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On Development and Implementation of Normative Documentation on Evaluation of Technical Status and Residual Life of NPP Pipelines Subjected to Erosion-Corrosion Wear

IAEA Technical Workshop «Erosion-corrosion wear including flow accelerated corrosion (FAC) and environmentally assisted cracking (EAC) issues at nuclear plants»
April 21-23, 2009, Moscow, Russian Federation

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Developed Normative Documentation on Erosion-Corrosion Wear (E/C)

- 1. **Software** ECI-02. ECI-02 software registration and qualification certificate date is 17.03.2003, passport issued 19.09.2003.
- 2. **Software** ECI-03. ECI-03 software registration and qualification certificate date is 17.03.2005, passport issued 23.06.2005.
- 3. **Guidelines** «Norms of permissible thickness for pipeline elements from carbon steel at nuclear plants» RD EO 0571-2006. Put into force in 01.11.2006.
- 4. **Methodological instruction** «Analysis of steel chemical composition by spectral and photoelectric method. Pipelines and components at power units 3&4 of Novovoronezh NPP» . 27.18.05.010-2004. Methodological instruction. Agreed by M.Miroshnichenko, Director of nuclear plant safety control department of Federal Service on environmental and nuclear inspection, 25.11.2004.

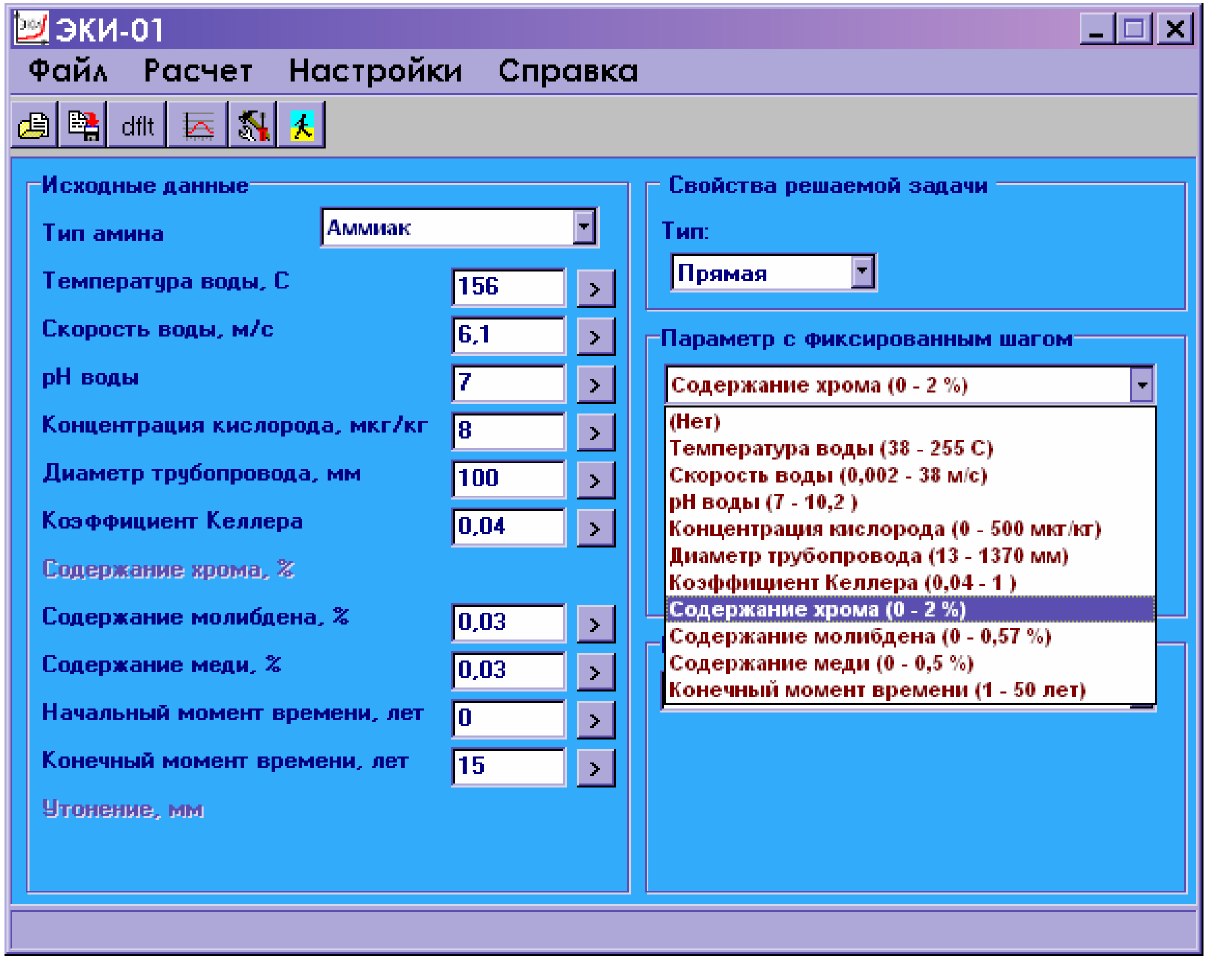
Factors Considered by the Software Tools

- **Software tools consider erosion-corrosion influence of the following factors:**
- **water chemistry indicators (type of amine applied, water pH, oxygen content in water);**
- **parameters of mode (water velocity and temperature);**
- **content of chemical elements in pipeline metal (chromium, molybdenum and copper);**
- **pipeline geometry (inner diameter, wall thickness, Keller factor);**
- **duration of operation (start and finish of pipeline operation).**
- **steam wetness (for ECI-DS software)**

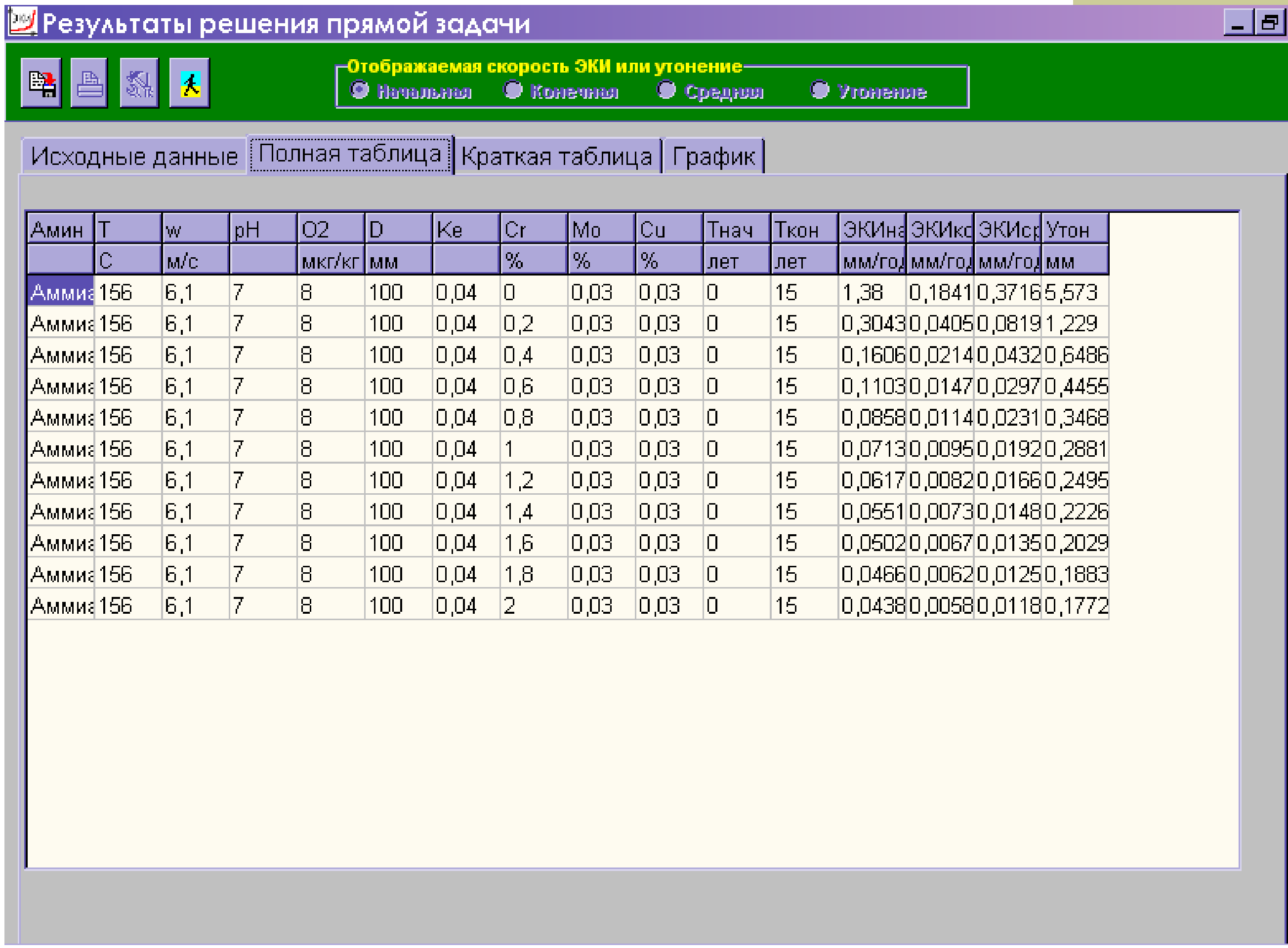
Software Possibilities

- ECI-OS & ECI-DS software allows for:
- Data input for calculations;
- Checking correctness of data input;
- Calculations of initial, final and average rate of E/C and wall thinning for a defined time period
  - With one set of initial parameters;
  - With many sets of initial parameters (one or two variable parameters);
- Output calculation results in graphs and tables:
  - to display;
  - to printer;
  - to file;
- Adjust graphic presentation of calculation results;
- Get help working with a software.

