





INTRODUCTION

Pipe Supports Group has developed a range of cryogenic products to meet the varying requirements of both the Piping and the Pipe Supporting Engineers. Our solutions provide options that satisfy the need of both specialists; a means to transfer the forces generated within the pipe into the surrounding structure that will not compromise the integrity of the insulation system.

Pipe Supports Group has been designing and manufacturing pipe hangers, restraints and associated equipment since 1968. We became involved in the design and development of cryogenic pipe supports in 2001 and have been instrumental in the development of the corporate standards of several major EPC's.

We have worked closely with chemical specialists to develop a range of chemicals that enable us to produce rigid high density polyurethane in densities ranging from 100 to 600kg/m³. The chemical is completely CFC and HCFC free and gives extremely low thermal conductivity combined with good compressive, flexural and tensile strength properties.

Our facility in Thailand is equipped with 4 modern high-pressure foam injection machines each equipped with an isocyanate tank and two polyol tanks enabling us to switch between densities very quickly ensuring maximum production flexibility.

Isolation vs Insulation: This discussion depends on your perspective; from the *Supporting* point of view these materials act as isolators because they separate the steel or concrete structure of the pipe support from the extreme temperatures of the pipe.

Low temperature causes normal carbon steel to become brittle and steels to withstand very low temperatures are expensive and sometimes difficult to process.

Freezing water expands and can cause serious damage to concrete structures if the concrete is not protected.

The use of a non-metallic material as a thermal break eliminates these problems and allows us to design the structure of the hanger for ambient temperature conditions thereby resulting in a more economic solution.

From the process engineer's perspective the need to insulate the pipe from the ambient temperature is often paramount to the viability of the process; localised breakdown of the insulation system can result in very high cost and disruption to the process.

The plant engineer however requires isolation from cold temperatures for personal protection, minimisation of condensation and the avoidance of structural damage.

The following extract from a spreadsheet compares the insulation and isolation performance of HD PUF with both glass reinforced composites and Densified Wood.



CRYOGENIC SUPPORTS

COMPARISON OF PROPERTIES:

Design Temp (°C)	Basic Data				GRE			HD PUF			Densified Wood		
	Pipe O/D (do)	Insu'n Thickness	Insu'n O/D (dn)	Dn/do	Thermal Resistance (R)	Heat Transfer Rate (q)	Surface Temp. (T2)	Thermal Resistance (R)	Heat Transfer Rate (q)	Surface Temp. (T2)	Thermal Resistance (R)	Heat Transfer Rate (q)	Surface Temp. (T2)
-190.0	26.9	50	126.9	4.717	0.15	-1378.63	1.76	0.71	-294.09	14.54	0.08	-2557.63	-12.12
-190.0	33.7	50	133.7	3.967	0.17	-1232.16	0.75	0.79	-263.95	14.30	0.09	-2275.55	-13.86
-190.0	42.4	50	142.4	3.358	0.19	-1107.76	-0.32	0.87	-238.35	14.06	0.10	-2036.14	-15.68
-190.0	48.3	50	148.3	3.070	0.20	-1046.78	-0.94	0.92	-225.81	13.91	0.11	-1918.83	-16.72
-190.0	60.3	50	160.3	2.658	0.22	-956.68	-1.99	1.00	-207.27	13.67	0.12	-1745.57	-18.48
-190.0	76.1	50	176.1	2.314	0.24	-878.25	-3.08	1.09	-191.15	13.41	0.13	-1594.83	-20.29
-190.0	88.9	50	188.9	2.125	0.25	-833.69	-3.80	1.14	-182.00	13.24	0.14	-1509.22	-21.46
-190.0	101.6	50	201.6	1.984	0.26	-799.79	-4.39	1.19	-175.03	13.10	0.14	-1444.12	-22.43
-190.0	114.3	50	214.3	1.875	0.27	-772.92	-4.90	1.23	-169.52	12.98	0.15	-1392.51	-23.26
-190.0	139.7	50	239.7	1.716	0.28	-732.94	-5.73	1.29	-161.31	12.78	0.16	-1315.76	-24.60
-190.0	168.3	50	268.3	1.594	0.30	-701.58	-6.45	1.34	-154.88	12.60	0.17	-1255.57	-25.76
-190.0	193.7	50	293.7	1.516	0.31	-681.08	-6.95	1.38	-150.68	12.48	0.17	-1216.24	-26.56
-190.0	219.1	50	319.1	1.456	0.31	-665.10	-7.37	1.41	-147.40	12.38	0.18	-1185.59	-27.23
-190.0	244.5	50	344.5	1.409	0.32	-652.29	-7.72	1.44	-144.78	12.29	0.18	-1161.02	-27.78
-190.0	273.0	50	373	1.366	0.32	-640.63	-8.05	1.46	-142.39	12.21	0.18	-1138.67	-28.30
-190.0	323.9	50	423.9	1.309	0.33	-624.72	-8.52	1.49	-139.14	12.09	0.19	-1108.16	-29.04
-190.0	355.6	50	455.6	1.281	0.34	-617.03	-8.76	1.51	-137.56	12.04	0.19	-1093.42	-29.41
-190.0	406.4	50	506.4	1.246	0.34	-607.13	-9.07	1.53	-135.54	11.96	0.19	-1074.43	-29.90
-190.0	457.0	50	557	1.219	0.35	-599.39	-9.32	1.55	-133.95	11.89	0.20	-1059.59	-30.30
-190.0	508.0	50	608	1.197	0.35	-593.10	-9.53	1.57	-132.67	11.84	0.20	-1047.55	-30.63
-190.0	610.0	50	710	1.164	0.36	-583.61	-9.86	1.59	-130.73	11.76	0.20	-1029.36	-31.13
-190.0	762.0	50	862	1.131	0.36	-574.09	-10.19	1.62	-128.78	11.68	0.21	-1011.12	-31.66
-190.0	914.0	50	1014	1.109	0.37	-567.68	-10.43	1.63	-127.47	11.62	0.21	-998.84	-32.02
-190.0	1016.0	50	1116	1.098	0.37	-564.44	-10.55	1.64	-126.81	11.59	0.21	-992.63	-32.20

From a purely thermal perspective it can be seen that the HD PUF is considerably better at insulating the pipe than either GRE or Densified Wood however mechanically HD PUF is not as strong as the other two materials.

The property that is not shown in the above table is the load carrying capacity; comparing GRE to HD PUF the allowable compressive load for GRE is approximately 7N/mm² whereas for HD PUF it is one-tenth that value at approximately 0.7N/mm². Densified Wood by comparison is capable of sustaining compressive stresses up to 58N/mm². Therefore it is clear that where good insulation is required and high loading is anticipated there has to be a compromise.

In highly loaded anchors and line stops it is often beneficial to incorporate a combination of both HD PUF and Densified Wood which allows acceptable insulation properties to be achieved and yet sustain very high loading.

The following photograph is of a line stop where the support has been fully fitted to a spool of pipe. This unit will be positioned and welded straight in to the main line pipe. Axial forces are transferred from the pipe via the flanges positioned each side of the insulation mouldings. The compressive force is transmitted through the PUF and is taken by a central flange welded to the inside of the cradle. The integrity of the insulation is maintained.



HIGH DENSITY POLYURETHANE SUPPORTS

Our High Density Polyurethane Supports utilise CFC free blowing agents in producing a moulded product with a very low isocyanurate index resulting in a virtually chloride-free composition.

Component parts are moulded to precise dimensions in steel moulds manufactured to accurate tolerances. Cylindrical components are monolithically moulded in 180° segments in layers to match the line insulation system.

Where conditions permit, we can also manufacture monolithically moulded components with machined steps to match up to the line insulation system. The benefit of this construction is found in the reduced installation requirements and the avoidance of having to apply expensive mastics and adhesives in the field. It should however be noted that for LNG services it is generally necessary to have a minimum of two layers of HD PUF.

CRYOGENIC SUPPORTS

THERMAL AND MECHANICAL PROPERTIES OF HD PUF MATERIALS

Testing has been carried out independently to determine the thermal conductivity, the density and the compressive strength of the HD PUF materials. Thermal conductivity was determined in accordance with ASTM C177 while density and compressive strength were determined in accordance with ASTM D1621.

The thermal conductivity at -165°C and compressive strength of the material, at 20°C were measured as follows

Density kg/m ³	Thermal Conductivity W/m.K	1% Compressive Modulus MPa	2% Compressive Modulus MPa	Ultimate Compressive Stress MPa	Recommended Design Stress MPa
160	0.0205	0.491	1.027	2.04	0.491
224	0.0267	0.8	1.8	4.44	0.8
320	0.0338	1.44	2.95	7.704	1.44
500	0.0372	3.15	6.69	15.54	3.15

DESIGN CONSIDERATIONS

Cryogenic pipe supports are required to perform three distinct functions -

- To support the pipe by restraining it against static and thermally generated forces.
- To isolate the pipe from the supporting structure.
- To maintain the thermal conditions within the pipe.

To carry out these functions effectively the support must combine strength with good thermal properties; high density polyurethane foam offers a good combination of both allowing for reasonably compact designs to be achieved.

Of primary importance is protection against the ingress of moisture, which if allowed to occur will cause a build up of ice around the pipe and a consequent break-down of the thermal insulation. Ultimately icing will lead to failure of the support.

