



Flow Accelerated Corrosion Programme in Angra NPP Units 1 and Angra 2

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www.eletronuclear.gov.br

Angra Site



Angra 1
Power: 657 MW
Start of Operation: 1982
Westinghouse

Angra 2
Power: 1390 MW
Start of Operation: 2000
Siemens/KWU

Historical Background

1986 → Surry 2 → Catastrophic failure of 18-inch MFW pump suction line elbow. Four workers died.

May 2, 1989 → US NRC issued Generic Letter 89-08, “Erosion/Corrosion-Induced Pipe Wall Thinning” requested US licensees to implement long-term erosion/corrosion monitoring programs to maintain the structural integrity of all carbon steel systems carrying high-energy fluids.

Historical Background

1993 – Start of Angra 1 Wall Thickness Monitoring Program

Tasks:

- (1) Selection of piping systems and locations for inspections based on US experience – EPRI (Electric Power Research Institute)
- (2) Evaluation of the results of UT examinations
- (3) Calculation of minimum wall thickness required
- (4) Replacement of piping pieces with thickness smaller than required

Weak Points:

- (a) Lack of program with predictive models
- (b) Lack of baseline thickness measurements
- (c) Inconsistency of UT measurements – poor grid
- (d) Unavailable documentation

Historical Background

2004 → Mihama 3 → Rupture of a condensate pipe downstream of a flow orifice.
Five workers died.

Material: Carbon Steel

Pressure: 9 bar

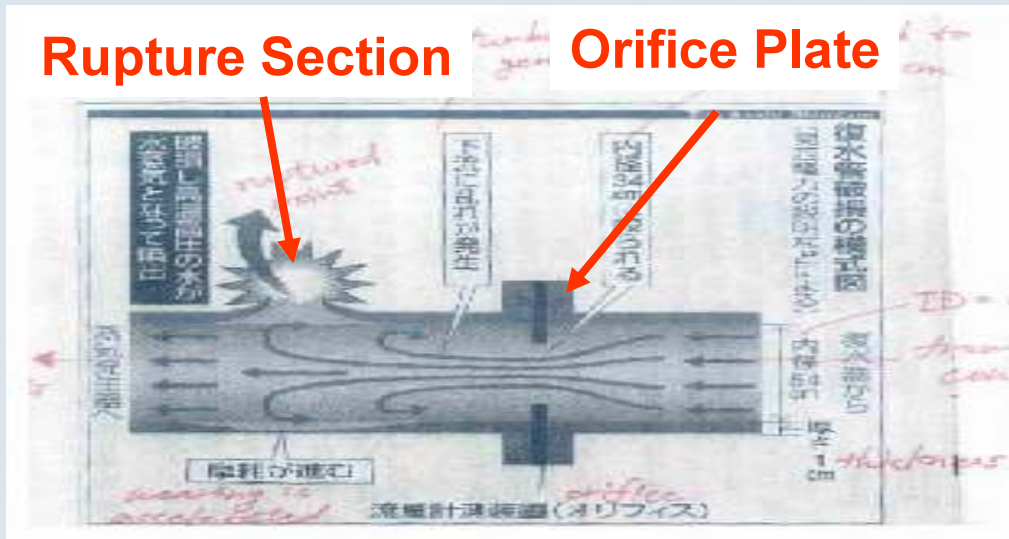
Temperature: 146°C

Flow Velocity: 2.1 m/s

Outer diameter: 558.8 mm (22 in)

Original wall thickness: 10.0 mm (0.4 in)

Minimum wall thickness of the ruptured area: 0.4 mm (0.02 in)



