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# ANEXO I

## Curvas esfuerzo-deformación

Datos obtenidos mediante ensayos de compresión en caliente y la ecuación:

$$\sigma = K\varepsilon^n$$

donde:

$$K = 280\text{MPa}$$

$$n = 0.256$$

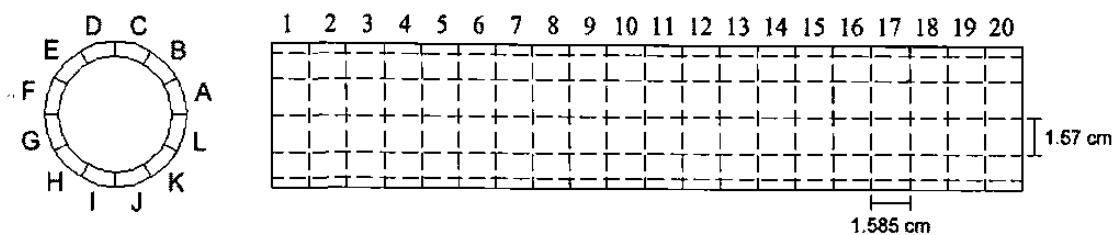
Ensayo1		Ensayo2		Ensayo3		Ensayo4		Curva de Fluencia	
$\sigma$ (MPa)	$\varepsilon$	$\sigma$ (MPa)	$\varepsilon$	$\sigma$ (MPa)	$\varepsilon$	$\sigma$ (MPa)	$\varepsilon$	$\sigma$ (MPa)	$\varepsilon$
35.1811	0.00060	5.0600	0.00000	11.0600	0.00000	0.1100	0.00000	0.0000	0.000
70.1939	0.00321	57.9700	0.00072	20.7107	0.00100	1.0306	0.00060	100.1170	0.018
90.3941	0.00833	72.7427	0.00100	45.3773	0.00371	11.6938	0.00290	101.5124	0.019
99.8891	0.01410	88.9396	0.00441	76.1292	0.00823	45.9925	0.00642	102.8541	0.020
105.9762	0.01928	99.2947	0.00944	91.4357	0.01379	81.3834	0.01116	104.1469	0.021
109.6514	0.02245	105.3252	0.01450	100.3606	0.01939	96.6353	0.01715	105.3946	0.022
116.0797	0.02717	109.4411	0.01928	105.4822	0.02429	103.4464	0.02265	106.6008	0.023
120.4523	0.03232	114.5111	0.02399	109.6065	0.02871	108.7083	0.02747	107.7686	0.024
124.4247	0.03739	117.5438	0.02861	114.2889	0.03325	113.8577	0.03211	108.9007	0.025
128.0884	0.04207	121.7052	0.03335	117.4931	0.03781	117.4523	0.03677	130.0452	0.050
130.3948	0.04657	125.2470	0.03822	121.9102	0.04259	122.6049	0.04155	144.2692	0.075
134.2402	0.05119	127.8448	0.04301	125.9764	0.04615	126.1380	0.04646	155.2952	0.100
136.9138	0.05594	131.5514	0.04793	129.8610	0.05171	129.7942	0.05150	164.4247	0.125
139.9019	0.06071	133.3889	0.05266	133.6938	0.05731	133.3689	0.05636	172.2810	0.150
143.0833	0.06561	136.8682	0.05763	134.9486	0.06241	135.6456	0.06124	179.2156	0.175
144.9490	0.07042	139.3336	0.06262	137.3721	0.06710	139.6550	0.06635	185.4478	0.200
148.1123	0.07526	141.1949	0.06753	139.6886	0.07160	141.7870	0.07128	191.1247	0.225
150.1737	0.08002	144.5356	0.07257	142.0398	0.07656	144.4824	0.07634	196.3499	0.250
151.9480	0.08501	145.7237	0.07742	145.2254	0.08154	147.4978	0.08143	201.1996	0.275
154.7162	0.09003	148.5273	0.08240	146.6599	0.08665	149.2207	0.08643	205.7316	0.300
155.4983	0.09497	150.9300	0.08752	149.2920	0.09157	152.5577	0.09168	209.9908	0.325
158.3775	0.09982	152.3760	0.09255	151.0949	0.09673	154.3060	0.09673	214.0127	0.350
159.3820	0.10492	155.1404	0.09761	152.8222	0.10159	156.6593	0.10192	217.8262	0.375
161.5244	0.10993	156.2982	0.10270	155.5005	0.10669	159.4786	0.10714	221.4549	0.400
163.2356	0.11496	159.0475	0.10781	156.7109	0.11171	160.6645	0.11227	224.9187	0.425



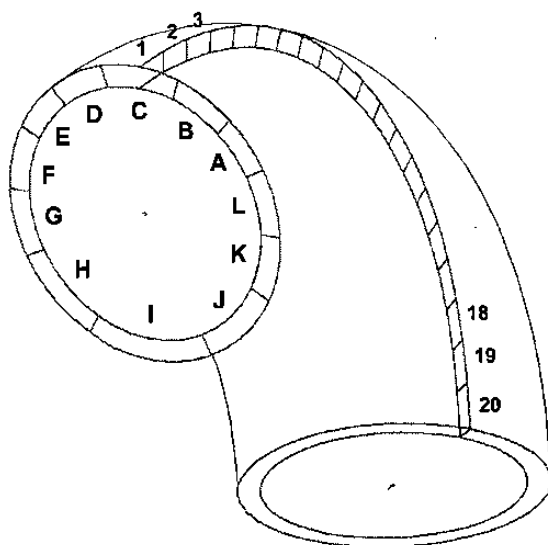
## ANEXO II

### Identificación de celdas y mediciones

Identificación por letra y número de cada celda (a) en el tubo (antes de la deformación) y (b) en el codo (después de la deformación).



