becomes less than stainless, if
8 I can use that term, and is subject to the intergranular
9 attack, chloride ions being the most prevalent ions
10 which can then break down the chromium oxide layers on
11 the surface of the stainless steel, and attack these
12 depleted areas.

13 The use of high nickel and high ^{molybdenum} ~~nickel~~
14 alloys prevents this particular degradation of the
15 material during fabrication from ^{occurring} ~~occurring~~. Hence, we
16 do not feel that we should have any intergranular attack
17 during the operation or lifetime of the alloys.

18 JUDGE SHON: Thank you. That was going to be
19 my next question, whether they could have been
20 sensitized in any way during the process.

21 WITNESS SPATARO: No.

22 JUDGE SHON: No. With regard to the portions
23 of the system which originally were cement lined mild
24 steel, have these portions been inspected and
25 protected? Mr. Rothstein told us that in the other

1 JUDGE PARIS: What causes the oxygen depletion
2 under the silt? Is the metal oxidizing, or what?

3 WITNESS SPATARO: The anerobic bacteria, as I
4 understand, are sulfate producing or sulfate reducing.
5 This sulfate combines with the copper oxide, which is
6 the main passive protection for the copper alloys. It
7 changes this to copper sulfate. The copper sulfate then
8 becomes ~~anodic~~ ^{cathodic} with respect to the remaining copper
9 oxide.

10 This reaction reduces the amount of -- well,
11 actually, increases the amount of oxygen necessary to
12 keep the protection of the alloy consistent. Once I
13 have depleted the oxygen under the silt, because it
14 cannot be replenished from the flowing water above the
15 silt level, I then do not have any more protection for
16 my copper alloy, meaning I do not have any more copper
17 oxide, or in various patches I do not.

18 This small cell, if we can call it that,
19 causes the pitting reaction to proceed such that I
20 continue to break down the copper oxide until I get to
21 the virgin material underneath. Once I do that, the
22 pitting proceeds at some corrosion rate.

23 JUDGE PARIS: Okay. I think that is the kind
24 of detail we need. Thank you.

25 JUDGE GLEASON: All right, gentlemen. The