Therefore consideration for providing a vapour seal, for layering of the insulation and for fit-up to line insulation must be given to ensure the thermal integrity of the support.

The table provides guidance for layering of the insulation material; it shall be confirmed with the insulation contractor in order to ensure compatibility between support and line insulation.

Where multi-layering is necessary, radial joints are staggered to avoid potential break-down of the vapour seal.

The vapour seal is provided by the correct selection and use of cryogenic adhesives, sealant mastics and the application of a proprietary vapour barrier of the following types —

Insulation Thickness (mm)	Layer Construction (mm)
25	25
30	30
40	40
50	50
60	30/30
70	30/40
80	40/40
90	50/40
100	50/50
110	50/60
120	30/40/50
130	30/50/50
140	40/50/50
150	50/50/50
160	50/60/50
170	50/70/50
180	50/80/50
190	50/90/50
200	50/100/50
210	50/50/60/50
220	50/50/70/50
230	50/50/80/50
240	50/50/90/50
250	50/50/100/50

Cryogenic Adhesive selected for the range of operating temperatures.

Sealant Mastic used to prevent ingress of moisture at joints and edges.

Foil vapour barrier, applied to the external surface of the insulation to provide primary resistance to moisture ingress.

All exposed surfaces of HD PUF where the high density skin has been removed are coated with sealant mastic to prevent damage by moisture ingress during the installation phase.

Protection of the vapour barrier is provided by the use of a suitable thin gauge steel or aluminium wrap.

Materials such as aluminium sheet 0.4-0.8mm thick, stainless steel sheet 0.6-0.8mm thick or various grades of coated carbon steel are suitable for this purpose and are usually dictated by the main insulation specification.

It is common practice for the layers of insulation in the lower half of the support to be factory bonded together. In order to ensure optimum 'fit-up' to pipe we use only a narrow strip of adhesive along the length of the PUF between each layer. This enables the multi-layered cradle to behave like a 'leaf-spring' and flex to accommodate any irregularities in both the pipe and cradle shape.

Please refer to the explanation of this further on in this text.

CRYOGENIC SUPPORTS

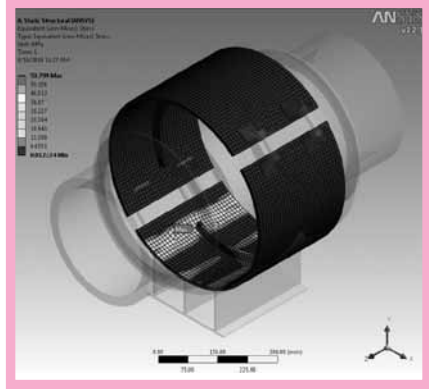
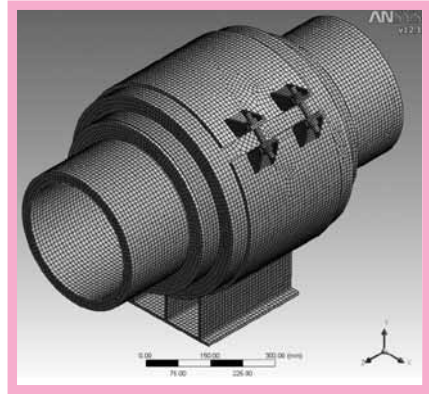
HD PUF is supplied in the following densities —

Pipe Size (NB)	Lower Cradle (kg/m ³)	Upper Cradle (kg/m ³) Resting type	Upper Cradle (kg/m ³) Line Stops and Anchors
Up to 150	160 (Natural)	160	160
200 to 600	224 (Red)	160	224
Over 600	320 (Green)	160	320
Special Needs	500 (Natural)	500	500

The different densities are coloured to allow easy identification at site. Layers are stepped in length by a minimum of 25mm (not more than 60mm) both circumferentially and longitudinally to allow fit-up to line insulation.

With regard to load capacities of foam components, consideration must be given to all forces being exerted on the pipe support and the respective bearing areas of either the pipe/foam interface or the foam/clamp interface. The allowable design stresses suggested in the previous text have been used to generate the load capacity and thermal tables that follow.

For special supports, line stops and anchors we utilize ANSYS finite element analysis to help us provide the optimum solution.



CRYOGENIC SUPPORTS

OUTSIDE DIAMETER OF INSULATION INSERTS

Insulation Thickness		25	30	40	50	60	70	80	90	100	110	120	130
Pipe O/D	No. Layers	1	1	1	1	2	2	2	2	2	2	3	3
21.3	15NB	71.3	81.3	101.3	121.3	141.3	161.3	181.3	201.3	221.3	241.3	261.3	281.3
26.9	20NB	76.9	86.9	106.9	126.9	146.9	166.9	186.9	206.9	226.9	246.9	266.9	286.9
33.7	25NB	83.7	93.7	113.7	133.7	153.7	173.7	193.7	213.7	233.7	253.7	273.7	293.7
42.4	32NB	92.4	102.4	122.4	142.4	162.4	182.4	202.4	222.4	242.4	262.4	282.4	302.4
48.3	40NB	98.3	108.3	128.3	148.3	168.3	188.3	208.3	228.3	248.3	268.3	288.3	308.3
60.3	50NB	110.3	120.3	140.3	160.3	180.3	200.3	220.3	240.3	260.3	280.3	300.3	320.3
76.1	65NB	126.1	136.1	156.1	176.1	196.1	216.1	236.1	256.1	276.1	296.1	316.1	336.1
88.9	80NB	138.9	148.9	168.9	188.9	208.9	228.9	248.9	268.9	288.9	308.9	328.9	348.9
114.3	100NB	164.3	174.3	194.3	214.3	234.3	254.3	274.3	294.3	314.3	334.3	354.3	374.3
139.7	125NB	189.7	199.7	219.7	239.7	259.7	279.7	299.7	319.7	339.7	359.7	379.7	399.7
168.3	150NB	218.3	228.3	248.3	268.3	288.3	308.3	328.3	348.3	368.3	388.3	408.3	428.3
193.7	175NB	243.7	253.7	273.7	293.7	313.7	333.7	353.7	373.7	393.7	413.7	433.7	453.7
219.1	200NB	269.1	279.1	299.1	319.1	339.1	359.1	379.1	399.1	419.1	439.1	459.1	479.1
244.5	225NB	294.5	304.5	324.5	344.5	364.5	384.5	404.5	424.5	444.5	464.5	484.5	504.5
273	250NB	323	333	353	373	393	413	433	453	473	493	513	533
323.9	300NB	373.9	383.9	403.9	423.9	443.9	463.9	483.9	503.9	523.9	543.9	563.9	583.9
355.6	350NB	405.6	415.6	435.6	455.6	475.6	495.6	515.6	535.6	555.6	575.6	595.6	615.6
406.4	400NB	456.4	466.4	486.4	506.4	526.4	546.4	566.4	586.4	606.4	626.4	646.4	666.4
457	450NB	507	517	537	557	577	597	617	637	657	677	697	717
508	500NB	558	568	588	608	628	648	668	688	708	728	748	768
559	550NB	609	619	639	659	679	699	719	739	759	779	799	819
610	600NB	660	670	690	710	730	750	770	790	810	830	850	870
660	650NB	710	720	740	760	780	800	820	840	860	880	900	920
711.2	700NB	761.2	771.2	791.2	811.2	831.2	851.2	871.2	891.2	911.2	931.2	951.2	971.2
762	750NB	812	822	842	862	882	902	922	942	962	982	1002	1022
813	800NB	863	873	893	913	933	953	973	993	1013	1033	1053	1073
864	850NB	914	924	944	964	984	1004	1024	1044	1064	1084	1104	1124
914	900NB	964	974	994	1014	1034	1054	1074	1094	1114	1134	1154	1174
965.2	950NB	1015	1025	1045	1065	1085	1105	1125	1145	1165	1185	1205	1225
1016	1000NB	1066	1076	1096	1116	1136	1156	1176	1196	1216	1236	1256	1276
1067	1050NB	1117	1127	1147	1167	1187	1207	1227	1247	1267	1287	1307	1327
1219	1200NB	1269	1279	1299	1319	1339	1359	1379	1399	1419	1439	1459	1479
1422	1400NB	1472	1482	1502	1522	1542	1562	1582	1602	1622	1642	1662	1682
1626	1600NB	1676	1686	1706	1726	1746	1766	1786	1806	1826	1846	1866	1886

NB. The inside diameter of the PUF insulation is moulded within the following limits –

$$(\text{Pipe Outside Diameter} \times 101\%) + 3\text{mm}/-0\text{mm}$$

To compensate for gaps between pipe and PUF we provide a clearance at the longitudinal joint as follows –

Pipe O/D < 355.6mm	Clearance = 6mm
323.9 < Pipe O/D < 660mm	Clearance = 9mm
610 < Pipe O/D < 1016mm	Clearance = 12mm
Pipe O/D > 914mm	Clearance = 20mm

CRYOGENIC SUPPORTS

OUTSIDE DIAMETER OF INSULATION INSERTS:

Insulation Thickness		140	150	160	170	180	190	200	210	220	230	240	250
Pipe O/D	No. Layers	3	3	3	3	3	3	3	4	4	4	4	4
21.3	15NB	301.3	321.3	341.3	361.3	381.3	401.3	421.3	441.3	461.3	481.3	501.3	521.3
26.9	20NB	306.9	326.9	346.9	366.9	386.9	406.9	426.9	446.9	466.9	486.9	506.9	526.9
33.7	25NB	313.7	333.7	353.7	373.7	393.7	413.7	433.7	453.7	473.7	493.7	513.7	533.7
42.4	32NB	322.4	342.4	362.4	382.4	402.4	422.4	442.4	462.4	482.4	502.4	522.4	542.4
48.3	40NB	328.3	348.3	368.3	388.3	408.3	428.3	448.3	468.3	488.3	508.3	528.3	548.3
60.3	50NB	340.3	360.3	380.3	400.3	420.3	440.3	460.3	480.3	500.3	520.3	540.3	560.3
76.1	65NB	356.1	376.1	396.1	416.1	436.1	456.1	476.1	496.1	516.1	536.1	556.1	576.1
88.9	80NB	368.9	388.9	408.9	428.9	448.9	468.9	488.9	508.9	528.9	548.9	568.9	588.9
114.3	100NB	394.3	414.3	434.3	454.3	474.3	494.3	514.3	534.3	554.3	574.3	594.3	614.3
139.7	125NB	419.7	439.7	459.7	479.7	499.7	519.7	539.7	559.7	579.7	599.7	619.7	639.7
168.3	150NB	448.3	468.3	488.3	508.3	528.3	548.3	568.3	588.3	608.3	628.3	648.3	668.3
193.7	175NB	473.7	493.7	513.7	533.7	553.7	573.7	593.7	613.7	633.7	653.7	673.7	693.7
219.1	200NB	499.1	519.1	539.1	559.1	579.1	599.1	619.1	639.1	659.1	679.1	699.1	719.1
244.5	225NB	524.5	544.5	564.5	584.5	604.5	624.5	644.5	664.5	684.5	704.5	724.5	744.5
273	250NB	553	573	593	613	633	653	673	693	713	733	753	773
323.9	300NB	603.9	623.9	643.9	663.9	683.9	703.9	723.9	743.9	763.9	783.9	803.9	823.9
355.6	350NB	635.6	655.6	675.6	695.6	715.6	735.6	755.6	775.6	795.6	815.6	835.6	855.6
406.4	400NB	686.4	706.4	726.4	746.4	766.4	786.4	806.4	826.4	846.4	866.4	886.4	906.4
457	450NB	737	757	777	797	817	837	857	877	897	917	937	957
508	500NB	788	808	828	848	868	888	908	928	948	968	988	1008
559	550NB	839	859	879	899	919	939	959	979	999	1019	1039	1059
610	600NB	890	910	930	950	970	990	1010	1030	1050	1070	1090	1110
660	650NB	940	960	980	1000	1020	1040	1060	1080	1100	1120	1140	1160
711.2	700NB	991.2	1011	1031	1051	1071	1091	1111	1131	1151	1171	1191	1211
762	750NB	1042	1062	1082	1102	1122	1142	1162	1182	1202	1222	1242	1262
813	800NB	1093	1113	1133	1153	1173	1193	1213	1233	1253	1273	1293	1313
864	850NB	1144	1164	1184	1204	1224	1244	1264	1284	1304	1324	1344	1364
914	900NB	1194	1214	1234	1254	1274	1294	1314	1334	1354	1374	1394	1414
965.2	950NB	1245	1265	1285	1305	1325	1345	1365	1385	1405	1425	1465	1485
1016	1000NB	1296	1316	1336	1356	1376	1396	1416	1436	1456	1476	1496	1516
1067	1050NB	1347	1367	1387	1407	1427	1447	1467	1487	1507	1527	1547	1567
1219	1200NB	1499	1519	1539	1559	1579	1599	1619	1639	1659	1679	1699	1719
1422	1400NB	1702	1722	1742	1762	1782	1802	1822	1842	1862	1882	1902	1922
1626	1600NB	1906	1926	1946	1966	1986	2006	2026	2046	2066	2086	2106	2126

NB. The inside diameter of the PUF insulation is moulded within the following limits –

(Pipe Outside Diameter x 101%) +3mm/0mm

To compensate for gaps between pipe and PUF we provide a clearance at the longitudinal joint as follows –

Pipe O/D < 355.6mm	Clearance = 6mm
323.9 < Pipe O/D < 660mm	Clearance = 9mm
610 < Pipe O/D < 1016mm	Clearance = 12mm
Pipe O/D > 914mm	Clearance = 20mm

CRYOGENIC SUPPORTS

INSULATION THICKNESS SELECTION CHARTS

Insul. Thick	25	30	40	50	60	70	80	90	100	110	120	130
Pipe O/D (do)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)
26.9	9.76	11.41	13.40	14.54	15.26	15.75	16.10	16.37	16.58	16.74	16.87	16.98
33.7	9.28	11.01	13.10	14.30	15.07	15.59	15.97	16.26	16.48	16.65	16.80	16.92
42.4	8.79	10.59	12.79	14.06	14.87	15.43	15.83	16.14	16.37	16.56	16.71	16.84
48.3	8.53	10.36	12.61	13.91	14.75	15.33	15.75	16.06	16.31	16.50	16.66	16.79
60.3	8.09	9.98	12.31	13.67	14.55	15.16	15.60	15.93	16.19	16.40	16.57	16.71
76.1	7.65	9.59	12.00	13.41	14.33	14.97	15.44	15.79	16.07	16.29	16.47	16.62
88.9	7.38	9.35	11.79	13.24	14.19	14.85	15.33	15.70	15.98	16.21	16.40	16.56
101.6	7.17	9.15	11.63	13.10	14.06	14.74	15.23	15.61	15.91	16.15	16.34	16.50
114.3	6.99	8.98	11.49	12.98	13.96	14.65	15.15	15.54	15.84	16.09	16.28	16.45
139.7	6.70	8.72	11.26	12.78	13.78	14.49	15.01	15.41	15.73	15.98	16.19	16.36
168.3	6.47	8.50	11.06	12.60	13.63	14.35	14.89	15.30	15.62	15.89	16.10	16.28
193.7	6.31	8.34	10.92	12.48	13.51	14.25	14.79	15.21	15.55	15.81	16.04	16.22
219.1	6.18	8.22	10.81	12.38	13.42	14.16	14.72	15.14	15.48	15.75	15.98	16.17
244.5	6.07	8.12	10.72	12.29	13.34	14.09	14.65	15.08	15.42	15.70	15.93	16.12
273.0	5.97	8.02	10.63	12.21	13.27	14.02	14.59	15.02	15.37	15.65	15.88	16.07
323.9	5.84	7.89	10.50	12.09	13.16	13.92	14.49	14.93	15.28	15.57	15.81	16.00
355.6	5.77	7.82	10.44	12.04	13.10	13.87	14.44	14.89	15.24	15.53	15.77	15.97
406.4	5.68	7.74	10.36	11.96	13.03	13.80	14.38	14.82	15.18	15.47	15.71	15.92
457.0	5.61	7.67	10.29	11.89	12.97	13.74	14.32	14.77	15.13	15.43	15.67	15.87
508.0	5.56	7.61	10.24	11.84	12.92	13.70	14.28	14.73	15.09	15.39	15.63	15.84
610.0	5.47	7.53	10.15	11.76	12.84	13.62	14.20	14.66	15.02	15.32	15.57	15.78
762.0	5.38	7.44	10.07	11.68	12.76	13.54	14.13	14.59	14.95	15.25	15.50	15.71
914.0	5.32	7.38	10.01	11.62	12.70	13.48	14.07	14.53	14.90	15.20	15.45	15.67
965.2	5.30	7.36	9.99	11.60	12.69	13.47	14.06	14.52	14.89	15.19	15.44	15.65
1016.0	5.29	7.34	9.98	11.59	12.67	13.46	14.05	14.51	14.87	15.18	15.43	15.64
1066.8	5.28	7.33	9.96	11.57	12.66	13.44	14.03	14.49	14.86	15.17	15.42	15.63
1219.2	5.24	7.30	9.93	11.54	12.63	13.41	14.00	14.46	14.83	15.14	15.39	15.60
1422.4	5.21	7.26	9.89	11.51	12.59	13.38	13.97	14.43	14.80	15.11	15.36	15.57
1625.6	5.18	7.24	9.87	11.48	12.57	13.35	13.94	14.41	14.78	15.08	15.34	15.55

Ambient Temperature T_m = 18°C, Fluid Temperature = -190°C, Medium Emissivity (f = 8W/m²K)
 Wind Velocity = 3m/second

The above data is applicable to cylindrical insulation and is based upon the following formulae

$$\text{Thermal Resistance } R(\text{m}^2\text{K/W}) = d_o / (f \cdot d_n) + \{ (d_o / k) \cdot \ln(d_o / d_n) \times 10^{-3} \}$$

$$\text{Rate of Heat Transfer } q(\text{W/m}^2) = (T_1 - T_m) \cdot R$$

$$\text{Surface Temperature } T_2(\text{°C}) = T_m + \{ q \cdot d_o / (f \cdot d_n) \}$$

- Where
- d_o = Pipe O/Dia.
 - d_n = Insulation O/Dia.
 - T₁ = Pipe Temperature.
 - T_m = The ambient temperature of the air.
 - T₂ = Surface temperature of the insulation.