(a)



(b)





▪ Codo

Mediciones longitudinales después de la deformación (mm).

	A	B	C	D	E	F	G	H	I	J	K	L
1	11.94	13.65	14.00	12.73	13.44	12.31	9.18	8.29	6.57	7.04	9.25	11.71
2	13.05	13.69	13.77	14.16	13.64	12.74	11.30	8.29	6.33	7.94	8.78	10.87
3	13.04	13.8	14.03	14.07	13.53	12.61	11.30	8.47	6.41	7.58	8.94	11.14
4	13.12	14.16	14.38	14.38	13.82	12.92	11.30	9.08	6.38	7.35	9.31	11.35
5	13.08	13.87	14.23	14.08	13.65	12.52	11.28	9.08	6.59	7.33	9.04	11.21
6	12.83	13.87	14.22	14.06	13.58	12.42	11.35	8.70	7.20	7.25	8.94	11.02
7	12.94	13.91	14.42	14.20	13.56	12.48	10.80	9.03	7.09	7.58	8.99	11.21
8	12.62	13.67	14.10	13.93	13.27	12.05	10.57	8.53	6.90	7.19	8.86	10.85
9	13.16	14.00	14.69	14.53	13.88	12.45	10.93	8.75	7.32	7.33	9.21	11.21
10	12.83	14.12	13.98	14.43	13.69	12.57	10.63	8.76	7.09	7.33	8.92	11.32
11	12.57	13.94	13.86	14.43	13.73	12.55	10.45	8.66	6.85	7.37	8.92	10.95
12	13.25	14.34	14.94	14.60	14.07	12.76	11.25	8.66	6.83	7.24	9.14	11.07
13	12.62	13.84	14.29	14.26	13.60	12.52	10.93	8.43	6.65	6.95	8.85	10.92
14	13.19	14.31	14.76	14.76	14.06	12.81	11.24	8.79	6.59	7.20	9.18	11.28
15	13.07	14.21	14.73	14.56	13.98	12.70	10.81	8.69	6.57	7.20	8.70	11.06
16	13.07	14.38	14.77	14.64	14.27	12.88	11.00	8.71	6.67	6.95	8.92	11.21
17	13.20	14.38	14.86	14.83	14.22	13.04	11.33	8.71	6.52	7.06	8.95	11.23
18	13.11	14.29	14.91	14.83	14.21	12.97	11.43	8.92	6.52	7.28	9.09	11.29
19	12.93	14.29	14.76	14.66	14.15	13.03	11.43	9.00	6.52	7.33	9.09	11.29
20	13.75	14.78	15.14	15.01	14.50	13.72	11.43	9.03	6.52	6.92	9.22	11.19

Mediciones circunferenciales después de la deformación (mm).

	A	B	C	D	E	F	G	H	I	J	K	L
1	18.30	17.88	18.04	18.44	17.83	20.50	24.52	31.89	40.75	27.50	21.97	20.55
2	17.99	18.14	18.04	18.32	18.05	19.94	23.75	32.27	39.14	28.27	22.73	19.71
3	18.17	18.14	18.04	18.32	18.68	19.94	22.97	31.95	37.94	28.99	22.96	19.52
4	18.27	18.14	18.24	18.32	18.85	20.10	23.44	31.33	36.17	29.48	23.32	19.81
5	18.56	18.14	18.24	18.35	18.87	20.40	23.74	30.88	34.53	29.62	23.77	20.10
6	18.52	18.29	18.24	18.35	18.87	21.00	24.09	30.84	34.04	29.38	23.84	20.30
7	18.69	18.21	18.24	18.35	18.82	20.83	24.27	30.84	34.04	29.18	23.79	20.41
8	18.83	18.2	18.24	18.25	18.83	20.99	24.55	30.84	33.45	29.18	23.85	20.66
9	18.82	18.07	17.84	18.25	18.90	21.15	25.00	31.15	33.78	29.63	23.85	20.70
10	18.79	17.89	17.70	18.07	18.90	21.15	25.00	31.15	34.30	29.63	24.03	20.73
11	18.54	17.89	17.49	18.07	18.71	20.55	25.09	31.46	34.30	29.63	24.03	20.75
12	18.42	17.89	17.49	17.97	18.71	20.55	24.78	31.46	34.84	29.76	24.00	20.55
13	18.42	17.89	17.49	17.97	18.71	20.57	24.37	31.64	35.79	30.07	24.10	20.31
14	18.17	17.89	17.28	17.97	18.45	20.57	24.40	31.86	36.01	29.97	24.07	20.31
15	18.17	17.64	17.27	17.83	18.39	20.57	24.40	31.86	36.03	30.42	24.28	19.89
16	18.16	17.64	17.20	17.71	18.20	20.29	24.38	31.86	36.64	30.59	24.18	20.18
17	18.16	17.64	17.20	17.71	18.20	20.10	24.26	31.86	37.27	30.89	23.98	20.28
18	18.16	17.526	17.20	17.71	18.19	20.10	23.55	31.23	37.77	30.91	23.61	20.38
19	18.16	17.36	17.20	17.71	17.11	20.10	23.55	31.23	37.93	31.09	23.62	20.38
20	18.14	17.37	17.32	17.71	17.79	20.06	24.28	31.23	36.19	31.34	24.43	20.38

▪ **Ángulo en tubo**

Ángulo inicial de la celda obtenida mediante  $\tan^{-1}(x_i/y_i)$  (radianes)

	A	B	C	D	E	F	G	H	I	J	K	L
1	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
2	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
3	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
4	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
5	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
6	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
7	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
8	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
9	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
10	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
11	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
12	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
13	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
14	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
15	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
16	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
17	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
18	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
19	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
20	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791

