

**THE RESISTANCE OF UNALLOYED STEEL AGAINST EROSION-COROSION IN WET STEAM.**

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## PROBLEM

Erosion-corrosion is a main problem in power stations.

Erosion-corrosion results in:

- damage of the installation;
- increased concentration of suspended ironoxides in the water.

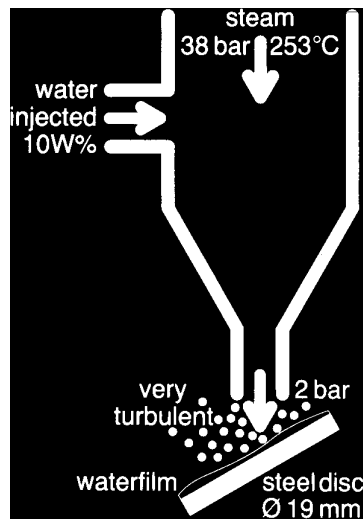
Presence of suspended ironoxides causes fouling and gives higher corrosion risk in steam generators and conventional boiler tubes.

Erosion-corrosion is influenced very much by:

- . waterchemistry;
- . water velocity / flowpattern;
- . steel quality.

This study deals only with the influenc of the chemical composition of mild stee on the erosion-corrosion resistance in wet steam.

## TEST METHOD



84 different steels were exposed to wet steam in a test chamber.



*KEMA experimental boiler installation*



*Test chamber*

For this test, steam and water were delivered by the KEMA experimental boiler installation.

A research unit was connected to the installation. This unit consisted of 24 test chambers.

## TEST CONDITIONS

Exposure time	100 hours
Metal temperature	127°C
Oxygen:	2 µg/kg
Water conductivity	< 30 µS/m
Steam velocity	960 m/s
Water content inlet	10 wt %
Water content outlet	25 wt %

## RESULTS

- The 84 steels were chemically analysed for the elements: C, Mn, Si, P, S, Cr, Mo, Al, Cu, Ni.
- Weight losses after 100 hours exposure time were determined.

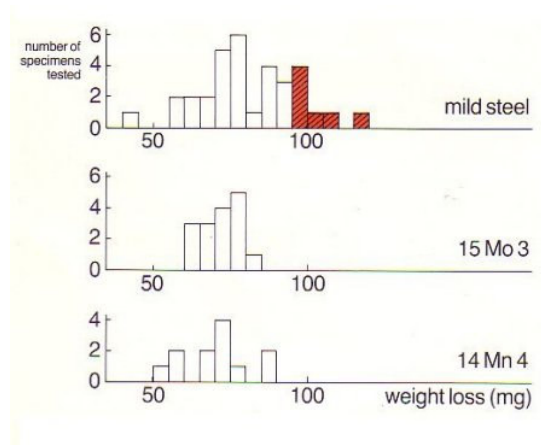
## TABLE

### *Wet steam erosion-corrosion test results*

Specimen nr.	C	Mn	Si	P	S	Cr	Mo	Al	Cu	Ni	Average Weight loss