CRYOGENIC SUPPORTS

INSULATION THICKNESS SELECTION CHARTS

Insul. Thick	140	150	160	170	180	190	200	210	220	230	240	250
Pipe O/D (do)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)
26.9	17.08	17.15	17.22	17.28	17.33	17.37	17.41	17.45	17.48	17.51	17.54	17.56
33.7	17.01	17.10	17.17	17.23	17.29	17.33	17.38	17.41	17.45	17.48	17.51	17.53
42.4	16.95	17.04	17.11	17.18	17.24	17.29	17.33	17.37	17.41	17.44	17.47	17.50
48.3	16.90	17.00	17.08	17.15	17.21	17.26	17.31	17.35	17.39	17.42	17.45	17.48
60.3	16.83	16.93	17.01	17.09	17.15	17.21	17.26	17.31	17.35	17.38	17.42	17.45
76.1	16.75	16.85	16.94	17.02	17.09	17.15	17.21	17.26	17.30	17.34	17.38	17.41
88.9	16.69	16.80	16.89	16.98	17.05	17.11	17.17	17.22	17.27	17.31	17.35	17.38
101.6	16.64	16.75	16.85	16.94	17.01	17.08	17.14	17.19	17.24	17.28	17.32	17.35
114.3	16.59	16.71	16.81	16.90	16.98	17.05	17.11	17.16	17.21	17.25	17.29	17.33
139.7	16.51	16.63	16.74	16.83	16.92	16.99	17.05	17.11	17.16	17.21	17.25	17.29
168.3	16.43	16.56	16.68	16.77	16.86	16.93	17.00	17.06	17.12	17.17	17.21	17.25
193.7	16.38	16.51	16.63	16.73	16.81	16.89	16.96	17.02	17.08	17.13	17.18	17.22
219.1	16.33	16.46	16.58	16.68	16.78	16.86	16.93	16.99	17.05	17.10	17.15	17.19
244.5	16.28	16.42	16.54	16.65	16.74	16.82	16.90	16.96	17.02	17.07	17.12	17.17
273.0	16.24	16.38	16.50	16.61	16.71	16.79	16.86	16.93	16.99	17.05	17.10	17.14
323.9	16.17	16.32	16.44	16.55	16.65	16.74	16.82	16.89	16.95	17.00	17.06	17.10
355.6	16.14	16.29	16.41	16.53	16.62	16.71	16.79	16.86	16.92	16.98	17.03	17.08
406.4	16.09	16.24	16.37	16.48	16.58	16.67	16.75	16.82	16.89	16.95	17.00	17.05
457.0	16.05	16.20	16.33	16.45	16.55	16.64	16.72	16.79	16.86	16.92	16.97	17.02
508.0	16.01	16.17	16.30	16.42	16.52	16.61	16.69	16.77	16.83	16.90	16.95	17.00
610.0	15.96	16.11	16.25	16.37	16.47	16.56	16.65	16.72	16.79	16.85	16.91	16.96
762.0	15.90	16.05	16.19	16.31	16.42	16.51	16.60	16.67	16.74	16.81	16.86	16.92
914.0	15.85	16.01	16.14	16.27	16.37	16.47	16.56	16.63	16.71	16.77	16.83	16.88
965.2	15.84	15.99	16.13	16.25	16.36	16.46	16.55	16.62	16.69	16.76	16.82	16.87
1016.0	15.83	15.98	16.12	16.24	16.35	16.45	16.54	16.61	16.68	16.75	16.81	16.86
1066.8	15.81	15.97	16.11	16.23	16.34	16.44	16.53	16.60	16.68	16.74	16.80	16.86
1219.2	15.79	15.95	16.09	16.21	16.32	16.41	16.50	16.58	16.65	16.72	16.78	16.83
1422.4	15.76	15.92	16.06	16.18	16.29	16.39	16.48	16.56	16.63	16.69	16.75	16.81
1625.6	15.74	15.90	16.04	16.16	16.27	16.37	16.46	16.54	16.61	16.67	16.74	16.79

Ambient Temperature T_m = 18°C, Fluid Temperature = -190°C, Medium Emissivity (f = 8W/m²K)
 Wind Velocity = 3m/second

Surface Coefficient (f W/m²K) is dependent upon the emissivity of the outer surface of the insulation and can be approximated as follows —

Wind Speed	Still Air	3m/sec	10m/sec
Low Emissivity — Bright metal, polished aluminium.	5.7	15.5	36
Medium Emissivity — Zinc / aluminium coated or galvanised steel.	8	18	38
High Emissivity — Matt black surfaces, plastic coated metals.	10	20	40

The above data is applicable to cylindrical insulation and is based upon the following formulae

$$\text{Thermal Resistance } R(m^2/KW) = d_o / (f \cdot d_n) + \{ (d_o / k) \cdot \ln(d_o / d_n) \times 10^{-3} \}$$

$$\text{Rate of Heat Transfer } q(W/m^2) = (T_1 - T_m) \cdot R$$

$$\text{Surface Temperature } T_2(°C) = T_m + \{ q \cdot d_o / (f \cdot d_n) \}$$

Where d_o = Pipe O/Dia.
 d_n = Insulation O/Dia.
 T₁ = Pipe Temperature.
 T_m = The ambient temperature of the air.
 T₂ = Surface temperature of the insulation.

CRYOGENIC SUPPORTS

INSULATION THICKNESS SELECTION CHARTS

Insul. Thick	25	30	40	50	60	70	80	90	100	110	120	130
Pipe O/D (do)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)
26.9	15.76	17.22	19.27	20.44	21.18	21.68	22.05	22.32	22.54	22.70	22.84	22.95
33.7	15.28	16.81	18.96	20.20	20.98	21.52	21.91	22.21	22.44	22.62	22.76	22.88
42.4	14.79	16.38	18.64	19.94	20.78	21.35	21.77	22.08	22.33	22.52	22.68	22.81
48.3	14.53	16.14	18.46	19.80	20.66	21.25	21.68	22.01	22.26	22.46	22.62	22.76
60.3	14.09	15.75	18.14	19.54	20.45	21.07	21.53	21.87	22.14	22.36	22.53	22.67
76.1	13.65	15.35	17.82	19.28	20.22	20.88	21.36	21.73	22.01	22.24	22.43	22.58
88.9	13.38	15.10	17.62	19.10	20.08	20.75	21.25	21.63	21.93	22.16	22.35	22.52
101.6	13.17	14.89	17.44	18.96	19.95	20.64	21.16	21.54	21.85	22.09	22.29	22.46
114.3	12.99	14.72	17.30	18.83	19.84	20.55	21.07	21.47	21.78	22.03	22.24	22.41
139.7	12.70	14.45	17.06	18.63	19.66	20.39	20.93	21.34	21.66	21.92	22.14	22.32
168.3	12.47	14.22	16.86	18.45	19.50	20.24	20.80	21.22	21.56	21.82	22.05	22.23
193.7	12.31	14.06	16.72	18.32	19.39	20.14	20.70	21.13	21.48	21.75	21.98	22.17
219.1	12.18	13.94	16.60	18.21	19.29	20.05	20.62	21.06	21.41	21.69	21.92	22.11
244.5	12.07	13.83	16.51	18.13	19.21	19.98	20.55	21.00	21.35	21.63	21.87	22.07
273.0	11.97	13.73	16.42	18.04	19.13	19.91	20.49	20.94	21.29	21.58	21.82	22.02
323.9	11.84	13.60	16.29	17.92	19.02	19.80	20.39	20.84	21.21	21.50	21.74	21.95
355.6	11.77	13.53	16.22	17.86	18.96	19.75	20.34	20.80	21.16	21.46	21.70	21.91
406.4	11.68	13.44	16.14	17.78	18.89	19.68	20.27	20.73	21.10	21.40	21.65	21.86
457.0	11.61	13.37	16.07	17.72	18.83	19.62	20.22	20.68	21.05	21.35	21.60	21.81
508.0	11.56	13.31	16.01	17.66	18.77	19.57	20.17	20.64	21.01	21.31	21.56	21.78
610.0	11.47	13.22	15.93	17.58	18.69	19.49	20.10	20.56	20.94	21.25	21.50	21.72
762.0	11.38	13.13	15.84	17.49	18.61	19.41	20.02	20.49	20.87	21.17	21.43	21.65
914.0	11.32	13.07	15.78	17.43	18.55	19.35	19.96	20.43	20.81	21.12	21.38	21.60
965.2	11.30	13.05	15.76	17.42	18.53	19.34	19.95	20.42	20.80	21.11	21.37	21.59
1016.0	11.29	13.04	15.74	17.40	18.52	19.32	19.93	20.40	20.78	21.10	21.35	21.57
1066.8	11.28	13.02	15.73	17.39	18.51	19.31	19.92	20.39	20.77	21.08	21.34	21.56
1219.2	11.24	12.99	15.70	17.35	18.47	19.28	19.89	20.36	20.74	21.05	21.31	21.53
1422.4	11.21	12.95	15.66	17.32	18.44	19.24	19.85	20.33	20.71	21.02	21.28	21.50
1625.6	11.18	12.93	15.63	17.29	18.41	19.22	19.83	20.30	20.68	21.00	21.26	21.48

Ambient Temperature T_m = 24°C, Fluid Temperature = -190°C, Medium Emissivity (f = 8W/m²K)
 Wind Velocity = 3m/second

The above data is applicable to cylindrical insulation and is based upon the following formulae

$$\text{Thermal Resistance } R(\text{m}^2\text{K/W}) = d_o / (f \cdot d_n) + \{ (d_o / k) \cdot \ln(d_o / d_n) \times 10^{-3} \}$$

$$\text{Rate of Heat Transfer } q(\text{W/m}^2) = (T_1 - T_m) \cdot R$$

$$\text{Surface Temperature } T_2(\text{°C}) = T_m + \{ q \cdot d_o / (f \cdot d_n) \}$$

Where
 d_o = Pipe O/Dia.
 d_n = Insulation O/Dia.
 T₁ = Pipe Temperature.
 T_m = The ambient temperature of the air.