▪ **Ángulo en codo**

Ángulo inicial de la celda obtenida mediante  $\tan^{-1}(x_f/y_f)$  (radianes)

	A	B	C	D	E	F	G	H	I	J	K	L
1	0.578	0.652	0.660	0.639	0.646	0.541	0.388	0.254	0.160	0.224	0.399	0.518
2	0.628	0.646	0.652	0.658	0.547	0.569	0.444	0.251	0.160	0.274	0.369	0.504
3	0.622	0.650	0.661	0.655	0.627	0.564	0.457	0.259	0.167	0.256	0.371	0.519
4	0.623	0.663	0.668	0.665	0.633	0.571	0.449	0.282	0.175	0.244	0.380	0.520
5	0.614	0.653	0.663	0.654	0.626	0.550	0.444	0.286	0.189	0.243	0.363	0.509
6	0.606	0.649	0.662	0.654	0.624	0.534	0.440	0.275	0.208	0.242	0.359	0.497
7	0.606	0.652	0.669	0.659	0.624	0.540	0.419	0.285	0.205	0.254	0.361	0.502
8	0.590	0.644	0.658	0.652	0.614	0.521	0.407	0.270	0.203	0.242	0.356	0.484
9	0.610	0.659	0.689	0.672	0.633	0.532	0.412	0.274	0.213	0.243	0.369	0.496
10	0.599	0.668	0.669	0.674	0.627	0.536	0.402	0.274	0.204	0.243	0.355	0.500
11	0.596	0.662	0.670	0.674	0.633	0.548	0.395	0.269	0.197	0.244	0.355	0.486
12	0.624	0.676	0.707	0.682	0.645	0.556	0.426	0.269	0.194	0.239	0.364	0.494
13	0.601	0.658	0.685	0.671	0.629	0.547	0.422	0.260	0.184	0.227	0.352	0.493
14	0.628	0.675	0.707	0.688	0.651	0.557	0.432	0.269	0.181	0.236	0.364	0.507
15	0.624	0.678	0.706	0.685	0.650	0.553	0.417	0.266	0.180	0.232	0.344	0.507
16	0.624	0.684	0.710	0.691	0.665	0.566	0.424	0.267	0.180	0.223	0.353	0.507
17	0.629	0.684	0.713	0.697	0.663	0.576	0.437	0.267	0.173	0.225	0.357	0.506
18	0.625	0.684	0.714	0.697	0.663	0.573	0.452	0.278	0.171	0.231	0.368	0.506
19	0.619	0.689	0.709	0.691	0.691	0.575	0.452	0.281	0.170	0.232	0.367	0.506
20	0.649	0.705	0.718	0.703	0.684	0.600	0.440	0.281	0.178	0.217	0.361	0.502

## ANEXO III

### Distribución de deformación obtenida por el método de visioelasticidad

▪ Deformación equivalente<sup>[19]</sup>

$$\bar{\varepsilon} = \frac{\sqrt{2}}{3} \left[ (\varepsilon_z - \varepsilon_\theta)^2 + (\varepsilon_\theta - \varepsilon_r)^2 + (\varepsilon_r - \varepsilon_z)^2 + \frac{3}{2} \gamma_{\theta z}^2 \right]^{1/2}$$

	A	B	C	D	E	F	G	H	I	J	K	L
1	0.376	0.229	0.215	0.250	0.241	0.417	0.701	1.001	1.288	1.107	0.709	0.458
2	0.275	0.237	0.228	0.221	0.236	0.369	0.596	1.009	1.284	0.956	0.772	0.505
3	0.282	0.231	0.213	0.225	0.270	0.377	0.568	0.990	1.259	1.003	0.759	0.476
4	0.279	0.212	0.208	0.213	0.264	0.366	0.585	0.939	1.236	1.035	0.729	0.464
5	0.293	0.227	0.214	0.227	0.273	0.401	0.596	0.928	1.191	1.039	0.764	0.484
6	0.309	0.234	0.215	0.227	0.276	0.431	0.605	0.950	1.126	1.044	0.775	0.505
7	0.307	0.228	0.207	0.221	0.275	0.421	0.641	0.930	1.136	1.007	0.769	0.492
8	0.335	0.241	0.220	0.229	0.292	0.451	0.664	0.961	1.144	1.047	0.783	0.529
9	0.298	0.216	0.174	0.204	0.264	0.435	0.658	0.954	1.111	1.039	0.750	0.501
10	0.319	0.201	0.201	0.197	0.272	0.429	0.675	0.954	1.140	1.039	0.781	0.493
11	0.329	0.211	0.200	0.197	0.261	0.405	0.688	0.967	1.162	1.035	0.781	0.523
12	0.276	0.191	0.145	0.185	0.246	0.394	0.635	0.967	1.172	1.051	0.760	0.508
13	0.322	0.217	0.173	0.199	0.268	0.408	0.637	0.986	1.204	1.086	0.789	0.514
14	0.271	0.192	0.139	0.180	0.233	0.393	0.622	0.969	1.213	1.058	0.757	0.484
15	0.280	0.185	0.140	0.178	0.233	0.398	0.645	0.974	1.215	1.065	0.807	0.492
16	0.279	0.176	0.134	0.168	0.210	0.377	0.634	0.973	1.215	1.094	0.784	0.486
17	0.270	0.176	0.130	0.162	0.212	0.360	0.612	0.973	1.239	1.087	0.777	0.487
18	0.276	0.175	0.128	0.162	0.212	0.364	0.582	0.946	1.246	1.065	0.756	0.485
19	0.290	0.167	0.135	0.168	0.166	0.361	0.582	0.941	1.249	1.064	0.756	0.485
20	0.234	0.143	0.129	0.157	0.178	0.330	0.608	0.940	1.223	1.109	0.762	0.493
Prom.	0.295	0.204	0.177	0.198	0.244	0.394	0.627	0.963	1.203	1.052	0.766	0.493
D.Est.	0.031	0.028	0.038	0.028	0.034	0.031	0.038	0.023	0.053	0.037	0.022	0.018