2.65	0.14	0.58	0.22	0.009	0.027	0.26	0.02	0.01	0.16	0.06	43.1
2.34	0.1	0.55	0.04	0.006	0.026	0.05	0.01	0.01	0.19	0.07	56.6
2.15	0.09	0.49	0.1	0.005	0.028	0.05	0.01	0.01	0.2	0.08	57.5
3.13	0.15	1.13	0.32	0.024	0.023	0.12	0.03	0.01	0.19	0.08	59.9
3.19	0.13	1.1	0.48	0.017	0.025	0.08	0.05	0.01	0.22	0.12	60.7
3.14	0.16	1.03	0.33	0.022	0.029	0.08	0.02	0.01	0.11	0.17	61.2
2.35	0.1	0.65	0.18	0.021	0.024	0.08	0.02	0.01	0.14	0.08	61.6
5.6	0.2	1.25	0.55	0.004	0.011	0.22	0.04	0.045	0.05	0.06	62.0
1.26	0.17	0.72	0.25	0.006	0.014	0.07	0.29	0.005	0.04	0.03	63.1
1.9	0.14	0.61	0.18	0.004	0.021	0.04	0.26	0.01	0.07	0.04	63.4
1.17-3	0.15	0.61	0.16	0.009	0.025	0.04	0.27	0.005	0.1	0.02	64.0
2.49-2	0.22	0.56	0.18	0.009	0.023	0.06	0.04	0.005	0.17	0.06	65.5
3.9	0.13	0.99	0.37	0.016	0.022	0.04	0.02	0.01	0.18	0.08	65.9
3.15	0.1	0.98	0.21	0.008	0.018	0.05	0.04	0.005	0.1	0.1	67.7
3.10	0.12	0.98	0.37	0.012	0.01	0.04	0.02	0.01	0.03	0.03	68.6
5.3	0.15	1.3	0.34	0.012	0.017	0.1	0.4	0.005	0.03	0.08	70.0
1.15	0.14	0.57	0.23	0.009	0.01	0.11	0.29	0.01	0.07	0.06	70.3
3.12	0.12	0.98	0.37	0.012	0.016	0.04	0.01	0.01	0.03	0.03	70.3
5.9	0.12	1.47	0.47	0.015	0.016	0.1	0.005	0.02	0.04	0.02	71.0
3.11	0.12	1.01	0.39	0.011	0.013	0.04	0.01	0.01	0.03	0.03	71.2
2.90	0.14	0.57	0.26	0.015	0.032	0.042	0.01	0.01	0.11	0.06	72.0
1.16	0.14	0.62	0.22	0.004	0.007	0.04	0.5	0.01	0.04	0.03	72.4
1.5	0.16	0.59	0.24	0.004	0.022	0.04	0.26	0.01	0.1	0.06	72.7
1.6	0.18	0.68	0.21	0.006	0.02	0.05	0.26	0.01	0.1	0.06	72.7
2.89-2	0.14	0.58	0.25	0.015	0.031	0.043	0.01	0.01	0.11	0.05	73.0
2.45	0.18	0.52	0.34	0.008	0.017	0.04	0.05	0.005	0.1	0.04	75.0