Historical Background

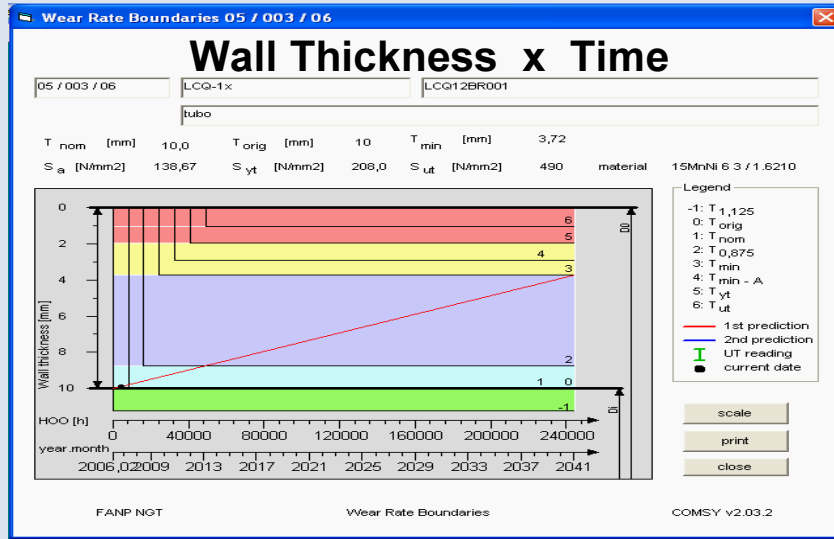
2005 – Implementation of Flow Accelerated Program in Angra NPP Units 1&2

- Acquisition of COMSY software by ELETRONUCLEAR**
- Angra 1 - Revision of the piping monitoring program**
- Angra 2 - Implementation of the program**

Improvements:

- (a) Implementation of predictive plant model**
- (b) Evaluation of susceptible systems**
- (c) Modeling of piping lines to determine critical points**
- (d) Implementation of full-coverage grid**
- (e) Implementation of measurement protocols**
- (f) Implementation of data bank**
- (g) Determination of trend curves**
- (h) Elaboration of evaluation report**

Comsy Tools



Component Priority Ranking

Priority Ranking

PADcode	element name	Rec-ISI exams factor	priority	phenomena	risk assessment
53	01 / 004 / 09 Medidor de fluxo LAB09CF004	2019,01	1,00	EC	
54	01 / 004 / 01 3" trecho de tubo	2019,01	1,00	EC	
55	03 / 001 / 04 LAB10BR001 - Nozde LAB08BR001	2020,06	1,00	EC	
56	05 / 001 / 04 LAB20BR004 - Pipe 00550	2021,04	1,00	EC	
57	03 / 003 / 01 LAB20BR003 - Pipe 00540	2021,07	1,00	EC	
58	03 / 003 / 07 LAB20BR003 - Pipe with nozzle - LAB20BR003P001	2021,09	1,00	EC	
59	05 / 001 / 03 LAB20BR004 - Pipe 00550	2021,09	1,00	EC	
60	03 / 003 / 01 LAB20BR002 - Pipe 00540	2022,03	1,00	EC	
61	03 / 002 / 07 LAB20BR002 - Pipe 00540	2022,07	1,00	EC	
62	01 / 004 / 01 Válvula Angular - LAB10AA002 - Peça Especial	2022,07	1,00	EC	
63	04 / 001 / 03 LAB20BR004 - Valve LAB20AA001	2022,07	1,00	EC	
64	01 / 004 / 02 1" trecho de tubo	2022,09	1,00	EC	
65	01 / 006 / 04 Válvula Ang. LAB12AA001	2022,09	1,00	EC	
66	01 / 002 / 03 1" trecho de tubo	2022,09	1,00	EC	
67	05 / 001 / 09 LAB20BR001 - Valve LAB20AA001	2024,07	1,00	EC	
68	01 / 003 / 02 01 1" Bocal	2025,07	1,00	EC	
69	01 / 000 / 02 1" trecho de tubo	2026,01	1,00	EC	
70	01 / 005 / 07 01 LAB10BR001 A - Bocal p/ LAB10BR001 B	2026,01	1,00	EC	
71	01 / 006 / 07 02 Bocal p/ LAB10BR001 B	2026,01	1,00	EC	
72	01 / 005 / 02 1" trecho de tubo	2026,01	1,00	EC	
73	01 / 006 / 01 LAB10BR001 B - Pipe DN 250	2026,01	1,00	EC	
74	01 / 002 / 02 Bocal DN 600 section flow inlet	2026,02	1,00	EC	
75	01 / 002 / 01 Pump LAC10AP001	2026,02	1,00	EC	
76	01 / 003 / 02 03 1" Bocal p/ LAB10BR001 - F0001	2026,03	1,00	'EC'	
77	01 / 003 / 02 02 2" Bocal p/ LAB10BR001 - F0001	2026,03	1,00	'EC'	
78	01 / 004 / 02 04 Bocal p/ LAB10BR002 P0001	2026,07	1,00	EC	
79	01 / 002 / 05 2" trecho de tubo	2026,08	1,00	EC	