CRYOGENIC SUPPORTS

INSULATION THICKNESS SELECTION CHARTS

Insul. Thick	140	150	160	170	180	190	200	210	220	230	240	250
Pipe O/D (do)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)
26.9	23.05	23.13	23.20	23.26	23.31	23.36	23.40	23.43	23.47	23.50	23.52	23.55
33.7	22.99	23.07	23.15	23.21	23.27	23.31	23.36	23.40	23.43	23.46	23.49	23.52
42.4	22.91	23.01	23.09	23.16	23.22	23.27	23.31	23.36	23.39	23.43	23.46	23.49
48.3	22.87	22.97	23.05	23.12	23.18	23.24	23.29	23.33	23.37	23.41	23.44	23.47
60.3	22.80	22.90	22.99	23.06	23.13	23.19	23.24	23.29	23.33	23.37	23.40	23.43
76.1	22.71	22.82	22.91	23.00	23.07	23.13	23.19	23.24	23.28	23.32	23.36	23.39
88.9	22.65	22.76	22.86	22.95	23.02	23.09	23.15	23.20	23.25	23.29	23.33	23.36
101.6	22.60	22.72	22.82	22.91	22.98	23.05	23.11	23.17	23.22	23.26	23.30	23.34
114.3	22.56	22.67	22.78	22.87	22.95	23.02	23.08	23.14	23.19	23.23	23.27	23.31
139.7	22.47	22.59	22.71	22.80	22.89	22.96	23.03	23.09	23.14	23.19	23.23	23.27
168.3	22.39	22.52	22.64	22.74	22.83	22.90	22.97	23.04	23.09	23.14	23.19	23.23
193.7	22.33	22.47	22.59	22.69	22.78	22.86	22.93	23.00	23.05	23.11	23.15	23.20
219.1	22.28	22.42	22.54	22.65	22.74	22.82	22.90	22.96	23.02	23.08	23.12	23.17
244.5	22.23	22.38	22.50	22.61	22.70	22.79	22.86	22.93	22.99	23.05	23.10	23.14
273.0	22.19	22.33	22.46	22.57	22.67	22.75	22.83	22.90	22.96	23.02	23.07	23.12
323.9	22.12	22.27	22.40	22.51	22.61	22.70	22.78	22.85	22.92	22.98	23.03	23.08
355.6	22.08	22.24	22.37	22.48	22.58	22.67	22.75	22.83	22.89	22.95	23.01	23.05
406.4	22.04	22.19	22.32	22.44	22.54	22.63	22.72	22.79	22.86	22.92	22.97	23.02
457.0	21.99	22.15	22.28	22.40	22.51	22.60	22.68	22.76	22.83	22.89	22.94	23.00
508.0	21.96	22.11	22.25	22.37	22.48	22.57	22.66	22.73	22.80	22.86	22.92	22.97
610.0	21.90	22.06	22.20	22.32	22.43	22.52	22.61	22.69	22.76	22.82	22.88	22.93
762.0	21.83	22.00	22.14	22.26	22.37	22.47	22.55	22.63	22.71	22.77	22.83	22.89
914.0	21.79	21.95	22.09	22.22	22.33	22.43	22.51	22.60	22.67	22.73	22.79	22.85
965.2	21.77	21.94	22.08	22.20	22.32	22.41	22.50	22.58	22.66	22.72	22.78	22.84
1016.0	21.76	21.93	22.07	22.19	22.30	22.40	22.49	22.57	22.65	22.71	22.77	22.83
1066.8	21.75	21.91	22.06	22.18	22.29	22.39	22.48	22.56	22.64	22.70	22.77	22.82
1219.2	21.72	21.89	22.03	22.16	22.27	22.37	22.46	22.54	22.61	22.68	22.74	22.80
1422.4	21.69	21.86	22.00	22.13	22.24	22.34	22.43	22.51	22.59	22.66	22.72	22.78
1625.6	21.67	21.83	21.98	22.11	22.22	22.32	22.41	22.49	22.57	22.64	22.70	22.76

Ambient Temperature T_m = 24°C, Fluid Temperature = -190°C, Medium Emissivity (f = 8W/m²K)
 Wind Velocity = 3m/second

The above data is applicable to cylindrical insulation and is based upon the following formulae

$$\text{Thermal Resistance } R(\text{m}^2\text{K}/\text{W}) = d_o / (f \cdot d_n) + \{ (d_o / k) \cdot \ln(d_o / d_n) \times 10^{-3} \}$$

$$\text{Rate of Heat Transfer } q(\text{W}/\text{m}^2) = (T_1 - T_m) \cdot R$$

$$\text{Surface Temperature } T_2(\text{°C}) = T_m + \{ q \cdot d_o / (f \cdot d_n) \}$$

- Where
- d_o = Pipe O/Dia.
 - d_n = Insulation O/Dia.
 - T₁ = Pipe Temperature.
 - T_m = The ambient temperature of the air.
 - T₂ = Surface temperature of the insulation.

CRYOGENIC SUPPORTS

INSULATION THICKNESS SELECTION CHARTS

Insul. Thick	25	30	40	50	60	70	80	90	100	110	120	130
Pipe O/D (do)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)
26.9	9.76	14.07	15.26	15.94	16.36	16.66	16.87	17.03	17.15	17.25	17.33	17.39
33.7	9.28	13.83	15.08	15.60	16.25	16.57	16.79	16.96	17.09	17.20	17.28	17.35
42.4	8.79	13.59	14.89	15.65	16.13	16.47	16.71	16.89	17.03	17.14	17.23	17.31
48.3	8.53	13.45	14.79	15.56	16.06	16.41	16.66	16.85	16.99	17.11	17.20	17.28
60.3	8.09	13.22	14.61	15.42	15.94	16.30	16.57	16.77	16.92	17.05	17.15	17.23
76.1	7.65	12.99	14.42	15.26	15.81	16.19	16.47	16.68	16.85	16.98	17.09	17.18
88.9	7.38	12.84	14.30	15.16	15.73	16.12	16.41	16.63	16.80	16.93	17.05	17.14
101.6	7.17	12.72	14.20	15.08	15.65	16.06	16.35	16.58	16.75	16.89	17.01	17.11
114.3	6.99	12.62	14.12	15.01	15.59	16.00	16.30	16.53	16.71	16.86	16.98	17.08
139.7	6.70	12.47	13.98	14.89	15.49	15.91	16.22	16.46	16.65	16.80	16.92	17.02
168.3	6.47	12.33	13.86	14.78	15.39	15.82	16.14	16.39	16.58	16.74	16.87	16.98
193.7	6.31	12.24	13.78	14.71	15.33	15.76	16.09	16.34	16.54	16.70	16.83	16.94
219.1	6.18	12.17	13.71	14.65	15.27	15.71	16.04	16.30	16.50	16.66	16.79	16.91
244.5	6.07	12.11	13.66	14.60	15.22	15.67	16.00	16.26	16.46	16.63	16.77	16.88
273.0	5.97	12.05	13.61	14.55	15.18	15.63	15.96	16.22	16.43	16.60	16.74	16.85
323.9	5.84	11.97	13.53	14.48	15.11	15.57	15.91	16.17	16.38	16.55	16.69	16.81
355.6	5.77	11.93	13.49	14.44	15.08	15.54	15.88	16.14	16.35	16.53	16.67	16.79
406.4	5.68	11.88	13.44	14.40	15.04	15.50	15.84	16.11	16.32	16.49	16.64	16.76
457.0	5.61	11.84	13.41	14.36	15.00	15.46	15.81	16.08	16.29	16.47	16.61	16.73
508.0	5.56	11.81	13.37	14.33	14.97	15.43	15.78	16.05	16.27	16.44	16.59	16.71
610.0	5.47	11.76	13.32	14.28	14.93	15.39	15.74	16.01	16.23	16.40	16.55	16.68
762.0	5.38	11.70	13.27	14.23	14.88	15.34	15.69	15.96	16.18	16.36	16.51	16.64
914.0	5.32	11.67	13.23	14.19	14.84	15.31	15.66	15.93	16.15	16.33	16.48	16.61
965.2	5.30	11.66	13.22	14.18	14.83	15.30	15.65	15.92	16.14	16.32	16.47	16.60
1016.0	5.29	11.65	13.22	14.18	14.82	15.29	15.64	15.92	16.14	16.32	16.47	16.59
1066.8	5.28	11.64	13.21	14.17	14.82	15.28	15.64	15.91	16.13	16.31	16.46	16.59
1219.2	5.24	11.62	13.19	14.15	14.80	15.26	15.62	15.89	16.11	16.29	16.44	16.57
1422.4	5.21	11.60	13.17	14.13	14.78	15.24	15.60	15.87	16.09	16.27	16.43	16.55
1625.6	5.18	11.58	13.15	14.11	14.76	15.23	15.58	15.86	16.08	16.26	16.41	16.54

Ambient Temperature T_m = 18°C, Fluid Temperature = -106°C, Medium Emissivity (f = 8W/m²K)
 Wind Velocity = 3m/second

The above data is applicable to cylindrical insulation and is based upon the following formulae

$$\text{Thermal Resistance } R(\text{m}^2\text{K/W}) = d_o / (f \cdot d_n) + \{ (d_o / k) \cdot \ln(d_o / d_n) \times 10^{-3} \}$$

$$\text{Rate of Heat Transfer } q(\text{W/m}^2) = (T_1 - T_m) \cdot R$$

$$\text{Surface Temperature } T_2(^\circ\text{C}) = T_m + \{ q \cdot d_o / (f \cdot d_n) \}$$

- Where
- d_o = Pipe O/Dia.
 - d_n = Insulation O/Dia.
 - T₁ = Pipe Temperature.
 - T_m = The ambient temperature of the air.
 - T₂ = Surface temperature of the insulation.