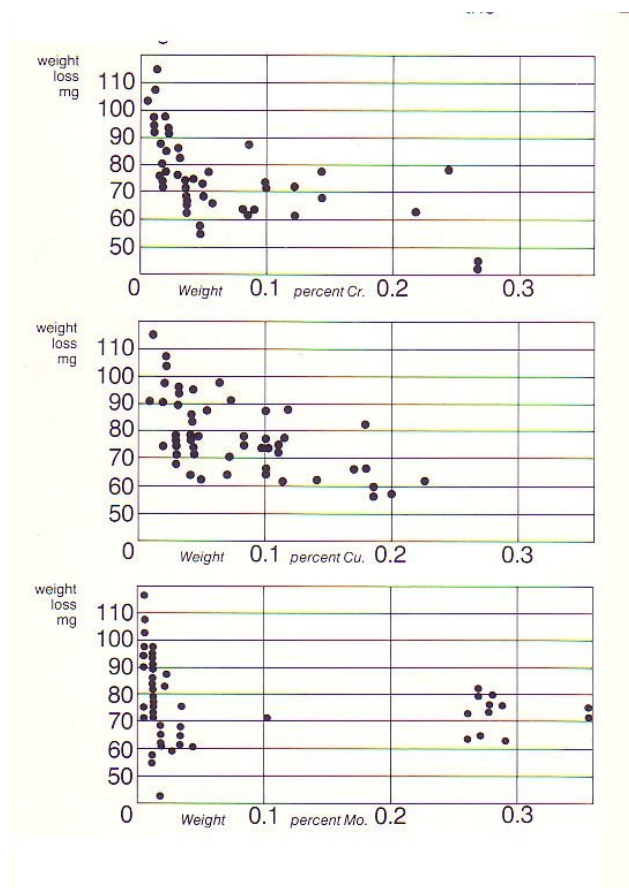
2.59	0.18	0.94	0.18	0.012	0.01	0.04	0.01	0.01	0.02	0.03	75.0
1.11	0.16	0.7	0.19	0.006	0.019	0.02	0.28	0.01	0.04	0.02	75.6
5.5	0.21	1.31	0.42	0.016	0.021	0.24	0.01	0.055	0.08	0.07	76.0
5.7	0.19	1.09	0.57	0.01	0.009	0.14	0.04	0.03	0.12	0.22	76.0
1.22	0.15	0.73	0.25	0.013	0.014	0.02	0.29	0.01	0.03	0.03	76.3
2.58	0.11	0.54	0.07	0.009	0.017	0.03	0.01	0.04	0.05	0.04	76.3
1.12	0.16	0.69	0.18	0.007	0.02	0.02	0.28	0.01	0.04	0.02	76.6
3.17	0.15	1.22	0.38	0.017	0.013	0.02	0.01	0.01	0.03	0.04	77.8
2.11	0.08	0.5	0.18	0.012	0.012	0.06	0.01	0.02	0.04	0.04	78.6
2.21	0.09	0.56	0.18	0.01	0.014	0.02	0.01	0.02	0.03	0.02	78.6
1.13	0.16	0.73	0.18	0.006	0.018	0.02	0.27	0.01	0.04	0.02	79.0
1.10	0.16	0.7	0.2	0.006	0.015	0.02	0.28	0.01	0.04	0.02	79.2
2.66	0.1	0.48	0.25	0.009	0.026	0.03	0.01	0.005	0.1	0.04	79.6
1.14	0.16	0.72	0.2	0.006	0.02	0.02	0.27	0.01	0.04	0.02	80.5
3.3	0.15	1.18	0.33	0.008	0.018	0.05	0.02	0.01	0.18	0.07	82.9
2.20	0.1	0.51	0.14	0.008	0.016	0.03	0.01	0.01	0.04	0.02	83.3
2.19	0.09	0.51	0.18	0.009	0.021	0.02	0.01	0.01	0.04	0.02	85.2
3.7	0.16	1.09	0.26	0.02	0.032	0.03	0.01	0.01	0.12	0.06	87.9
2.85	0.14	1.05	0.005	0.014	0.019	0.017	0.003	0.003	0.05	0.02	88.6
3.6	0.16	1.11	0.42	0.007	0.022	0.08	0.02	0.03	0.1	0.06	88.9
2.16	0.1	0.49	0.2	0.011	0.022	0.02	0.01	0.02	0.03	0.02	89.5
5.10	0.18	0.99	0.28	0.011	0.009	0.02	0.005	0.03	0.01	0.02	90.0
2.17	0.1	0.48	0.2	0.007	0.018	0.02	0.01	0.01	0.02	0.02	90.4
2.40-1	0.37	0.63	0.32	0.004	0.026	0.02	0.01	0.01	0.07	0.04	91.0
2.18	0.1	0.49	0.16	0.012	0.024	0.02	0.01	0.02	0.03	0.02	92.7
2.88	0.15	1.15	0.005	0.027	0.034	0.01	0.003	0.003	0.04	0.02	95.2
2.72	0.09	0.55	0.1	0.028	0.018	0.01	0.005	0.02	0.03	0.05	96.9
2.84	0.18	1.09	0.005	0.011	0.025	0.018	0.003	0.003	0.06	0.02	98.0
2.73	0.17	0.64	0.26	0.015	0.014	0.01	0.005	0.02	0.02	0.01	98.3
2.89-1	0.17	0.64	0.28	0.017	0.016	0.005	0.003	0.02	0.02	0.02	103.1
2.104	0.18	1.11	0.32	0.014	0.024	0.014	0.003	0.05	0.02	0.02	107.0
2.83	0.09	0.97	0.23	0.009	0.014	0.01	0.005	0.003	0.01	0.01	116.0
2.109	0.1	0.48	0.2	0.033	0.018	0.01	0.005	0.055	0.01	0.04	not tested