add for plant rank by Rec-ISI rough analysis disregard rough analysis

Inspection Improvements

Full-coverage grid



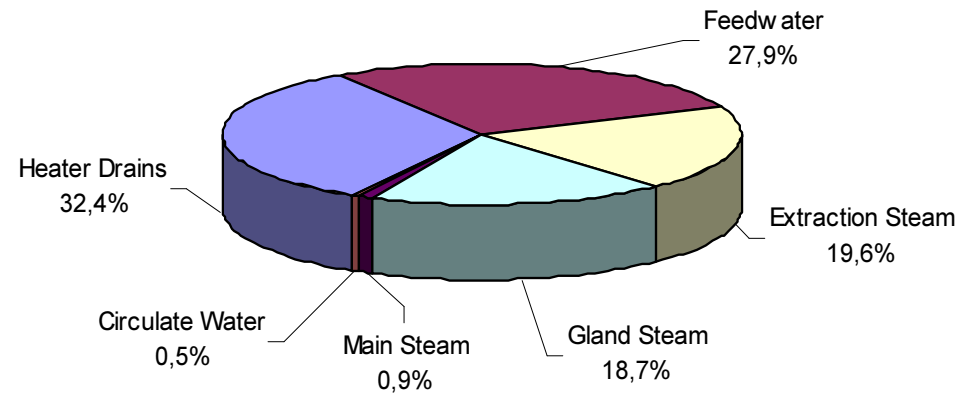
Inspection Protocol

PROTÓTIPO				PROTÓTIPO Nº								
FOLHA				Nº DE FOLHAS								
USINA	COMPONENTE			RC	ELEMENTO (PEÇA) N.º							
ANGRA 1	TUBULAÇÃO			NN	US							
EDIFÍCIO	SALA	ELEVAÇÃO	DESENHO / BOMÉTRICO	FLUXOGRAMA								
E1G			TU4-001-27-6									
LT/SOT	NORMA / CÓDIGO	PROCEDIMENTO ENSAIO	MATERIAL	DIMENSÕES	ESTADO SUPERFÍCIE							
	ASME V	PNT-021			ESCUVADO							
APARELHO (Fabricante/Modelo/Série)		TRANSDUTOR (Fabricante/Modelo/Série)		ACOPLANTE	TEMP. PEÇA(º)							
PANAMETRICS 26MG		U/993 MRE TVS149		WETIL CELULOSE	AMBIENTE							
	A	B	C	D	E	F	G	H	I	J	L	M
1	125	128	127	123	127	128	128	123	119	114	116	126
2	125	125	122	123	128	129	138	127	120	114	116	126
3	126	125	123	121	123	127	130	132	120	119	123	126
4	126	127	122	123	126	131	133	129	121	116	120	130
5	128	129	127	124	127	130	131	127	118	114	121	131
6	124	129	128	127	130	133	137	128	119	112	117	128
7	124	128	130	126	130	133	134	129	120	113	116	126
8	122	126	125	123	130	134	133	132	122	113	118	127
9	124	126	122	121	128	132	135	131	124	119	124	129
10	127	126	121	118	126	132	133	130	122	118	122	129
11	126	124	123	123	126	128	129	130	134	113	131	129
12	128	127	---	---	---	131	---	---	136	---	134	131
13	123	126	---	---	---	126	---	---	137	---	133	129
14	129	123	123	122	121	123	123	128	133	136	136	132
Local: Angra dos Reis, RJ			Local: Angra dos Reis, RJ			Local: Angra dos Reis, RJ						
DATA: 07 / 02 / 2006			DATA: 07 / 02 / 2006			DATA: 07 / 02 / 2006						
INSPECTOR: FABIO BITTENCOURT NÍVEL I			INSPECTOR: NÍVEL II			SUPERVISOR: JOSE MORAIS SOARES 1301-4						