CRYOGENIC SUPPORTS

INSULATION THICKNESS SELECTION CHARTS

Insul. Thick	140	150	160	170	180	190	200	210	220	230	240	250
Pipe O/D (do)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)
26.9	17.45	17.50	17.54	17.57	17.60	17.63	17.65	17.67	17.69	17.71	17.72	17.74
33.7	17.41	17.46	17.50	17.54	17.57	17.60	17.63	17.65	17.67	17.69	17.71	17.72
42.4	17.37	17.42	17.47	17.51	17.55	17.58	17.60	17.63	17.65	17.67	17.69	17.70
48.3	17.35	17.40	17.45	17.49	17.53	17.56	17.59	17.61	17.64	17.66	17.67	17.69
60.3	17.30	17.36	17.41	17.46	17.50	17.53	17.56	17.59	17.61	17.63	17.65	17.67
76.1	17.25	17.32	17.37	17.42	17.46	17.50	17.53	17.56	17.58	17.61	17.63	17.65
88.9	17.22	17.28	17.34	17.39	17.43	17.47	17.51	17.54	17.56	17.59	17.61	17.63
101.6	17.19	17.26	17.31	17.37	17.41	17.45	17.49	17.52	17.55	17.57	17.59	17.61
114.3	17.16	17.23	17.29	17.34	17.39	17.43	17.47	17.50	17.53	17.56	17.58	17.60
139.7	17.11	17.19	17.25	17.31	17.35	17.40	17.44	17.47	17.50	17.53	17.55	17.58
168.3	17.07	17.14	17.21	17.27	17.32	17.36	17.41	17.44	17.47	17.50	17.53	17.55
193.7	17.03	17.11	17.18	17.24	17.29	17.34	17.38	17.42	17.45	17.48	17.51	17.53
219.1	17.00	17.08	17.15	17.22	17.27	17.32	17.36	17.40	17.43	17.46	17.49	17.52
244.5	16.98	17.06	17.13	17.19	17.25	17.30	17.34	17.38	17.42	17.45	17.48	17.50
273.0	16.95	17.03	17.11	17.17	17.23	17.28	17.32	17.36	17.40	17.43	17.46	17.49
323.9	16.91	17.00	17.07	17.14	17.20	17.25	17.29	17.34	17.37	17.41	17.44	17.46
355.6	16.89	16.98	17.05	17.12	17.18	17.23	17.28	17.32	17.36	17.39	17.42	17.45
406.4	16.86	16.95	17.03	17.10	17.16	17.21	17.26	17.30	17.34	17.37	17.40	17.43
457.0	16.84	16.93	17.01	17.07	17.14	17.19	17.24	17.28	17.32	17.36	17.39	17.42
508.0	16.82	16.91	16.99	17.06	17.12	17.17	17.22	17.27	17.31	17.34	17.37	17.40
610.0	16.78	16.87	16.96	17.03	17.09	17.14	17.19	17.24	17.28	17.32	17.35	17.38
762.0	16.75	16.84	16.92	16.99	17.06	17.11	17.16	17.21	17.25	17.29	17.32	17.35
914.0	16.72	16.81	16.89	16.97	17.03	17.09	17.14	17.19	17.23	17.27	17.30	17.33
965.2	16.71	16.80	16.89	16.96	17.02	17.08	17.13	17.18	17.22	17.26	17.30	17.33
1016.0	16.70	16.80	16.88	16.95	17.02	17.08	17.13	17.17	17.22	17.25	17.29	17.32
1066.8	16.70	16.79	16.87	16.95	17.01	17.07	17.12	17.17	17.21	17.25	17.28	17.32
1219.2	16.68	16.78	16.86	16.93	17.00	17.05	17.11	17.15	17.20	17.24	17.27	17.30
1422.4	16.66	16.76	16.84	16.92	16.98	17.04	17.09	17.14	17.18	17.22	17.26	17.29
1625.6	16.65	16.75	16.83	16.90	16.97	17.03	17.08	17.13	17.17	17.21	17.25	17.28

Ambient Temperature T_m = 18°C, Fluid Temperature = -106°C, Medium Emissivity (f = 8W/m²K)
 Wind Velocity = 3m/second

The above data is applicable to cylindrical insulation and is based upon the following formulae

$$\text{Thermal Resistance } R(\text{m}^2\text{K/W}) = d_o / (f \cdot d_n) + \{ (d_o / k) \cdot \ln(d_o / d_n) \times 10^{-3} \}$$

$$\text{Rate of Heat Transfer } q(\text{W/m}^2) = (T_1 - T_m) \cdot R$$

$$\text{Surface Temperature } T_2(^\circ\text{C}) = T_m + \{ q \cdot d_o / (f \cdot d_n) \}$$

- Where
- d_o = Pipe O/Dia.
 - d_n = Insulation O/Dia.
 - T₁ = Pipe Temperature.
 - T_m = The ambient temperature of the air.
 - T₂ = Surface temperature of the insulation.

CRYOGENIC SUPPORTS

INSULATION THICKNESS SELECTION CHARTS

Insul. Thick	25	30	40	50	60	70	80	90	100	110	120	130
Pipe O/D (do)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)
26.9	15.76	19.88	21.13	21.84	22.29	22.59	22.81	22.98	23.11	23.21	23.30	23.37
33.7	15.28	19.63	20.94	21.69	22.17	22.50	22.73	22.91	23.05	23.16	23.25	23.32
42.4	14.79	19.37	20.74	21.54	22.04	22.39	22.64	22.83	22.98	23.10	23.20	23.27
48.3	14.53	19.23	20.63	21.45	21.97	22.33	22.59	22.79	22.94	23.06	23.16	23.25
60.3	14.09	18.99	20.44	21.29	21.84	22.22	22.50	22.71	22.87	23.00	23.11	23.19
76.1	13.65	18.74	20.25	21.13	21.71	22.11	22.40	22.62	22.79	22.93	23.04	23.14
88.9	13.38	18.59	20.12	21.03	21.62	22.03	22.33	22.56	22.74	22.88	23.00	23.10
101.6	13.17	18.47	20.02	20.94	21.54	21.96	22.27	22.51	22.69	22.84	22.96	23.06
114.3	12.99	18.36	19.93	20.86	21.47	21.90	22.22	22.46	22.65	22.80	22.93	23.03
139.7	12.70	18.20	19.78	20.74	21.36	21.81	22.13	22.38	22.58	22.74	22.87	22.98
168.3	12.47	18.06	19.66	20.63	21.27	21.72	22.05	22.31	22.51	22.68	22.81	22.93
193.7	12.31	17.96	19.58	20.55	21.20	21.66	22.00	22.26	22.47	22.63	22.77	22.89
219.1	12.18	17.89	19.51	20.49	21.14	21.60	21.95	22.21	22.43	22.60	22.74	22.85
244.5	12.07	17.82	19.45	20.43	21.09	21.56	21.91	22.18	22.39	22.56	22.71	22.82
273.0	11.97	17.76	19.39	20.38	21.04	21.51	21.87	22.14	22.35	22.53	22.67	22.80
323.9	11.84	17.68	19.31	20.31	20.97	21.45	21.81	22.08	22.30	22.48	22.63	22.75
355.6	11.77	17.64	19.28	20.27	20.94	21.42	21.78	22.05	22.28	22.46	22.60	22.73
406.4	11.68	17.59	19.22	20.22	20.89	21.37	21.74	22.02	22.24	22.42	22.57	22.70
457.0	11.61	17.54	19.18	20.18	20.86	21.34	21.70	21.98	22.21	22.39	22.54	22.67
508.0	11.56	17.51	19.15	20.15	20.83	21.31	21.67	21.96	22.18	22.37	22.52	22.65
610.0	11.47	17.45	19.10	20.10	20.78	21.26	21.63	21.91	22.14	22.33	22.48	22.61
762.0	11.38	17.40	19.04	20.05	20.73	21.21	21.58	21.87	22.10	22.28	22.44	22.57
914.0	11.32	17.36	19.00	20.01	20.69	21.18	21.55	21.83	22.06	22.25	22.41	22.54
965.2	11.30	17.35	18.99	20.00	20.68	21.17	21.54	21.82	22.05	22.24	22.40	22.53
1016.0	11.29	17.34	18.98	19.99	20.67	21.16	21.53	21.82	22.05	22.24	22.39	22.53
1066.8	11.28	17.33	18.98	19.98	20.66	21.15	21.52	21.81	22.04	22.23	22.39	22.52
1219.2	11.24	17.31	18.96	19.96	20.64	21.13	21.50	21.79	22.02	22.21	22.37	22.50
1422.4	11.21	17.29	18.93	19.94	20.62	21.11	21.48	21.77	22.00	22.19	22.35	22.48
1625.6	11.18	17.27	18.92	19.93	20.61	21.10	21.47	21.75	21.99	22.18	22.33	22.47