▪ **Componente longitudinal**

$$\varepsilon_z = \ln\left(\frac{X_i}{X_f}\right)$$

	A	B	C	D	E	F	G	H	I	J	K	L
1	-0.285	-0.151	-0.126	-0.221	-0.167	-0.254	-0.548	-0.650	-0.882	-0.813	-0.540	-0.304
2	-0.196	-0.148	-0.142	-0.114	-0.152	-0.220	-0.340	-0.650	-0.919	-0.693	-0.592	-0.379
3	-0.197	-0.140	-0.124	-0.121	-0.160	-0.230	-0.340	-0.628	-0.907	-0.739	-0.574	-0.354
4	-0.191	-0.114	-0.099	-0.099	-0.139	-0.206	-0.340	-0.559	-0.912	-0.770	-0.534	-0.336
5	-0.194	-0.135	-0.109	-0.120	-0.151	-0.237	-0.342	-0.559	-0.879	-0.773	-0.563	-0.348
6	-0.213	-0.135	-0.110	-0.121	-0.156	-0.245	-0.336	-0.601	-0.791	-0.784	-0.574	-0.365
7	-0.204	-0.132	-0.096	-0.112	-0.158	-0.241	-0.385	-0.564	-0.806	-0.739	-0.569	-0.348
8	-0.229	-0.150	-0.119	-0.131	-0.179	-0.276	-0.407	-0.621	-0.833	-0.792	-0.583	-0.381
9	-0.188	-0.126	-0.078	-0.089	-0.134	-0.243	-0.373	-0.596	-0.774	-0.773	-0.544	-0.348
10	-0.213	-0.117	-0.127	-0.095	-0.148	-0.233	-0.401	-0.595	-0.806	-0.773	-0.576	-0.338
11	-0.233	-0.130	-0.136	-0.095	-0.145	-0.235	-0.418	-0.606	-0.840	-0.767	-0.576	-0.371
12	-0.181	-0.102	-0.061	-0.084	-0.121	-0.218	-0.344	-0.606	-0.843	-0.785	-0.552	-0.361
13	-0.229	-0.137	-0.105	-0.107	-0.155	-0.237	-0.373	-0.633	-0.870	-0.826	-0.584	-0.374
14	-0.185	-0.104	-0.073	-0.073	-0.121	-0.215	-0.345	-0.591	-0.879	-0.791	-0.548	-0.342
15	-0.194	-0.111	-0.075	-0.086	-0.127	-0.223	-0.384	-0.603	-0.882	-0.791	-0.601	-0.361
16	-0.194	-0.099	-0.072	-0.081	-0.107	-0.209	-0.367	-0.600	-0.867	-0.826	-0.576	-0.348
17	-0.185	-0.099	-0.066	-0.068	-0.110	-0.197	-0.337	-0.600	-0.890	-0.810	-0.573	-0.346
18	-0.191	-0.105	-0.063	-0.068	-0.111	-0.202	-0.329	-0.576	-0.890	-0.780	-0.558	-0.341
19	-0.205	-0.105	-0.073	-0.080	-0.115	-0.197	-0.329	-0.568	-0.890	-0.773	-0.558	-0.341
20	-0.144	-0.071	-0.047	-0.056	-0.091	-0.146	-0.329	-0.564	-0.890	-0.830	-0.543	-0.350

▪ **Componente circunferencial**

$$\varepsilon_{\theta} = \ln \left( \frac{y_i}{y_f} \right)$$

	A	B	C	D	E	F	G	H	I	J	K	L
1	0.153	0.130	0.138	0.160	0.127	0.266	0.445	0.708	0.953	0.560	0.336	0.269
2	0.136	0.144	0.138	0.154	0.139	0.239	0.413	0.720	0.913	0.588	0.370	0.227
3	0.146	0.144	0.138	0.154	0.173	0.239	0.380	0.710	0.882	0.613	0.380	0.217
4	0.151	0.144	0.150	0.154	0.182	0.247	0.400	0.690	0.834	0.630	0.395	0.232
5	0.167	0.144	0.150	0.156	0.183	0.261	0.413	0.676	0.788	0.634	0.414	0.247
6	0.165	0.152	0.150	0.156	0.183	0.290	0.428	0.675	0.773	0.626	0.417	0.257
7	0.174	0.148	0.150	0.156	0.181	0.282	0.435	0.675	0.773	0.619	0.415	0.262
8	0.181	0.147	0.150	0.150	0.181	0.290	0.447	0.675	0.756	0.619	0.418	0.274
9	0.181	0.140	0.127	0.150	0.185	0.298	0.465	0.685	0.766	0.635	0.418	0.276
10	0.180	0.130	0.119	0.140	0.185	0.298	0.465	0.685	0.781	0.635	0.425	0.277
11	0.166	0.130	0.108	0.140	0.175	0.269	0.468	0.695	0.781	0.635	0.425	0.278
12	0.159	0.130	0.108	0.135	0.175	0.269	0.456	0.695	0.797	0.639	0.424	0.269
13	0.159	0.130	0.108	0.135	0.175	0.270	0.439	0.700	0.824	0.649	0.428	0.257
14	0.146	0.130	0.095	0.135	0.161	0.270	0.440	0.707	0.830	0.646	0.427	0.257
15	0.146	0.116	0.095	0.127	0.158	0.270	0.440	0.707	0.830	0.661	0.436	0.236
16	0.145	0.116	0.091	0.120	0.147	0.256	0.440	0.707	0.847	0.667	0.431	0.251
17	0.145	0.116	0.091	0.120	0.147	0.247	0.435	0.707	0.864	0.676	0.423	0.256
18	0.145	0.110	0.091	0.120	0.147	0.247	0.405	0.687	0.877	0.677	0.408	0.260
19	0.145	0.100	0.091	0.120	0.086	0.247	0.405	0.687	0.882	0.683	0.408	0.260
20	0.144	0.101	0.098	0.120	0.125	0.245	0.436	0.687	0.835	0.691	0.442	0.260