ANGRA 1 – Piping Elements – 2006/2009

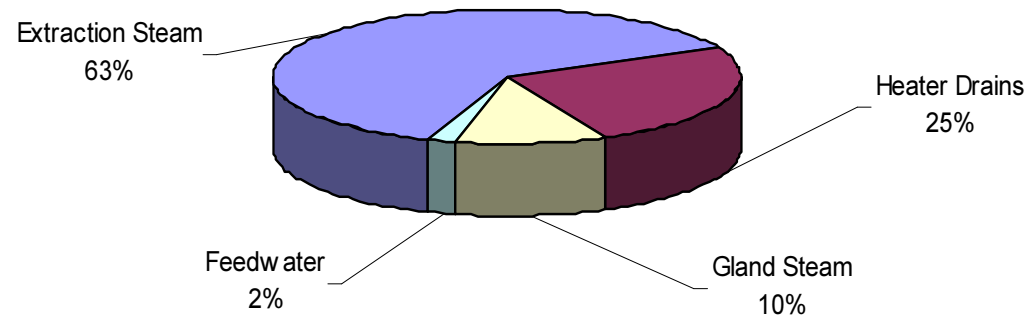
Inspected Elements	
System	Total
Heater Drains	528
Feedwater	455
Extraction Steam	320
Gland Steam	304
Main Steam	15
Circulate Water	8
Total	1630

Inspected elements by system



Replaced Elements	
System	Total
Extraction Steam	30
Heater Drains	12
Gland Steam	5
Feedwater	1
Total	48

Replaced elements by system



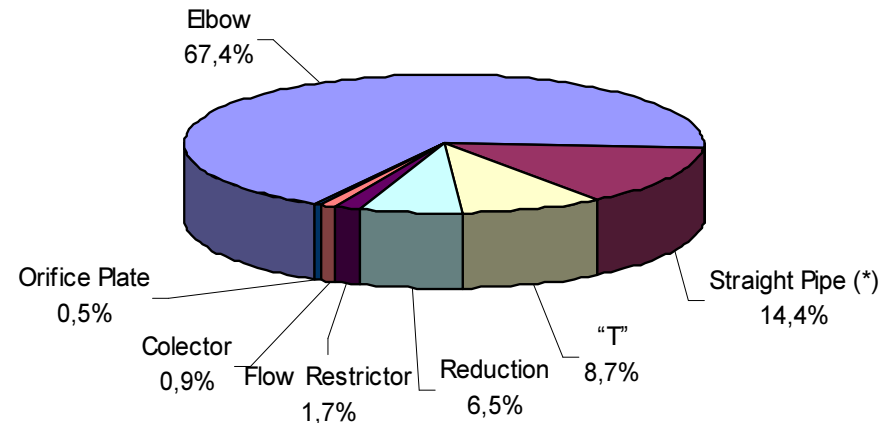
ANGRA 1 – Piping Elements – 2006/2009

Inspected elements	
Type	Total
Elbow	1098
Straight Pipe (*)	235
"T"	141
Reduction	106
Flow Restrictor	28
Collector	14
Orifice Plate	8
Total	1630