Ambient Temperature T_m = 24°C, Fluid Temperature = -106°C, Medium Emissivity (f = 8W/m²K)
 Wind Velocity = 3m/second

The above data is applicable to cylindrical insulation and is based upon the following formulae

$$\text{Thermal Resistance } R(\text{m}^2\text{K/W}) = d_o / (f \cdot d_n) + \{ (d_o / k) \cdot \ln(d_o / d_n) \times 10^{-3} \}$$

$$\text{Rate of Heat Transfer } q(\text{W/m}^2) = (T_1 - T_m) \cdot R$$

$$\text{Surface Temperature } T_2(\text{°C}) = T_m + \{ q \cdot d_o / (f \cdot d_n) \}$$

- Where
- d_o = Pipe O/Dia.
 - d_n = Insulation O/Dia.
 - T₁ = Pipe Temperature.
 - T_m = The ambient temperature of the air.
 - T₂ = Surface temperature of the insulation.

CRYOGENIC SUPPORTS

INSULATION THICKNESS SELECTION CHARTS

Insul. Thick	140	150	160	170	180	190	200	210	220	230	240	250
Pipe O/D (do)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)	T ₂ (°C)
26.9	23.42	23.47	23.51	23.55	23.58	23.61	23.63	23.66	23.68	23.69	23.71	23.72
33.7	23.38	23.44	23.48	23.52	23.55	23.58	23.61	23.63	23.65	23.67	23.69	23.71
42.4	23.34	23.40	23.45	23.49	23.52	23.56	23.58	23.61	23.63	23.65	23.67	23.69
48.3	23.31	23.37	23.42	23.47	23.50	23.54	23.57	23.59	23.62	23.64	23.66	23.68
60.3	23.27	23.33	23.38	23.43	23.47	23.51	23.54	23.57	23.59	23.61	23.64	23.65
76.1	23.22	23.28	23.34	23.39	23.43	23.47	23.51	23.54	23.56	23.59	23.61	23.63
88.9	23.18	23.25	23.31	23.36	23.41	23.45	23.48	23.51	23.54	23.57	23.59	23.61
101.6	23.15	23.22	23.28	23.34	23.38	23.42	23.46	23.49	23.52	23.55	23.57	23.60
114.3	23.12	23.19	23.26	23.31	23.36	23.40	23.44	23.48	23.51	23.53	23.56	23.58
139.7	23.07	23.15	23.21	23.27	23.32	23.37	23.41	23.44	23.48	23.51	23.53	23.56
168.3	23.02	23.10	23.17	23.23	23.29	23.33	23.38	23.41	23.45	23.48	23.51	23.53
193.7	22.99	23.07	23.14	23.20	23.26	23.31	23.35	23.39	23.43	23.46	23.49	23.51
219.1	22.95	23.04	23.11	23.18	23.23	23.28	23.33	23.37	23.41	23.44	23.47	23.49
244.5	22.93	23.01	23.09	23.15	23.21	23.26	23.31	23.35	23.39	23.42	23.45	23.48
273.0	22.90	22.99	23.06	23.13	23.19	23.24	23.29	23.33	23.37	23.40	23.44	23.46
323.9	22.86	22.95	23.03	23.10	23.16	23.21	23.26	23.30	23.34	23.38	23.41	23.44
355.6	22.84	22.93	23.01	23.08	23.14	23.19	23.24	23.29	23.33	23.36	23.40	23.43
406.4	22.81	22.90	22.98	23.05	23.11	23.17	23.22	23.27	23.31	23.34	23.38	23.41
457.0	22.78	22.86	22.96	23.03	23.09	23.15	23.20	23.25	23.29	23.32	23.36	23.39
508.0	22.76	22.85	22.94	23.01	23.07	23.13	23.18	23.23	23.27	23.31	23.34	23.38
610.0	22.72	22.82	22.90	22.98	23.04	23.10	23.15	23.20	23.24	23.28	23.32	23.35
762.0	22.68	22.78	22.87	22.94	23.01	23.07	23.12	23.17	23.21	23.25	23.29	23.32
914.0	22.66	22.75	22.84	22.92	22.98	23.04	23.10	23.15	23.19	23.23	23.27	23.30
965.2	22.65	22.75	22.83	22.91	22.98	23.04	23.09	23.14	23.18	23.22	23.26	23.30
1016.0	22.64	22.74	22.83	22.90	22.97	23.03	23.08	23.13	23.18	23.22	23.26	23.29
1066.8	22.63	22.73	22.82	22.90	22.96	23.02	23.08	23.13	23.17	23.21	23.25	23.28
1219.2	22.62	22.72	22.80	22.88	22.95	23.01	23.06	23.11	23.16	23.20	23.24	23.27
1422.4	22.60	22.70	22.79	22.86	22.93	22.99	23.05	23.10	23.14	23.18	23.22	23.26
1625.6	22.58	22.68	22.77	22.85	22.92	22.98	23.03	23.08	23.13	23.17	23.21	23.24

Ambient Temperature T_m = 24°C, Fluid Temperature = -106°C, Medium Emissivity (f = 8W/m²K)
 Wind Velocity = 3m/second

The above data is applicable to cylindrical insulation and is based upon the following formulae

$$\text{Thermal Resistance } R(\text{m}^2\text{K/W}) = d_o / (f \cdot d_n) + \{ (d_o / k) \cdot \ln(d_o / d_n) \times 10^{-3} \}$$

$$\text{Rate of Heat Transfer } q(\text{W/m}^2) = (T_1 - T_m) \cdot R$$

$$\text{Surface Temperature } T_2(^\circ\text{C}) = T_m + \{ q \cdot d_o / (f \cdot d_n) \}$$

- Where d_o = Pipe O/Dia.
- d_n = Insulation O/Dia.
- T₁ = Pipe Temperature.
- T_m = The ambient temperature of the air.
- T₂ = Surface temperature of the insulation.