## FREQUENCY DISTRIBUTION OF THE WEIGHT LOSSES



## EVALUATION

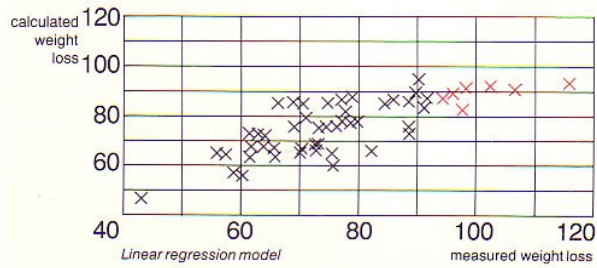
Minute quantities of chromium, copper and molybdenum proved to have a considerable influence on the resistance against erosion-corrosion.



The weight losses were correlated with the chemical compositions. A linear regression model was assumed.

Regression Formula:

## Calculated weight loss: 94-100.Cr-120.Cu-35Mo



No influence was found of the other six elements.

### IN-SERVICE FAILURES

Steels originated from some obvious in-service failures due to erosion-corrosion proved to have high weight losses in our wet steam-jet test.

These steels are red marked in the table and the histogram.

#### CASE 1

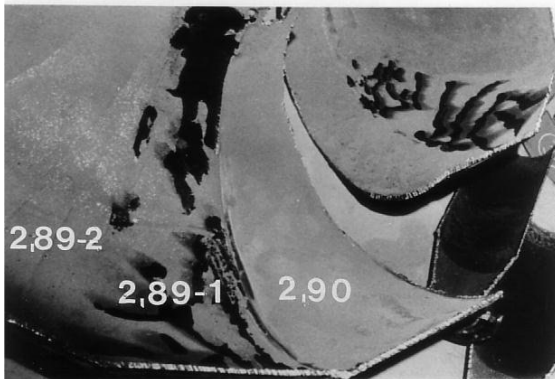
Water-separator of BWR



Specimen number	2.88
Cr	0.01
Cu	0.04
Mo	0.003
Calculated weight loss	88.5
Measured weight loss	95.2

**CASE 2**

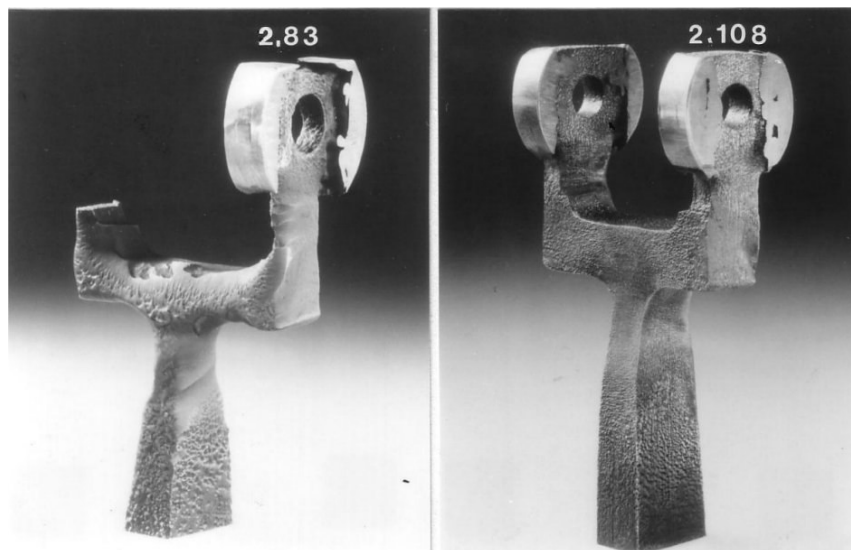
A bend pipe was eroded-corroded on one plate only



Specimen number	2.89-2	2.89-1	2.90
	a	b	c
Cr	0.04	0.01	0.04
Cu	0.11	0.02	0.11
Mo	0.01	0.003	0.01
Calculated weight loss	76.5	91.5	76.5
Measured weight loss	73	103.1	72

**CASE 3**

Two switch levers of feed water pumps were attacked by erosion-corrosion



Specimen number	2.83	2.108
Operation hours	10,000	40,000
Cr	0.01	0.025
Cu	0.01	0.034
Mo	0.005	0.02
Calculated weight loss	91.6	86.7
Measured weight loss	116	under test

### CASE 4

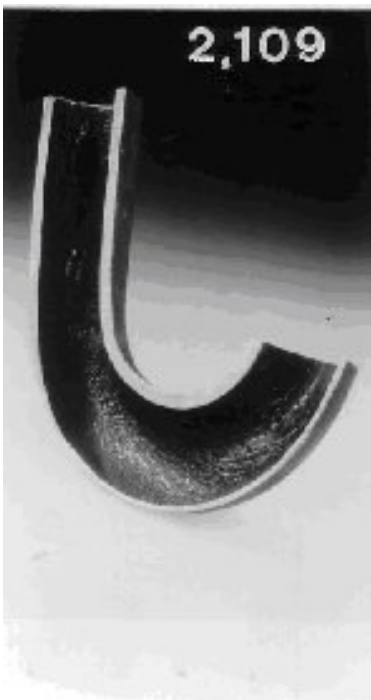
A mild steel spindle-partly coated with 9% Cr steel - was eroded-corroded on the non-coated side.



Specimen number	2.114
Cr	0.02
Cu	0.05
Mo	0.02
Calculated weight loss	85
Measured weight loss	under test

### CASE 5

Economiser



Specimen number	2.109
Cr	0.01
Cu	0.01
Mo	0.005
Calculated weight loss	92
Measured weight loss	under test

## **CONCLUSIONS**

1. Our experiments show:

- minute amounts of Cr, Cu and Mo in carbon steels increase the resistance against erosion-corrosion strongly;
- the steels 15 Mo 3 and 14 Mn 4 show a better erosion-corrosion resistance than carbon steel;
- the test results correlate well with the in-service failures investigated.

2. It can be inferred from our results that fouling in water-steam circuits will be diminished by using steels with slightly elevated concentrations of Cr, Cu and Mo.

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