Dialog Box of ECI 02.1 Software

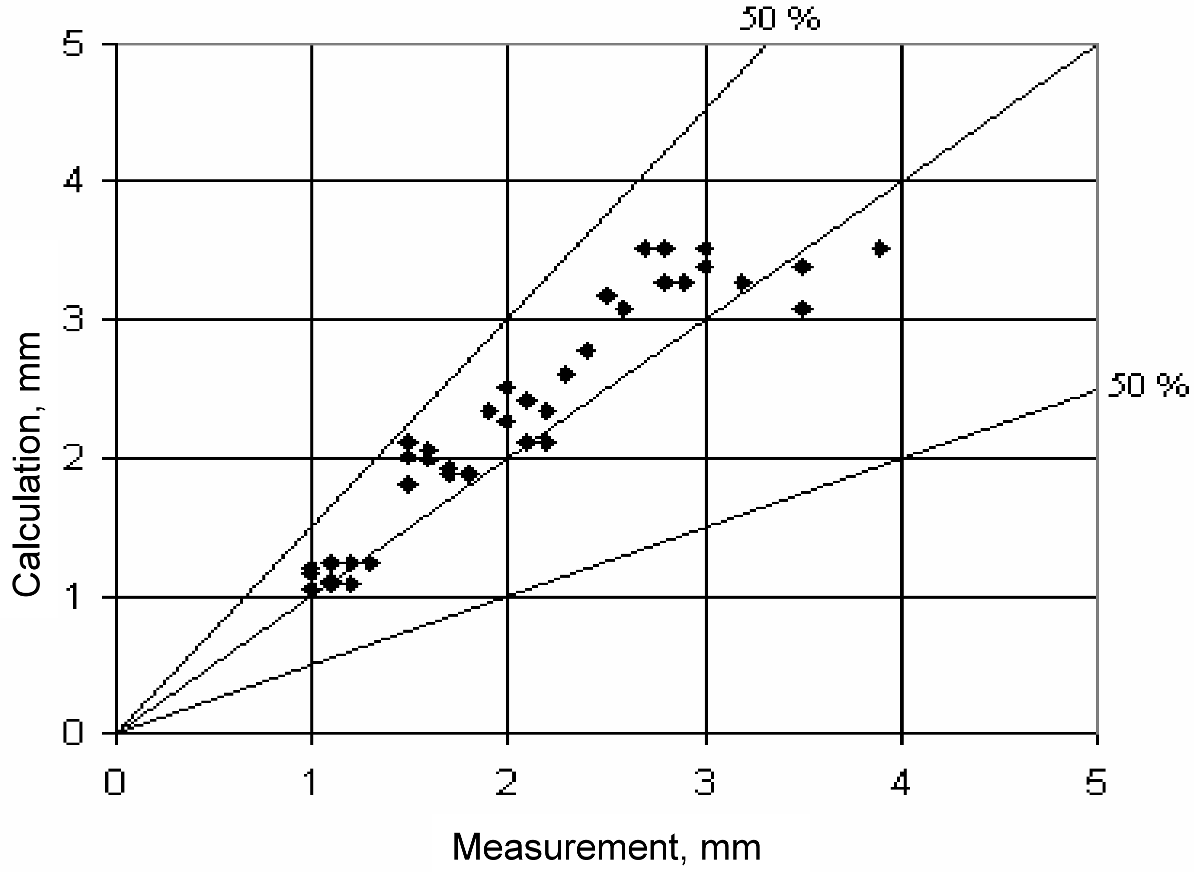


Example of Calculations by ECI-02.1 Software



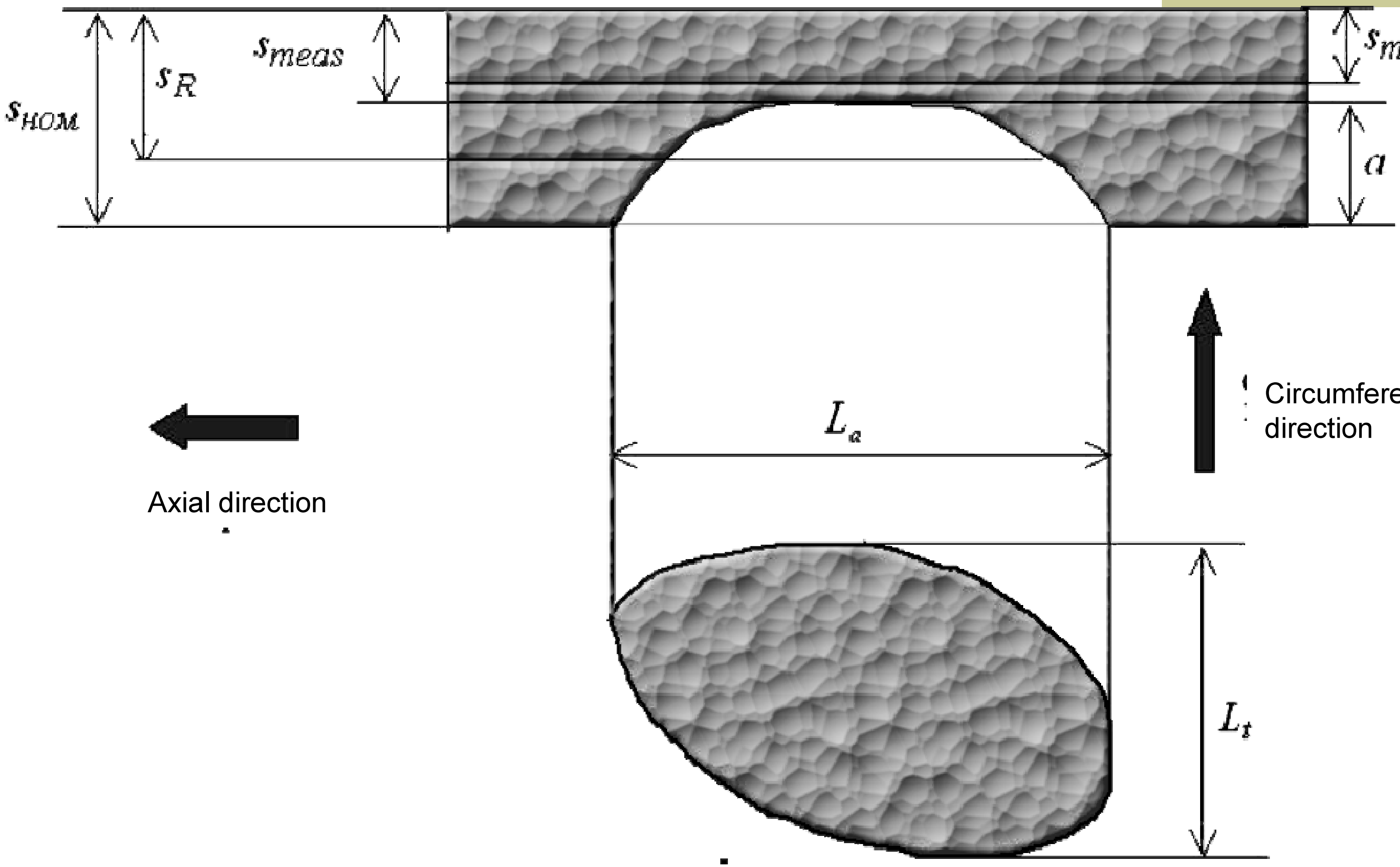
Амин	T	w	pH	O2	D	Ke	Cr	Mo	Cu	Тнач	Ткон	ЭКИна	ЭКИко	ЭКИср	Утон
	C	м/с		мкг/кг	мм		%	%	%	лет	лет	мм/год	мм/год	мм/год	мм
Аммиа	156	6,1	7	8	100	0,04	0	0,03	0,03	0	15	1,38	0,1841	0,3716	5,573
Аммиа	156	6,1	7	8	100	0,04	0,2	0,03	0,03	0	15	0,3043	0,0405	0,0819	1,229
Аммиа	156	6,1	7	8	100	0,04	0,4	0,03	0,03	0	15	0,1606	0,0214	0,0432	0,6486
Аммиа	156	6,1	7	8	100	0,04	0,6	0,03	0,03	0	15	0,1103	0,0147	0,0297	0,4455
Аммиа	156	6,1	7	8	100	0,04	0,8	0,03	0,03	0	15	0,0858	0,0114	0,0231	0,3468
Аммиа	156	6,1	7	8	100	0,04	1	0,03	0,03	0	15	0,0713	0,0095	0,0192	0,2881
Аммиа	156	6,1	7	8	100	0,04	1,2	0,03	0,03	0	15	0,0617	0,0082	0,0166	0,2495
Аммиа	156	6,1	7	8	100	0,04	1,4	0,03	0,03	0	15	0,0551	0,0073	0,0148	0,2226
Аммиа	156	6,1	7	8	100	0,04	1,6	0,03	0,03	0	15	0,0502	0,0067	0,0135	0,2029
Аммиа	156	6,1	7	8	100	0,04	1,8	0,03	0,03	0	15	0,0466	0,0062	0,0125	0,1883
Аммиа	156	6,1	7	8	100	0,04	2	0,03	0,03	0	15	0,0438	0,0058	0,0118	0,1772