▪ **Componente radial**

$$\varepsilon_r = -(\varepsilon_\theta + \varepsilon_z)$$

	A	B	C	D	E	F	G	H	I	J	K	L
1	0.132	0.021	-0.013	-0.013	0.040	-0.012	0.016	-0.058	-0.071	0.330	0.205	0.036
2	0.060	0.004	0.004	-0.040	0.013	-0.019	-0.074	-0.070	0.006	0.105	0.223	0.152
3	0.051	-0.004	-0.015	-0.033	-0.014	-0.008	-0.040	-0.082	0.025	0.126	0.195	0.137
4	0.039	-0.030	-0.051	-0.055	-0.044	-0.041	-0.060	-0.132	0.077	0.140	0.138	0.103
5	0.027	-0.009	-0.040	-0.036	-0.032	-0.024	-0.071	-0.117	0.091	0.138	0.149	0.101
6	0.048	-0.017	-0.039	-0.034	-0.027	-0.045	-0.092	-0.073	0.017	0.158	0.157	0.109
7	0.031	-0.016	-0.053	-0.044	-0.023	-0.042	-0.050	-0.111	0.033	0.120	0.153	0.086
8	0.048	0.002	-0.031	-0.019	-0.002	-0.014	-0.040	-0.054	0.077	0.173	0.166	0.106
9	0.007	-0.014	-0.050	-0.062	-0.051	-0.055	-0.092	-0.089	0.008	0.138	0.127	0.072
10	0.033	-0.013	0.008	-0.045	-0.037	-0.064	-0.064	-0.090	0.025	0.138	0.151	0.061
11	0.068	0.000	0.028	-0.045	-0.030	-0.034	-0.050	-0.089	0.059	0.133	0.151	0.093
12	0.021	-0.028	-0.047	-0.051	-0.054	-0.050	-0.112	-0.089	0.047	0.146	0.128	0.092
13	0.070	0.007	-0.002	-0.027	-0.020	-0.032	-0.066	-0.067	0.047	0.177	0.156	0.117
14	0.040	-0.026	-0.023	-0.062	-0.040	-0.055	-0.095	-0.116	0.050	0.145	0.121	0.085
15	0.049	-0.005	-0.020	-0.040	-0.031	-0.047	-0.056	-0.105	0.052	0.130	0.166	0.125
16	0.049	-0.017	-0.019	-0.039	-0.041	-0.047	-0.073	-0.107	0.020	0.159	0.145	0.097
17	0.039	-0.017	-0.025	-0.052	-0.037	-0.050	-0.097	-0.107	0.026	0.134	0.150	0.091
18	0.046	-0.004	-0.028	-0.052	-0.036	-0.045	-0.077	-0.111	0.012	0.103	0.150	0.080
19	0.060	0.005	-0.018	-0.040	0.029	-0.049	-0.077	-0.120	0.008	0.090	0.150	0.080
20	0.000	-0.029	-0.050	-0.064	-0.034	-0.099	-0.107	-0.123	0.055	0.140	0.102	0.089