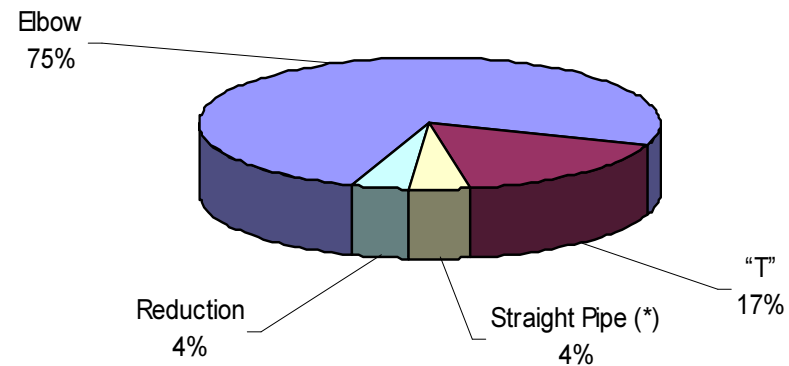
Replaced Elements	
Type	Total
Elbow	36
"T"	8
Straight Pipe (*)	2
Reduction	2
Total	48

(*) Downstream valves or nozzles

Inspected elements by type



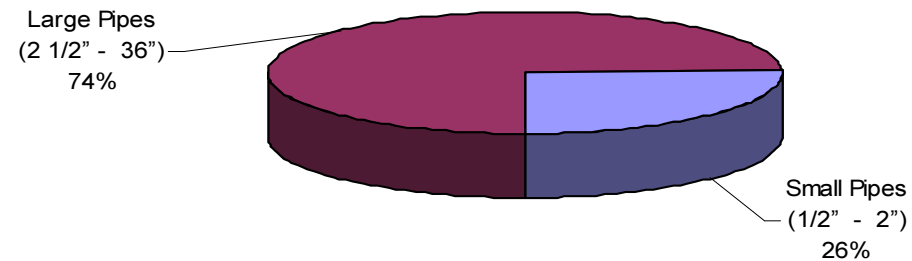
Replaced elements by type



ANGRA 1 – Piping Elements – 2006/2009

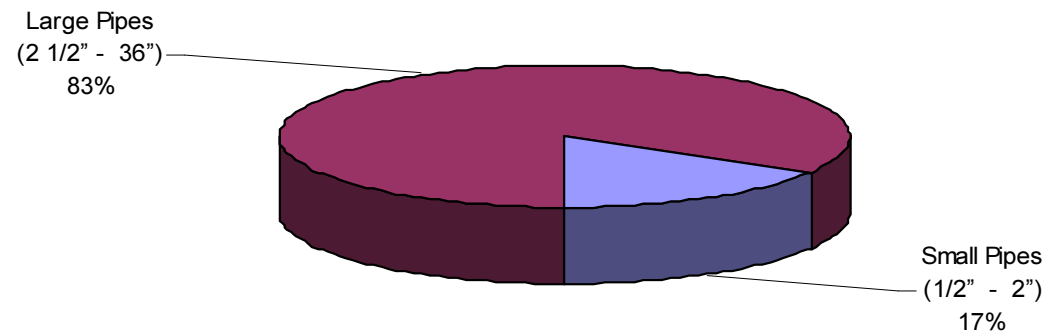
Inspected elements	
Size	Total
Small Pipes (1/2" - 2")	416
Large Pipes (2 1/2" - 36")	1214
Total	1630