Comparison of Calculation Results by ECI-01 Software with Operating Measurement Data of Wall Thinning in Feedwater Pipelines

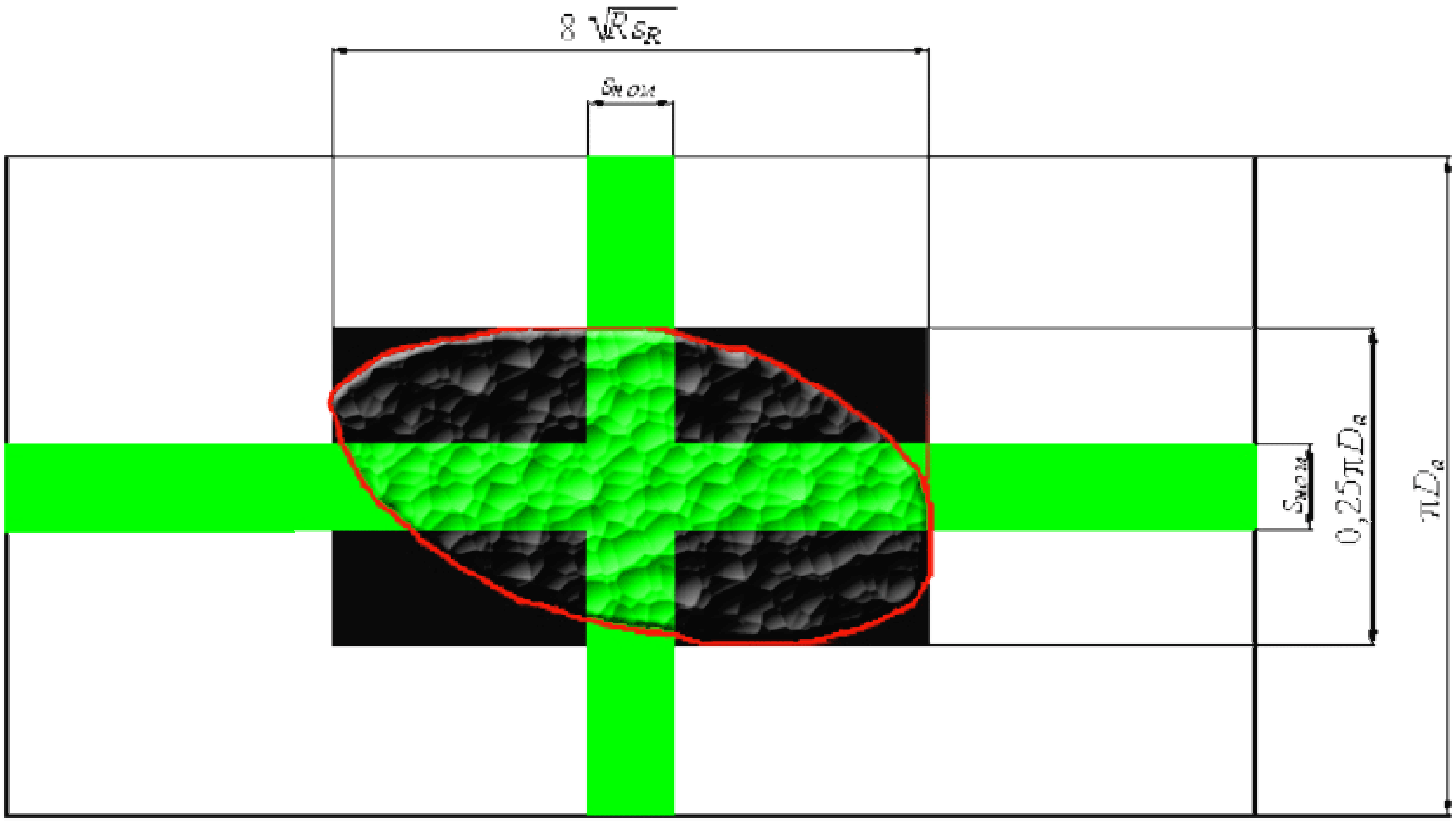


RD EO 0571-2006 Guidelines
«Permissible thickness of pipeline elements from carbon steel at nuclear plants».
Put into force 01.11.2006

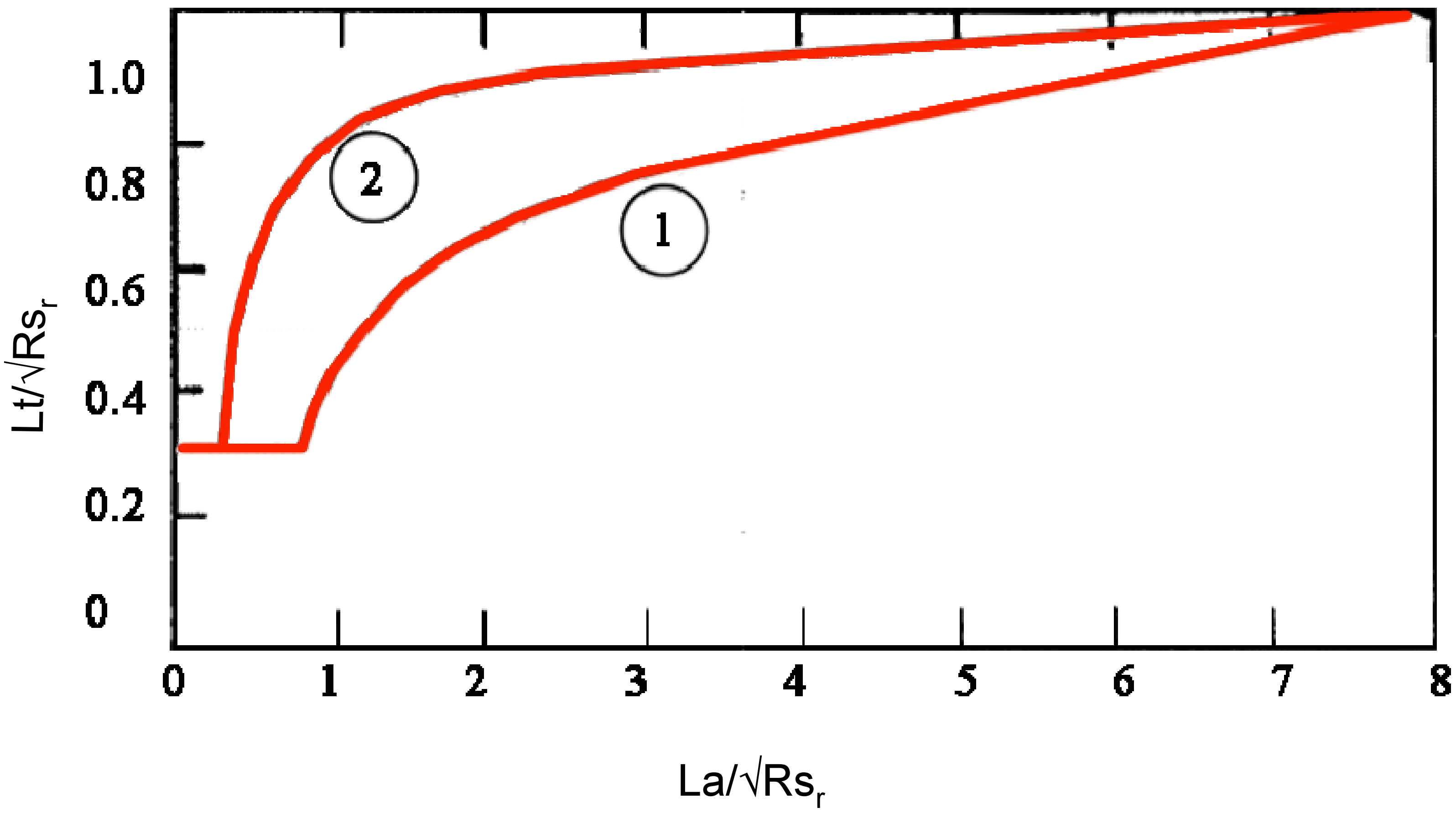
Local Wear of Pipeline Wall with Main Dimensions