▪ **Componente cortante  $\theta_z$**

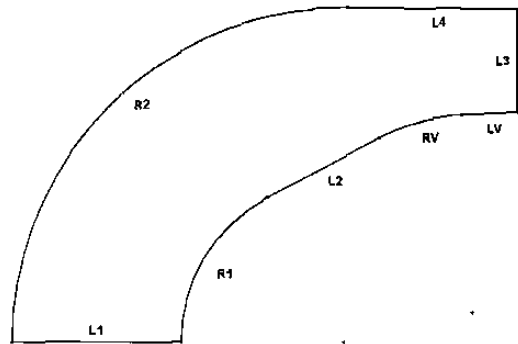
$$\gamma_{\theta z} = 2\Delta\alpha$$

	A	B	C	D	E	F	G	H	I	J	K	L
1	0.425	0.277	0.261	0.303	0.290	0.500	0.806	1.073	1.262	1.116	0.784	0.546
2	0.326	0.288	0.278	0.265	0.287	0.444	0.693	1.079	1.261	1.034	0.844	0.573
3	0.336	0.281	0.259	0.272	0.328	0.454	0.667	1.063	1.247	1.070	0.839	0.544
4	0.336	0.256	0.246	0.250	0.316	0.439	0.683	1.017	1.232	1.093	0.822	0.541
5	0.354	0.276	0.256	0.272	0.329	0.481	0.694	1.009	1.204	1.096	0.855	0.564
6	0.370	0.284	0.257	0.274	0.334	0.513	0.701	1.032	1.165	1.098	0.864	0.587
7	0.370	0.277	0.244	0.264	0.333	0.502	0.744	1.012	1.171	1.073	0.859	0.577
8	0.401	0.293	0.265	0.278	0.354	0.539	0.768	1.042	1.175	1.098	0.870	0.614
9	0.361	0.263	0.204	0.237	0.315	0.517	0.757	1.034	1.155	1.096	0.844	0.589
10	0.384	0.245	0.244	0.234	0.328	0.509	0.777	1.033	1.174	1.096	0.871	0.582
11	0.390	0.258	0.241	0.234	0.315	0.485	0.792	1.044	1.187	1.094	0.871	0.610
12	0.334	0.230	0.168	0.217	0.292	0.470	0.729	1.044	1.194	1.104	0.854	0.593
13	0.380	0.265	0.211	0.240	0.324	0.488	0.738	1.061	1.214	1.127	0.878	0.595
14	0.326	0.232	0.168	0.206	0.279	0.467	0.718	1.043	1.219	1.110	0.853	0.567
15	0.334	0.225	0.169	0.212	0.281	0.475	0.747	1.049	1.221	1.117	0.893	0.566
16	0.334	0.214	0.162	0.200	0.252	0.450	0.734	1.048	1.221	1.135	0.875	0.567
17	0.324	0.214	0.156	0.187	0.255	0.430	0.708	1.048	1.235	1.132	0.867	0.570
18	0.331	0.213	0.153	0.187	0.255	0.435	0.678	1.025	1.240	1.119	0.846	0.570
19	0.344	0.204	0.163	0.199	0.199	0.431	0.678	1.020	1.241	1.118	0.847	0.570
20	0.284	0.171	0.145	0.175	0.214	0.382	0.701	1.018	1.225	1.147	0.860	0.577

# ANEXO IV

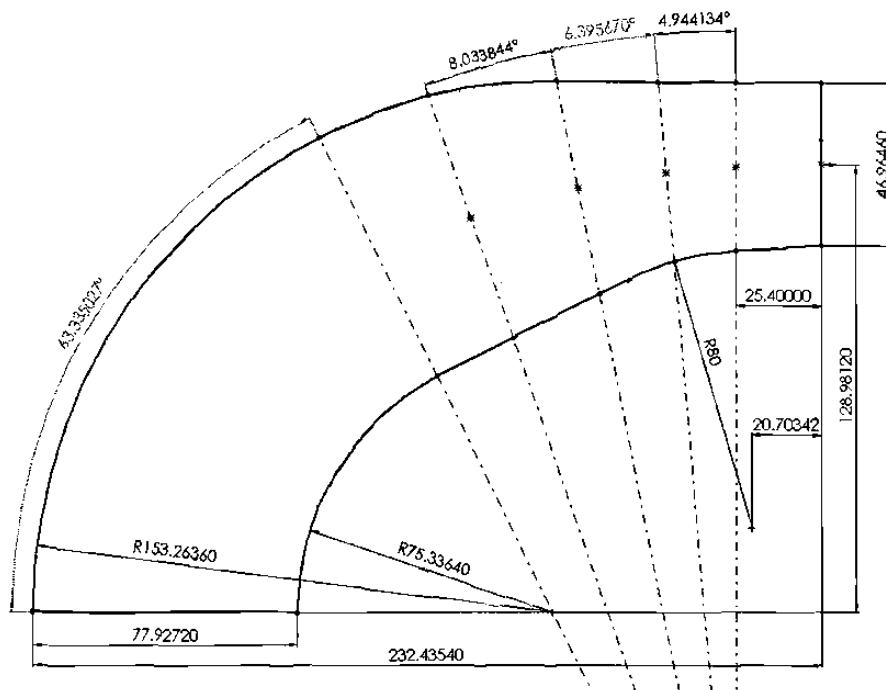
## Geometría básica y diseños de prueba del mandril

### Líneas que conforman la geometría del mandril



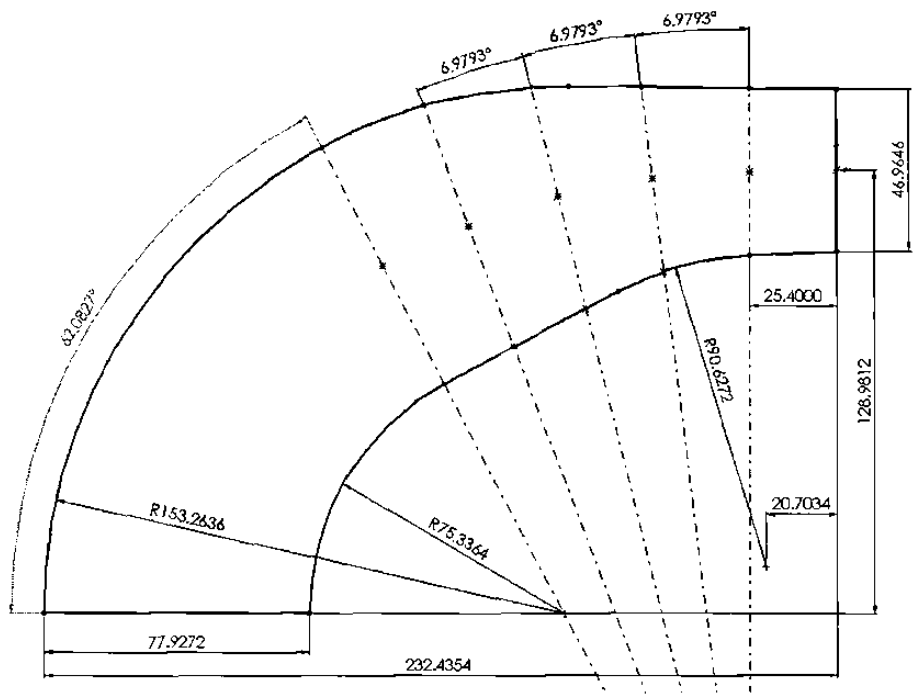
### Diseños de prueba del mandril (unidades en milímetros)