Inspected elements by size



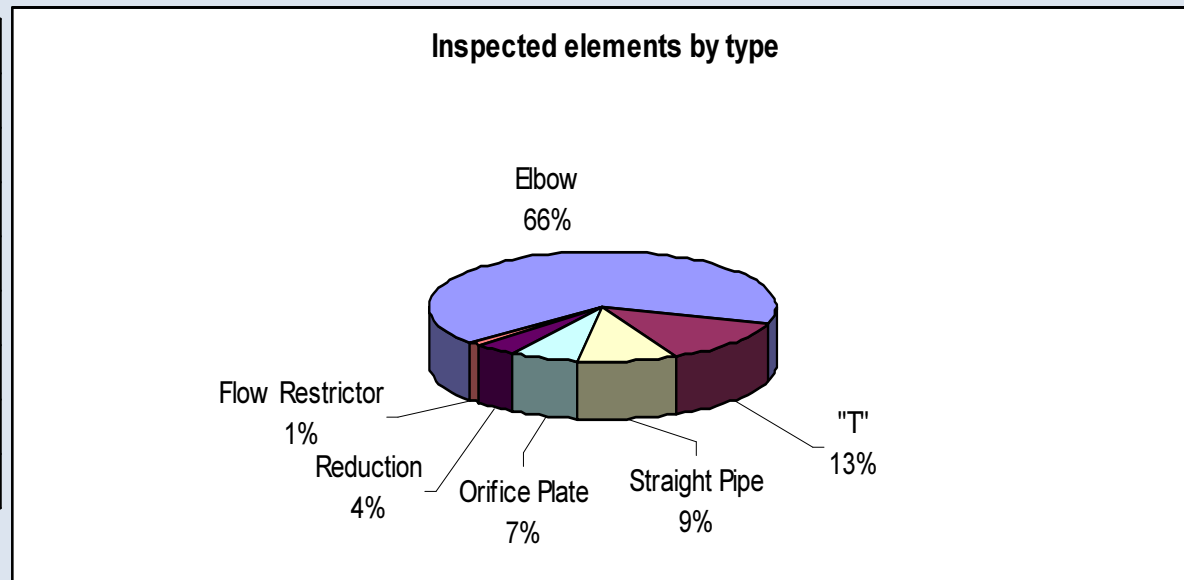
Replaced elements	
Size	Total
Small Pipes (1/2" - 2")	8
Large Pipes (2 1/2" - 36")	40
Total	48

Replaced elements by size



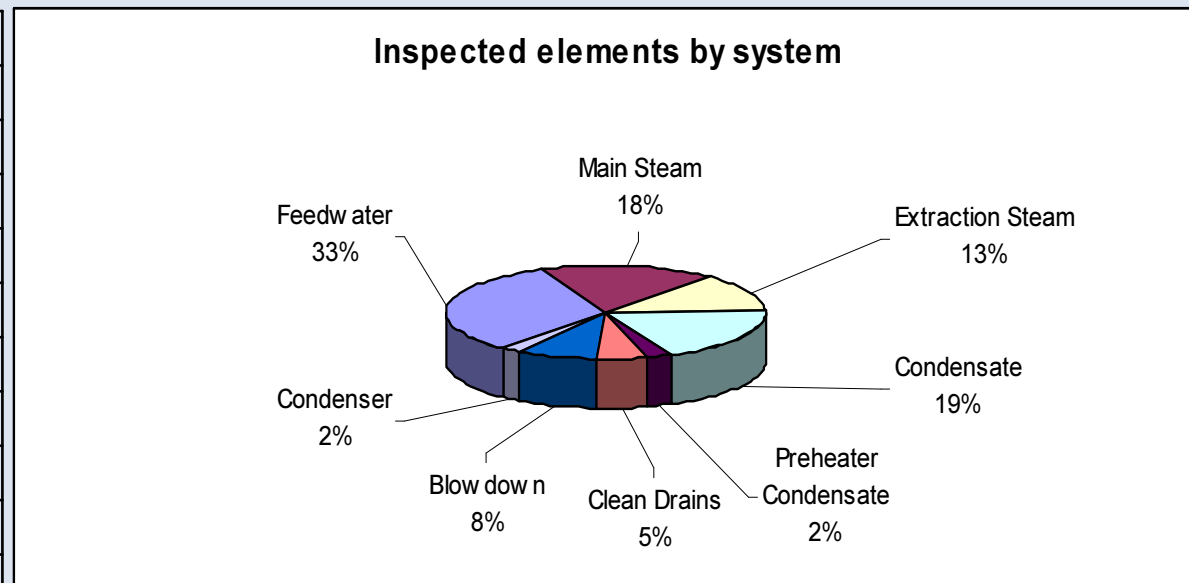
ANGRA 2 – Piping Elements – 2006/2009

Inspected Elements	
Type	Total
Elbow	319
"T"	64
Straight Pipe	43
Orifice Plate	32
Reduction	19
Flow Restrictor	6
Total	483