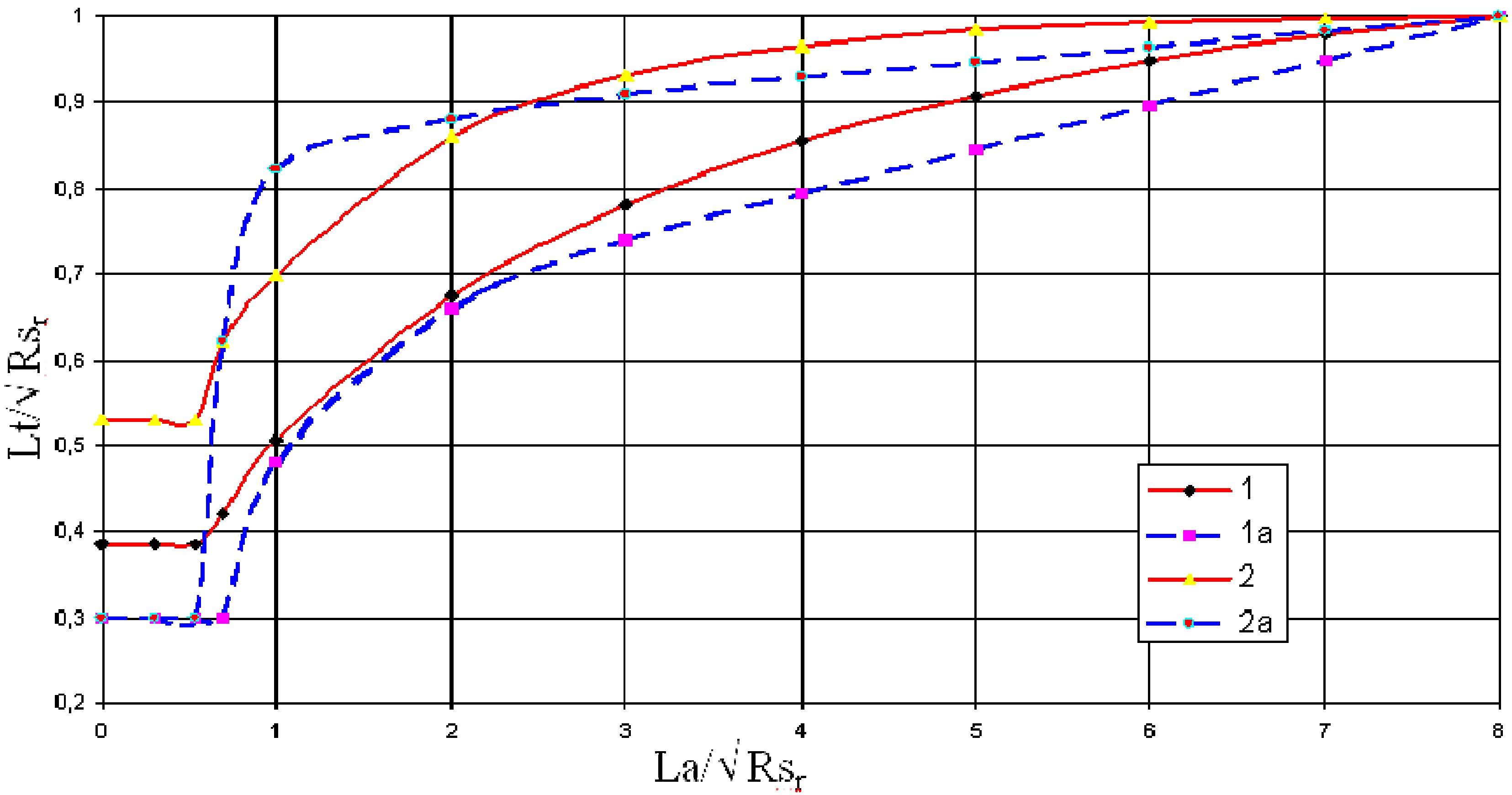
Scanning of Pipeline Surface Divided into Three Areas



Permissible Depth and Length of Local Thinning Area (fig. A)



Comparison of Permissible Thickness Calculations by Developed Method and by Data fig. A when L_{t1} = 1,0, √Rs_r, and L_{t1} = 2,65√RS (1,2 – Guideline, 1a, 2a –data fig. A)



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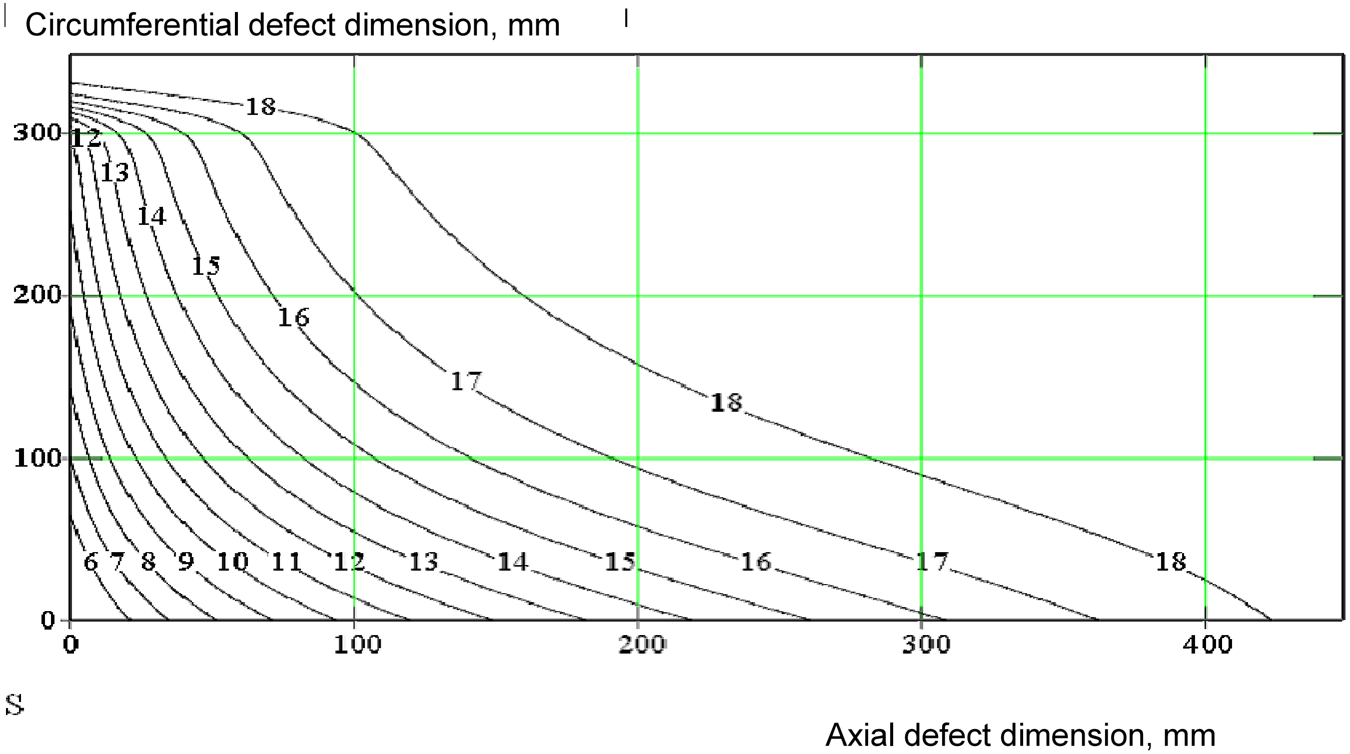
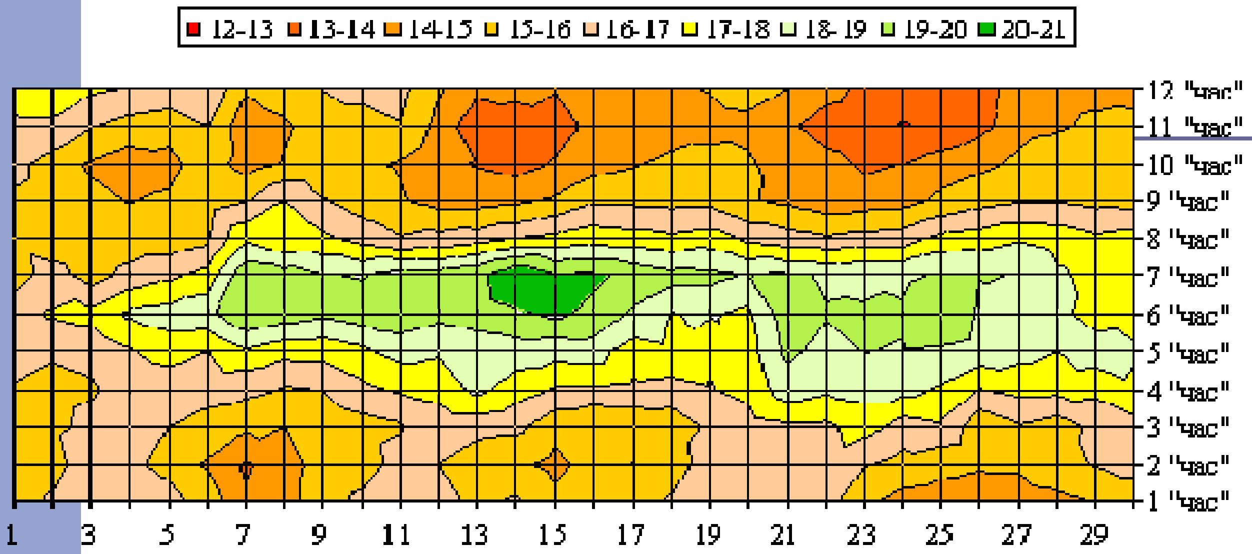
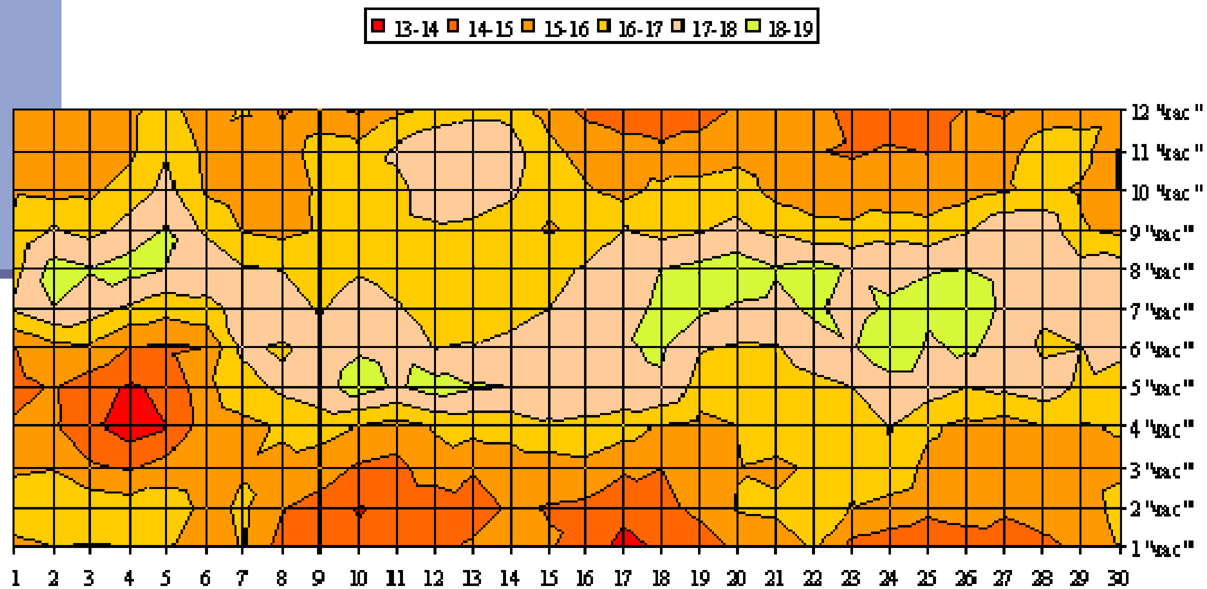
Graphs Defining the Values for Permissible Thickness of Pipelines with 530x28 mm Diameter