#### ▪ Mandril01

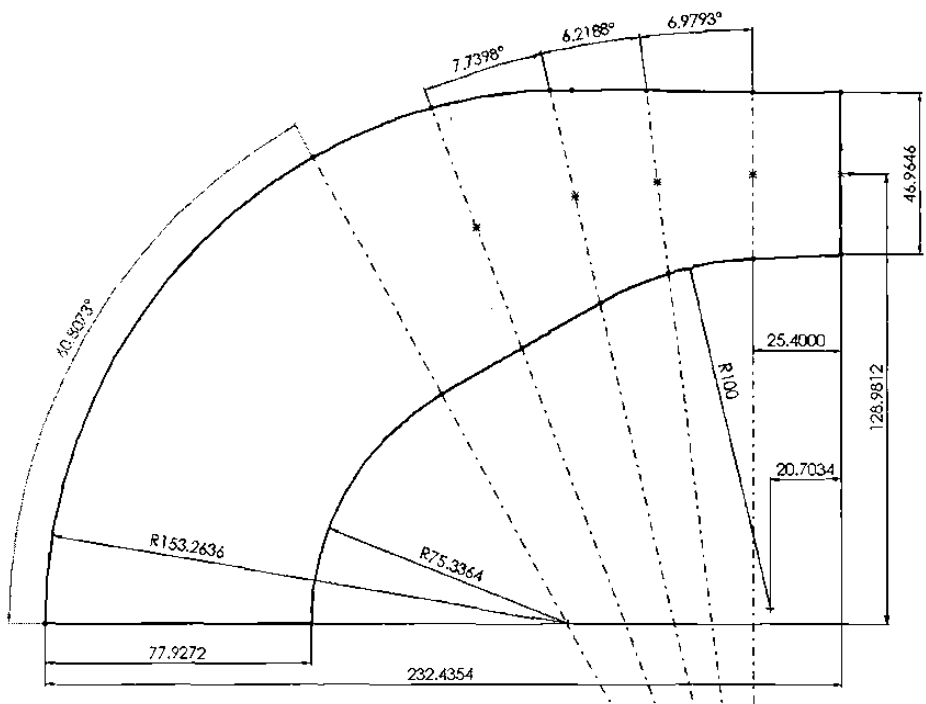




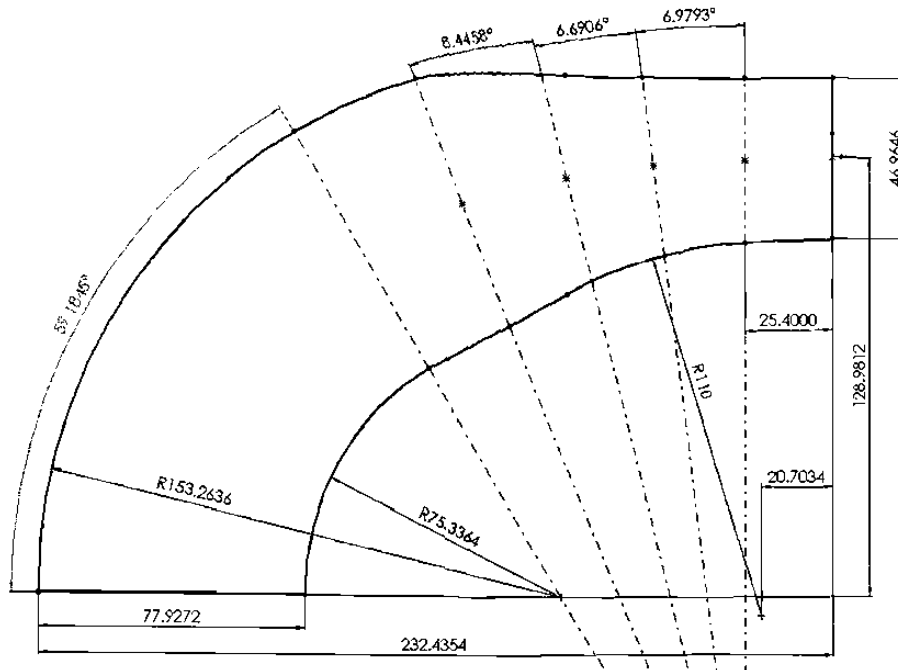
▪ Mandril02 (original)