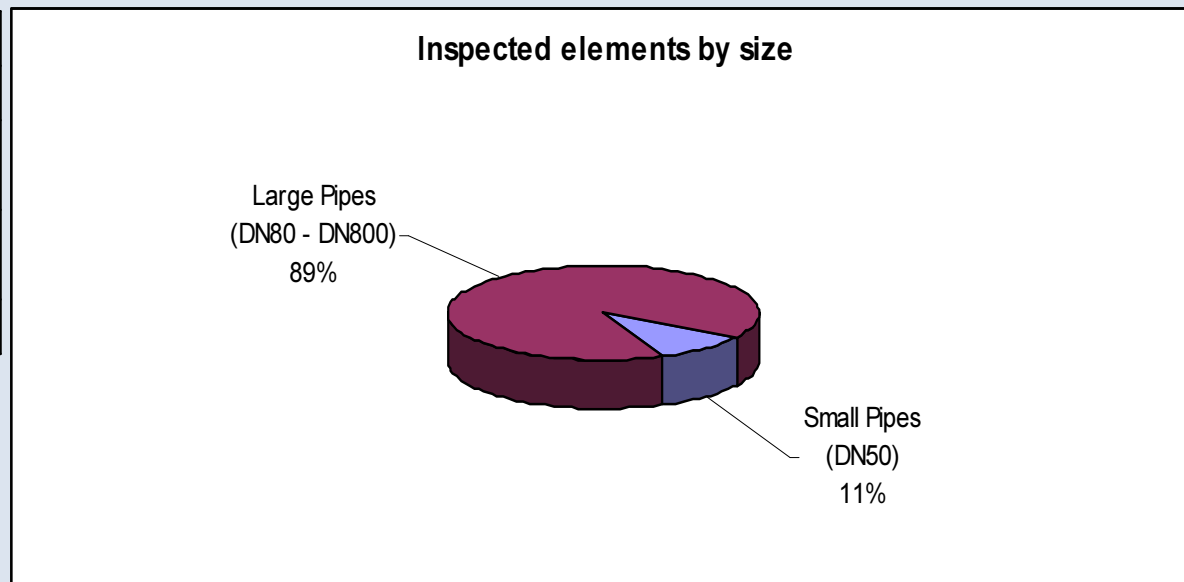
ANGRA 2 – Piping Elements – 2006/2009

Inspected Elements	
System	Total
Feedwater	156
Main Steam	87
Extraction Steam	61
Condensate	93
Preheater Condensate	12
Clean Drains	25
Blowdown	40
Condenser	9
Total	483



ANGRA 2 – Piping Elements – 2006/2009

Inspected Elements	
Size	Total
Small Pipes (DN50)	51
Large Pipes (DN80 - DN800)	432
Total	483



Summary of Results – 2006 ↔ 2009

ANGRA 1

Inspected Systems - CW / EX / FW / GS / HD / MS

Period of application - 5 Outages

1630 piping pieces inspected with 48 replacements

ANGRA 2

Inspected Systems - LAB / LAH / LBA / LBJ / LCA / LCJ / LCM / LCQ / MAG

Period of application - 3 Outages

483 piping pieces inspected with 3 replacements

Replacements



Heater Drain Line – DN 3”

Replacements



Steam Extraction Line – DN 16”

Replacements



Steam Extraction Line – DN 16”

Conclusions

- The internal degradation of piping due to flow accelerated corrosion mechanism is not visible and can cause severe accidents.
- An effective flow accelerated corrosion program will increase personnel safety, plant safety and plant availability.
- The continuing occurrence of failures caused by piping wall thinning evidences that plant programs for FAC monitoring should be maintained and improved as industry knowledge evolves and more operating and plant data become available.

Thank you for your attention!