Initial data						Calculated values			
Steel type	Outer diam., D_a ($2R_a$) mm	Nom. thickn.., $s_{ном}$, mm	Temp. t, ºC	Inner press.., p, MPa	Add. stress [σ], MPa	Calc. thickn., s_R, mm	L_{ct}= $0.25\pi\ D_a$ mm	$\sqrt{R_a s_R}$, mm	L_{ca}= $8\sqrt{R_a s_R}$, mm
20	530	28	230	12,0	130,67	23,3	416,26	76,4	611.4







Distribution scanning of 06-K elbow wall thickness (1996 and 2002, top and bottom correspondingly)

Influence of Corrosion Products Deposits on Reliability of Wall Thickness Measurements During Operating Inspections

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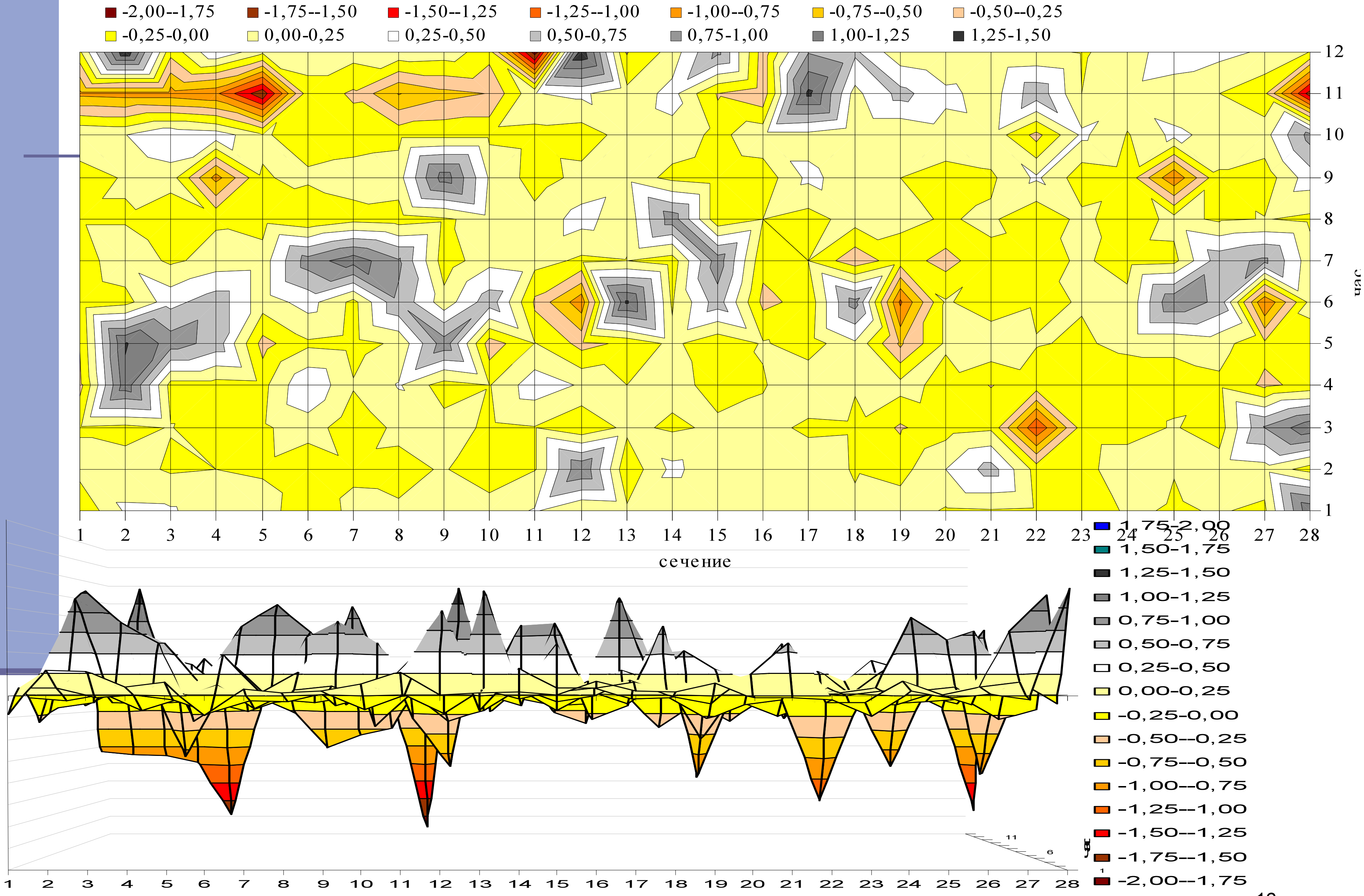

Distribution of thickness change between 1996 and 2000 measurements

Date and Number of Measurements, Minimum and Maximum Values for Each Thickness Elbow, Thickness Difference, Range of Elbow Wall Thickness Change in Different Sections of Feedwater Pipeline with 465x16 mm diameter

Elbow N	Date of meas.	Number		Values, mm			Thickness difference range. In different «hours», mm
		Section	Meas.	$S_{мин}$, mm	$S_{мак}$, mm	ΔS, mm	
Elbow A	1996	31	372	12,96	20,86	7,90	1,8 – 3,6
Elbow A	2002	30	360	13,50	18,72	5,23	1,6 – 2,3
Elbow Б	1995	33	394	13,84	19,94	6,10	1,9 – 2,1
Elbow Б	1996	29	342	13,95	20,13	6,18	2,1 – 2,2
Elbow Б	2000	29	348	13,76	20,12	6,37	2,2 – 2,6
Total, average value		231	2964	13,40	19,83	6,43	1,9 – 2,6