▪ Mandril03



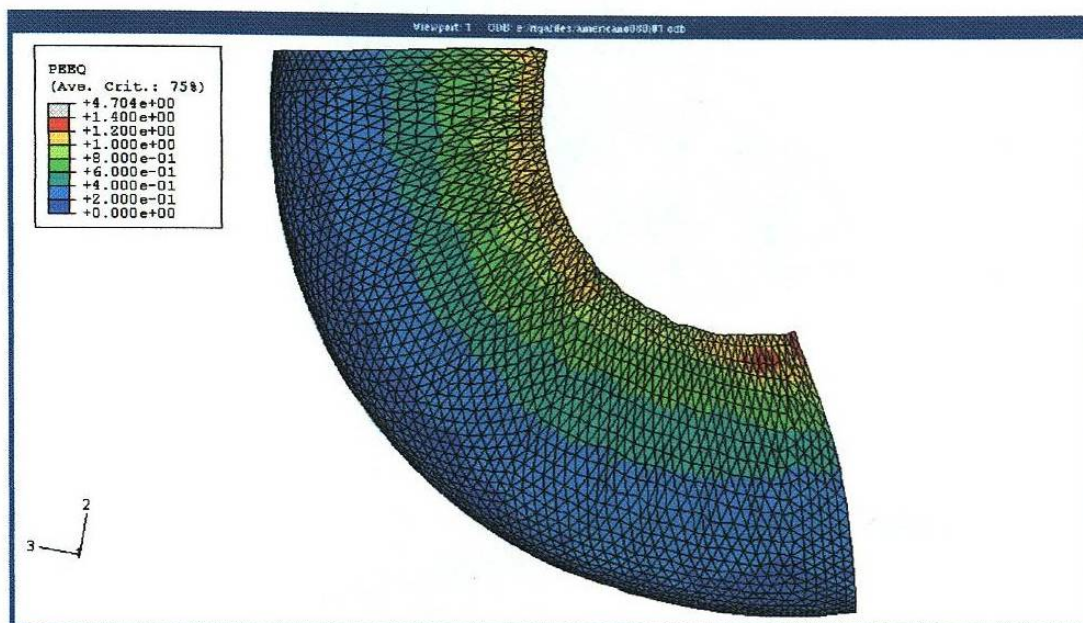
▪ Mandril04



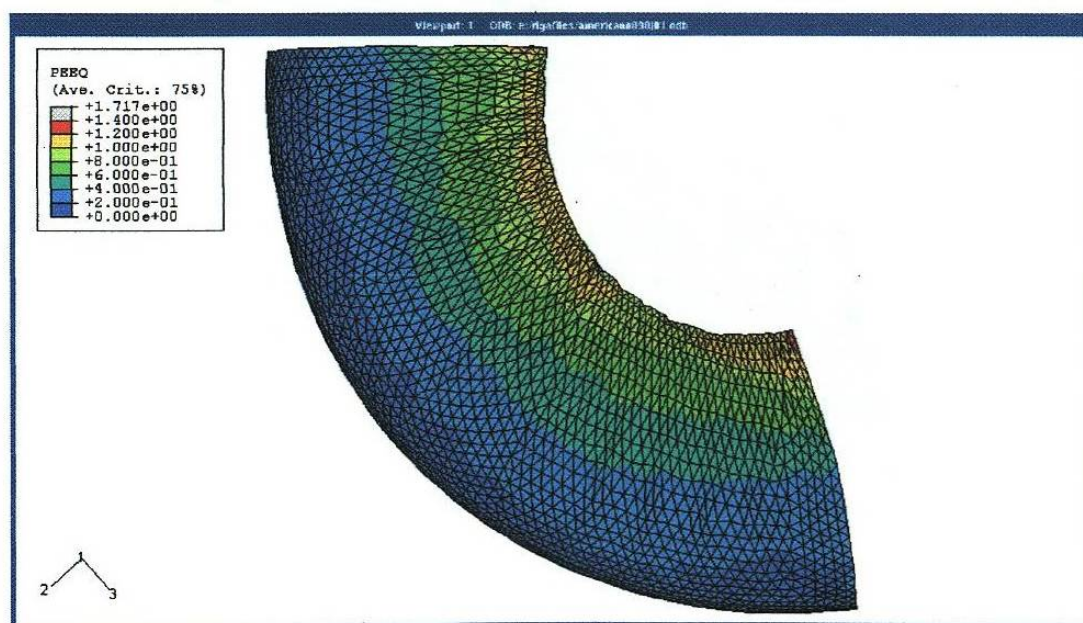
# ANEXO V

## Distribución de deformación obtenida por el método de elementos finitos

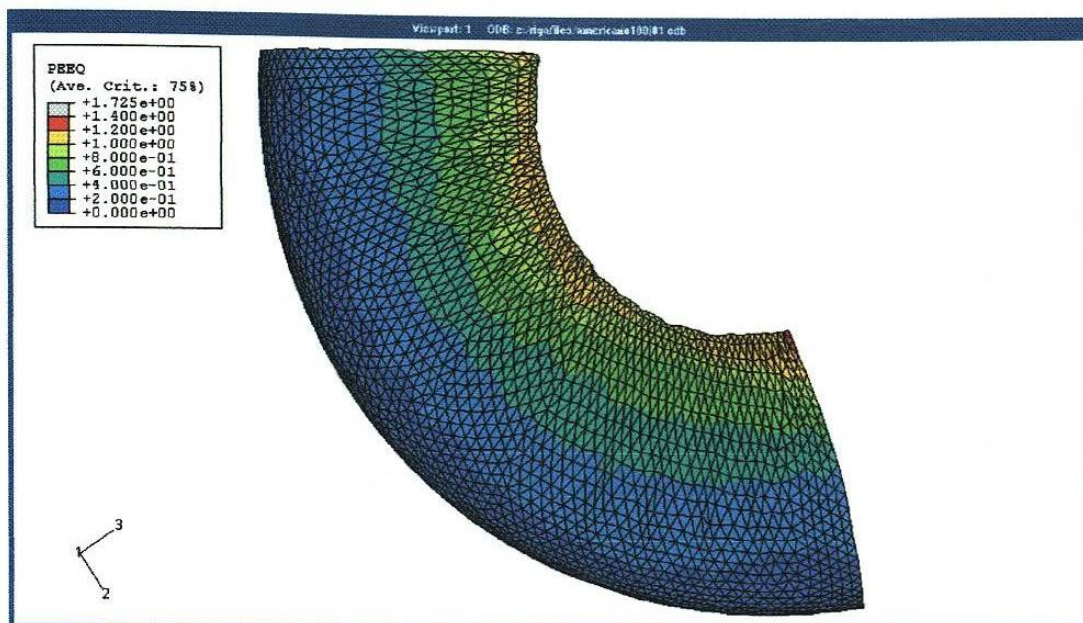
### ■ Deformación equivalente en Mandril01



### ■ Deformación equivalente en Mandril02



### ▪ Deformación equivalente en mandril03



### ▪ Deformación equivalente en mandril04