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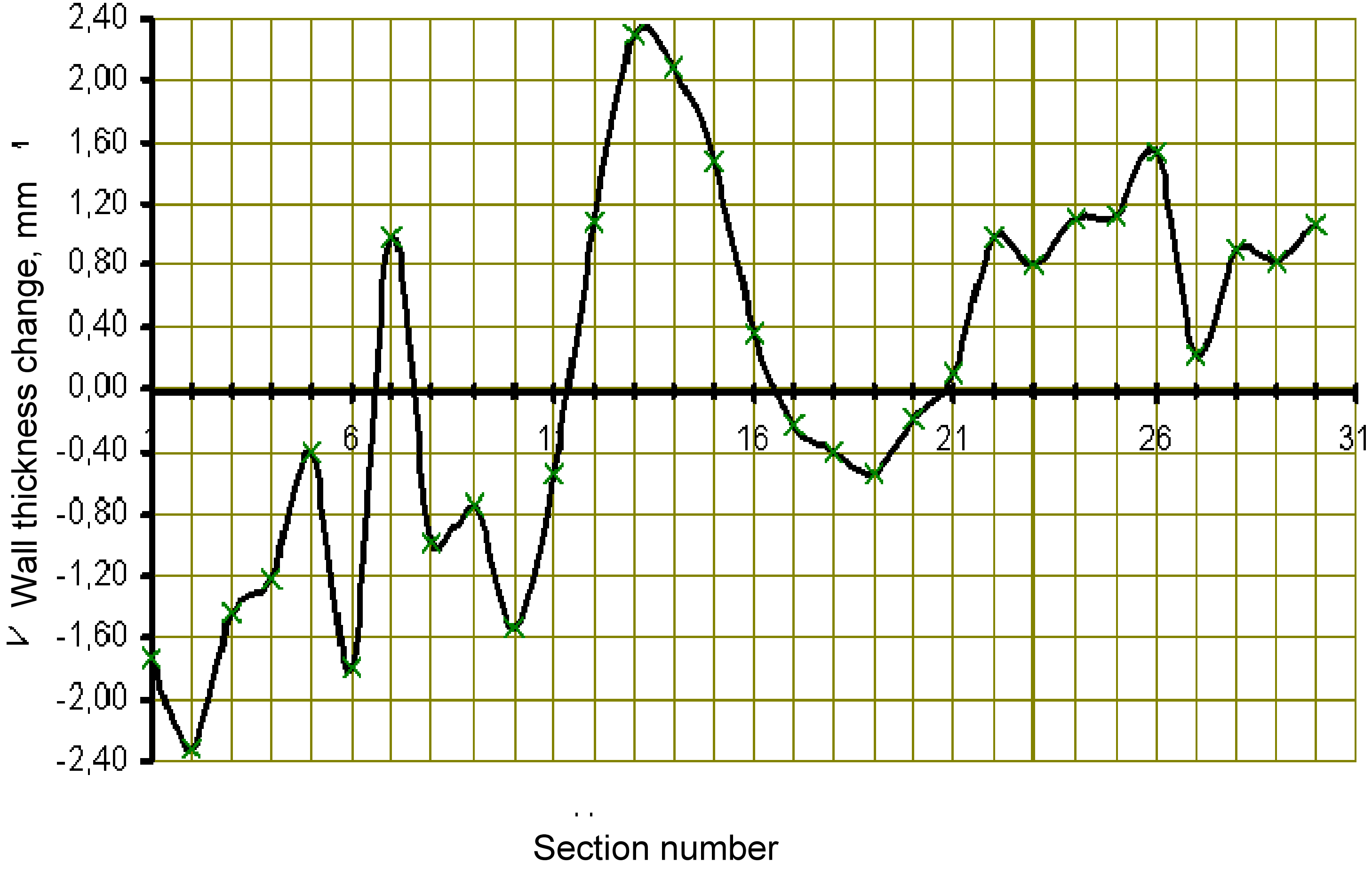
Wall Thickness Behavior of Ǿ 465x16 mm Pipeline Elbow within the Period from 1996 to 2002 in 12th «hour»



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Wall Thickness Behavior of Ǿ 465x16 mm Pipeline Elbow within the Period from 1996 to 2002 in 6th «hour»

Section number

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Wall Thickness Behavior of Ǿ 465x16 mm Pipeline Elbow within the Period from 1996 to 2002 in 3rd «hour»

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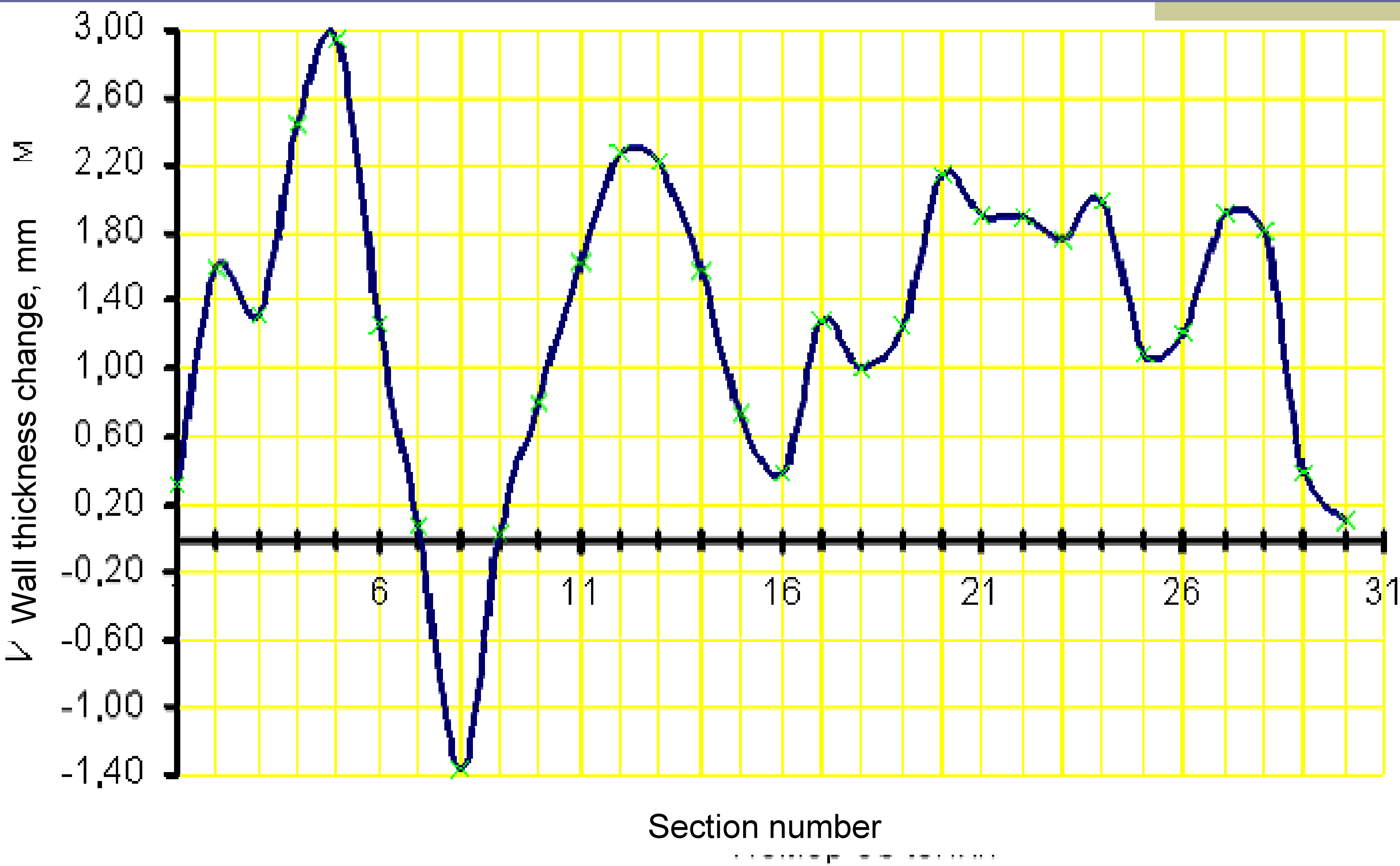
Analysis of Wall Thickness Behavior of Ǿ 465x16 mm Pipeline Elbow within the Period from 1996 to 2002 in 9th «hour»



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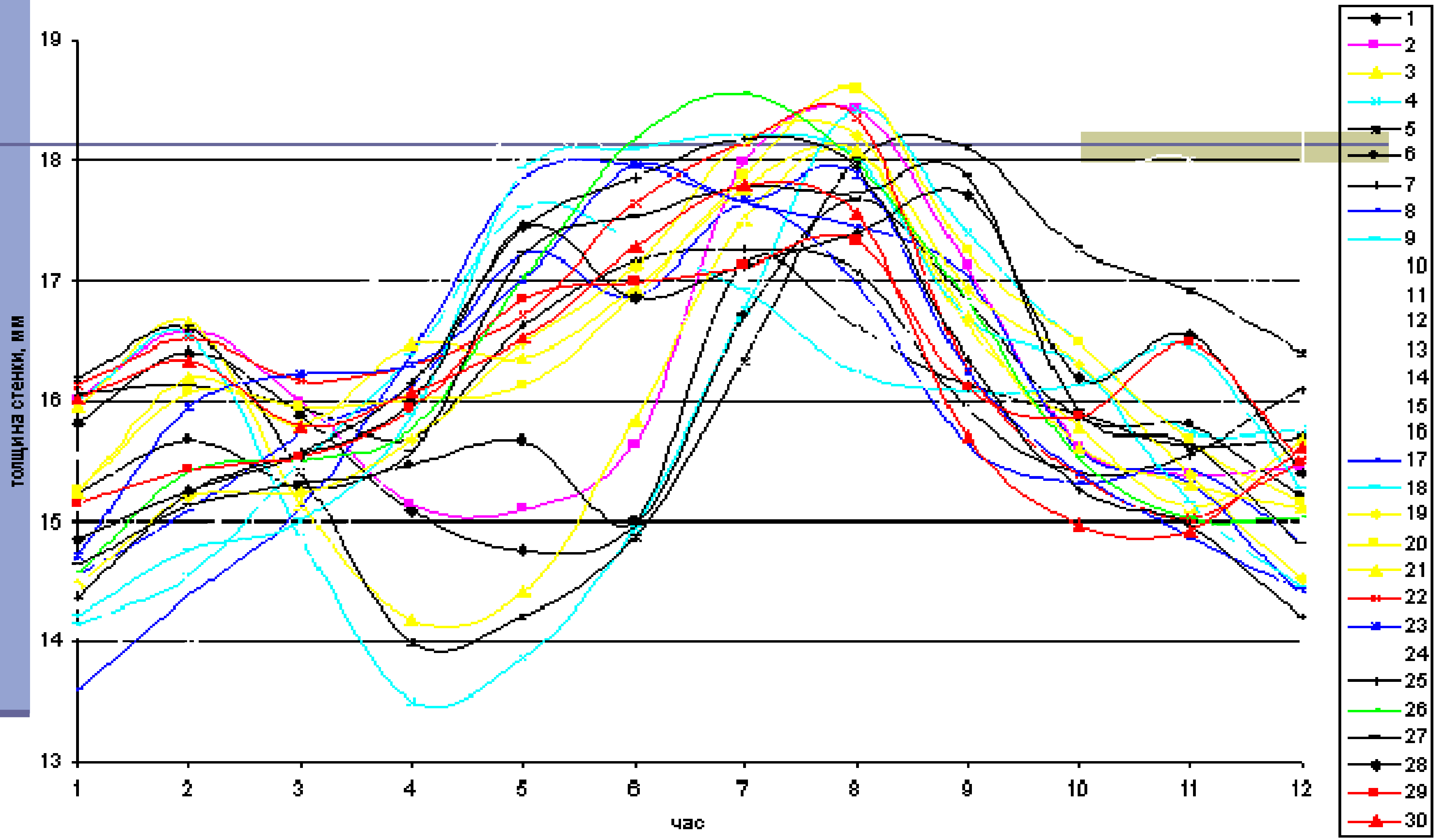
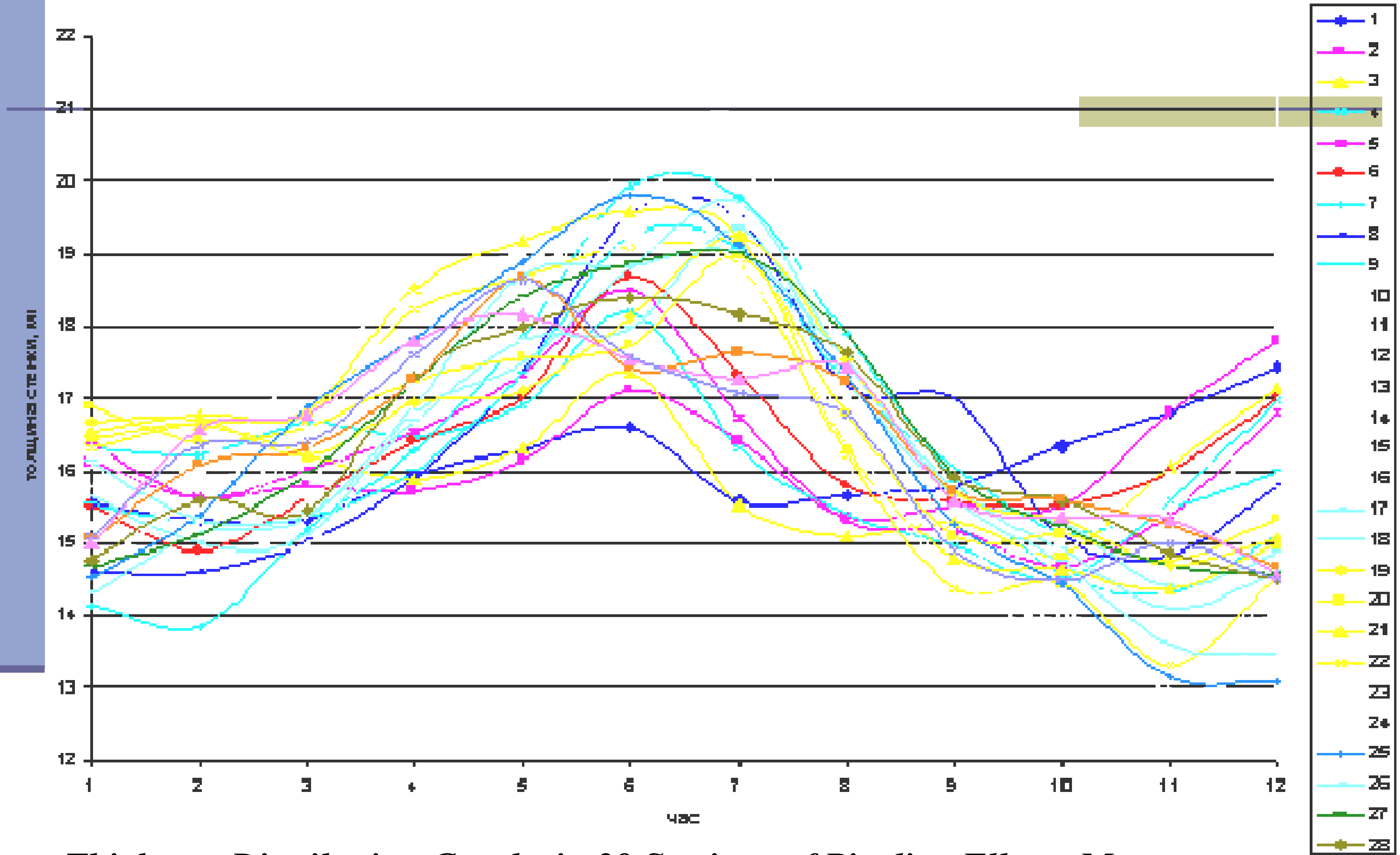


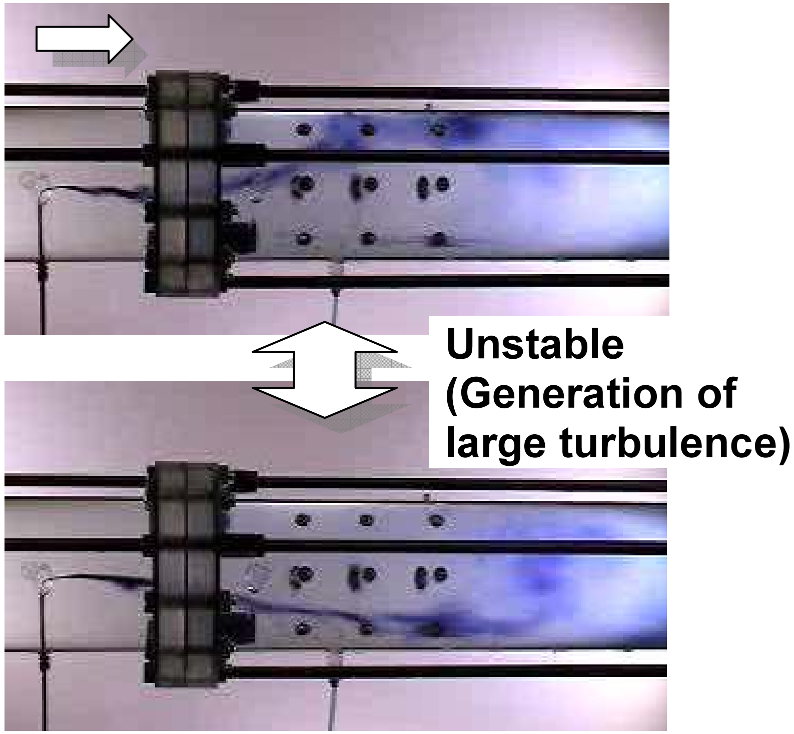
Thickness Distribution Graphs in 30 Sections of Pipeline Elbow. Measurement of 11.09.2002, **Ø 465x16 mm**



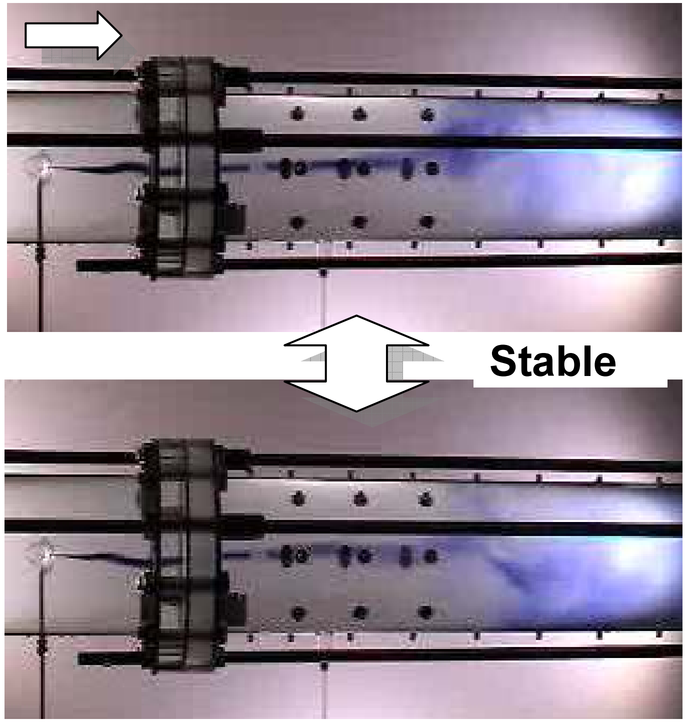
Thickness Distribution Graphs in 29 Sections of Pipeline Elbow. Measurement of 11.09.96, Ó 465x16 mm

Turbulent Flow Downstream of Orifice (Mihama)

A-train



B-train



Generation of relatively strong turbulence

- **Unstable position of flow axis**
- **Faster circumferential flow velocity than B-train**

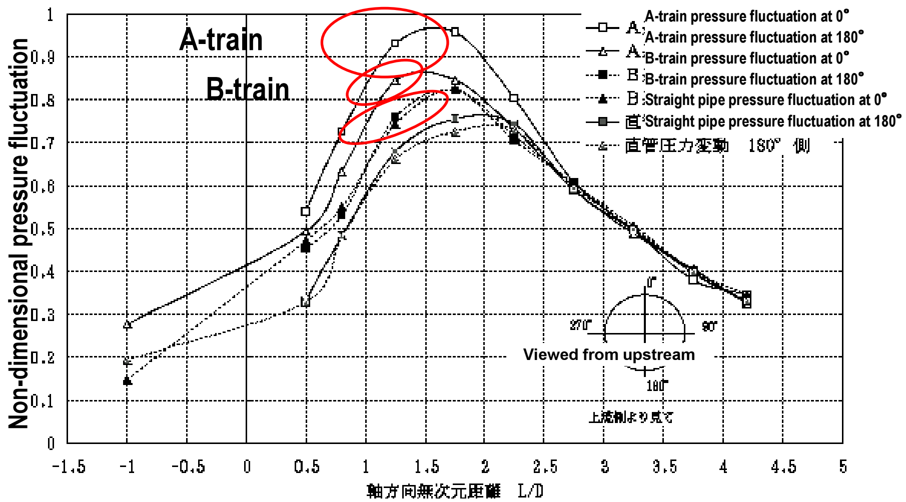
Generation of relatively weak turbulence

- **Stable position of flow axis**
- **Slower circumferential flow velocity than A-train**

Analytical result also shows that turbulence appeared in A-train is larger than that in B-train.

Distribution of Pressure Fluctuation (Mihama)

Distribution of Axial Pressure Fluctuation

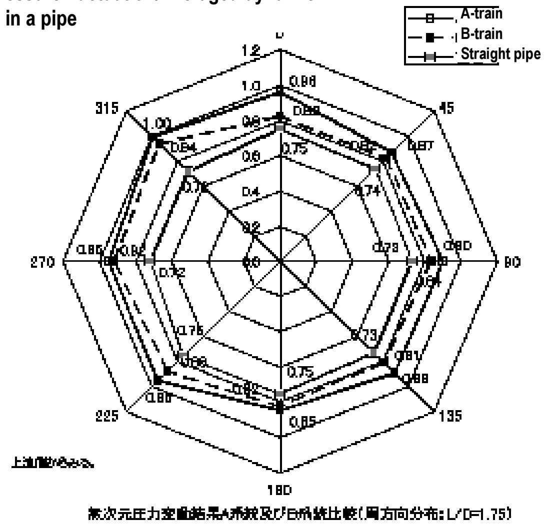


Non-dimensional axial distance (l/D)

Distribution of Non-dimensional pressure fluctuation (Comparison between A-train and B-train)

Distribution of Circumferential Pressure Fluctuation

Non-dimensional pressure fluctuation = RMS of pressure fluctuation/Averaged dynamic pressure in a pipe



Comparison of non-dimensional pressure fluctuations between A-train and B-train (circumferential distribution at L/D = 0.8)

- Degree of pressure fluctuation: A-train>B-train>Straight pipe
- Characteristics of A-train: Pressure fluctuations at 0° is larger than 180°
- Characteristics of B-train and straight pipe: No difference between 0° and 180°

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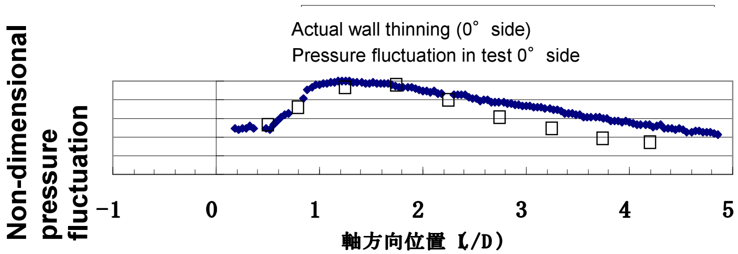
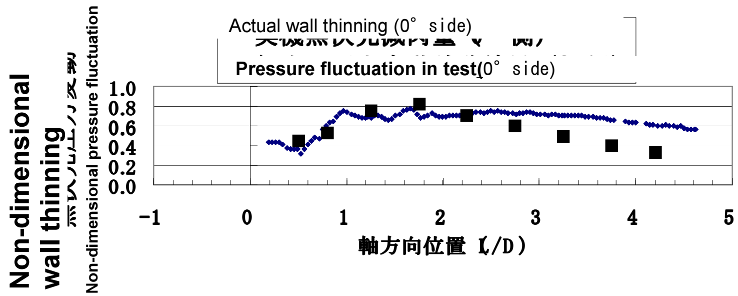
Comparison Between Actual Wall Thinning and Visualization Test (Mihama)

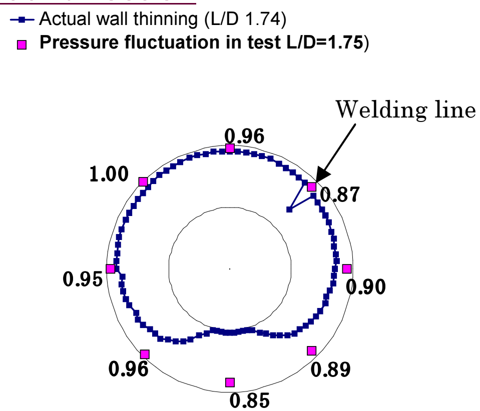
Axial direction ***A-train***



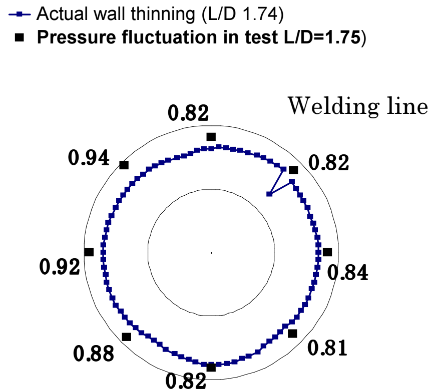
Axial direction ***B-train***



Circumferential direction



Circumferential direction



- Axial wall thinning: wall thinning trends at the actual plant corresponds to pressure fluctuation trends in visualization test.
- Circumferential wall thinning: wall thinning trends at the actual unit (A>B) corresponds to pressure fluctuation trends in visualization test (A>B).

Conclusions

1. The set of normative documents on calculation of erosion-corrosion wear has been developed including software tools, guidelines on calculations of permissible thickness for pipeline elements, guidelines on establishing chemical composition of pipeline metal

2. Application of normative documents provides for optimization of operating inspection scope and frequency, evaluation of technical state and definition of residual life.

3. It was found that availability of corrosion products deposits influences significantly on UT measurements reliability of pipeline wall thickness.