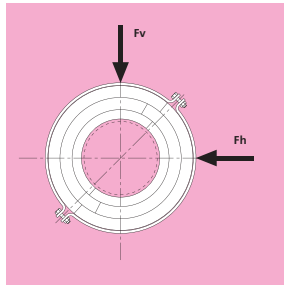
CRYOGENIC SUPPORTS

MAXIMUM RADIAL APPLIED LOADING

Shoe Length	150				200				250			
No. Layers	1	2	3	4	1	2	3	4	1	2	3	4
Pipe O/D	Limiting Radial Load (kN)											
21.3	2.51	2.99	3.47	3.95	3.19	3.67	4.15	4.63	3.87	4.35	4.83	5.31
26.9	3.17	3.78	4.38	4.99	4.03	4.64	5.24	5.85	4.89	5.49	6.10	6.70
33.7	3.98	4.73	5.49	6.25	5.05	5.81	6.57	7.32	6.12	6.88	7.64	8.40
42.4	5.00	5.96	6.91	7.86	6.35	7.31	8.26	9.21	7.70	8.66	9.61	10.56
48.3	5.70	6.79	7.87	8.96	7.24	8.32	9.41	10.50	8.77	9.86	10.95	12.03
60.3	7.11	8.47	9.83	11.19	9.03	10.39	11.75	13.10	10.95	12.31	13.67	15.02
76.1	8.98	10.69	12.40	14.12	11.40	13.11	14.83	16.54	13.82	15.53	17.25	18.96
88.9	10.49	12.49	14.49	16.49	13.32	15.32	17.32	19.32	16.15	18.15	20.15	22.15
114.3	13.49	16.06	18.55	20.46	17.12	19.70	22.27	24.84	20.76	23.33	25.90	28.48
139.7	16.48	19.07	20.98	22.89	20.93	24.07	27.22	30.36	25.37	28.52	31.66	34.81
168.3	19.86	21.80	23.71	25.62	25.21	29.00	32.79	36.57	30.57	34.36	38.14	41.93
193.7	35.76	37.90	40.89	43.87	45.40	52.22	59.04	65.86	55.05	61.87	68.69	75.51
219.1	40.20	41.69	44.68	47.67	51.35	59.07	66.78	74.50	62.27	69.98	77.69	85.41
244.5	43.99	45.49	48.48	51.46	57.31	65.92	74.53	83.14	69.48	78.09	86.70	95.31
273	48.25	49.75	52.73	55.72	63.99	73.60	83.21	90.23	77.58	87.20	96.81	106.42
323.9	55.86	57.35	60.34	63.32	75.92	87.32	96.38	100.37	92.05	103.45	114.86	126.26
355.6	60.59	62.08	65.07	68.06	83.35	95.87	102.70	106.68	101.06	113.58	126.10	138.62
406.4	68.18	69.67	72.66	75.65	95.26	108.83	112.82	116.80	115.49	129.80	144.11	158.42
457	75.74	77.23	80.22	83.21	107.12	118.91	122.89	126.88	129.87	145.96	162.06	178.15
508	83.36	84.85	87.84	90.83	119.07	129.07	133.05	137.04	144.37	162.25	180.14	191.21
559	90.98	92.47	95.46	98.44	131.02	139.23	143.21	147.19	158.86	178.54	198.22	203.91
610	98.59	100.09	103.08	106.06	142.98	149.39	153.37	157.35	173.35	194.83	211.63	216.61
660	166.01	168.35	173.03	177.70	242.14	249.41	255.64	261.88	293.58	329.95	350.73	358.52
711.2	177.98	180.32	185.00	189.67	259.13	265.37	271.61	277.84	316.35	355.55	370.68	378.48
762	189.86	192.20	196.88	201.55	274.97	281.21	287.44	293.68	338.95	380.94	390.48	398.27
813	201.79	204.12	208.80	213.48	290.87	297.11	303.34	309.58	361.63	402.56	410.35	418.15
864	213.71	216.05	220.73	225.40	306.77	313.01	319.24	325.48	384.32	422.43	430.23	438.02
914	225.40	227.74	232.42	237.09	322.36	328.60	334.83	341.07	406.56	441.92	449.71	457.51
965.2	237.37	239.71	244.39	249.07	338.32	344.56	350.79	357.03	429.33	461.87	469.67	477.46
1016	249.25	251.59	256.27	260.94	354.16	360.39	366.63	372.86	451.93	481.67	489.46	497.26
1066.8	261.13	263.47	268.14	272.82	370.00	376.23	382.47	388.70	474.53	501.47	509.26	517.05
1219.2	296.76	299.10	303.78	308.46	417.51	423.74	429.98	436.21	542.31	560.86	568.65	576.44
1422.4	344.28	346.61	351.29	355.97	480.86	487.09	493.33	499.56	632.25	640.04	647.84	655.63
1625.6	391.79	394.13	398.80	403.48	544.21	550.44	556.68	562.91	711.44	719.23	727.02	734.82

NB. The maximum radial load is calculated as the resultant force due to all vertical and transverse loadings such that —

$$\text{Radial Force } Fr = \sqrt{(Fv^2 + Fh^2)}$$



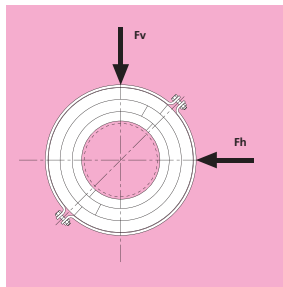
CRYOGENIC SUPPORTS

MAXIMUM RADIAL APPLIED LOADING

Shoe Length	300				450				600			
No. Layers	1	2	3	4	1	2	3	4	1	2	3	4
Pipe O/D	Limiting Radial Load (kN)											
21.3	4.55	5.03	5.51	5.98	6.58	7.06	7.54	8.02	8.61	9.09	9.57	10.05
26.9	5.74	6.35	6.95	7.56	8.31	8.92	9.52	10.13	10.88	11.48	12.09	12.69
33.7	7.19	7.95	8.71	9.47	10.41	11.17	11.93	12.69	13.63	14.39	15.15	15.90
42.4	9.05	10.00	10.96	11.91	13.10	14.05	15.01	15.96	17.15	18.10	19.06	20.01
48.3	10.31	11.40	12.48	13.57	14.92	16.01	17.10	18.18	19.53	20.62	21.71	22.79
60.3	12.87	14.23	15.59	16.94	18.63	19.99	21.34	22.70	24.39	25.74	27.10	28.46
76.1	16.24	17.96	19.67	21.38	23.51	25.22	26.93	28.65	30.78	32.49	34.20	35.91
88.9	18.98	20.98	22.98	24.98	27.46	29.46	31.47	33.47	35.95	37.95	39.95	41.95
114.3	24.40	26.97	29.54	32.11	35.31	37.88	40.46	43.03	46.22	48.80	51.37	53.94
139.7	29.82	32.96	36.11	39.25	43.16	46.30	49.45	52.59	56.50	59.64	62.78	65.93
168.3	35.92	39.71	43.50	47.29	51.99	55.78	59.57	63.36	68.06	71.85	75.64	79.42
193.7	64.69	71.51	78.33	85.15	93.63	100.45	107.27	114.09	122.56	129.38	136.20	143.02
219.1	73.18	80.89	88.60	96.32	105.91	113.62	121.33	129.05	138.64	146.35	154.06	161.78
244.5	81.66	90.27	98.88	107.49	118.18	126.79	135.40	144.01	154.71	163.32	171.93	180.53
273	91.18	100.79	110.40	120.01	131.96	141.57	151.18	160.80	172.74	182.35	191.97	201.58
323.9	108.18	119.58	130.99	142.39	156.56	167.97	179.37	190.78	204.95	216.35	227.76	239.16
355.6	118.76	131.28	143.81	156.33	171.88	184.41	196.93	209.45	225.01	237.53	250.05	262.57
406.4	135.73	150.04	164.35	178.66	196.44	210.75	225.06	239.37	257.15	271.46	285.77	300.08
457	152.63	168.72	184.81	200.90	220.90	236.99	253.08	269.17	289.17	305.26	321.35	337.44
508	169.66	187.55	205.44	223.32	245.55	263.44	281.32	299.21	321.44	339.32	357.21	375.10
559	186.70	206.38	226.06	245.74	270.20	289.88	309.57	329.25	353.71	373.39	393.07	412.76
610	203.73	225.21	246.68	268.16	294.85	316.33	337.81	359.29	385.98	407.46	428.93	450.41
660	345.02	381.39	417.76	454.14	499.34	535.71	572.09	608.46	653.66	699.03	726.41	762.78
711.2	371.78	410.98	450.17	489.37	538.07	577.27	616.47	655.66	704.37	743.56	782.76	821.95
762	398.34	440.33	482.33	515.34	576.51	618.50	660.50	702.49	754.68	796.67	838.67	880.66
813	425.00	469.80	514.61	539.19	615.09	659.90	704.70	749.51	805.19	849.99	894.80	939.61
864	451.66	499.27	546.89	563.04	653.68	701.29	748.91	796.53	855.70	903.32	950.93	998.55
914	477.80	528.17	577.07	586.42	691.51	741.88	792.25	842.62	905.22	955.59	1005.96	1056.34
965.2	504.56	557.75	601.01	610.36	730.24	783.44	836.63	889.83	955.93	1009.12	1062.31	1115.51
1016	531.12	587.11	624.77	634.12	768.68	824.67	880.66	936.66	1006.24	1062.23	1118.23	1174.22
1066.8	557.67	616.47	648.52	657.88	807.11	865.90	924.70	983.49	1056.55	1115.34	1174.14	1232.93
1219.2	637.34	704.53	719.79	729.14	922.41	989.60	1056.80	1123.99	1207.49	1274.68	1341.87	1409.06
1422.4	743.56	805.46	814.82	824.17	1076.15	1154.54	1232.93	1292.37	1408.73	1487.12	1565.52	1643.91
1625.6	849.79	900.49	909.84	919.19	1229.88	1319.47	1409.06	1434.91	1609.98	1699.57	1789.16	1878.75

NB. The maximum radial load is calculated as the resultant force due to all vertical and transverse loadings such that —

$$\text{Radial Force } Fr = \sqrt{(Fv^2 + Fh^2)}$$



CRYOGENIC SUPPORTS

MAXIMUM AXIAL TORSION

Pipe O/D	Shoe Length No. of Layers Clamp Bolt	150				200				250				300				450				600			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
		4 Bolts				4 Bolts				4 Bolts				4 Bolts				6 Bolts				6 Bolts			
21.3	M10	3.25Nm				4.33Nm				5.42Nm				6.50Nm				9.75Nm				13.00Nm			
26.9	M10	5.18Nm				6.91Nm				8.63Nm				10.36Nm				15.54Nm				20.72Nm			
33.7	M10	8.13Nm				10.84Nm				13.55Nm				16.27Nm				24.40Nm				32.53Nm			
42.4	M10	12.87Nm				17.17Nm				21.46Nm				25.75Nm				38.62Nm				51.50Nm			
48.3	M10	16.71Nm				22.22Nm				27.84Nm				33.41Nm				50.12Nm				66.82Nm			
60.3	M10	26.04Nm				34.71Nm				43.40Nm				52.07Nm				78.11Nm				101.98Nm			
76.1	M12	41.46Nm				55.30Nm				69.12Nm				82.94Nm				124.41Nm				165.87Nm			
88.9	M12	56.60Nm				75.45Nm				94.32Nm				113.18Nm				169.77Nm				218.53Nm			
114.3	M12	93.55Nm				124.73Nm				155.92Nm				187.11Nm				280.66Nm				360.97Nm			
139.7	M12	139.75Nm				186.32Nm				228.94Nm				288.94Nm				433.41Nm				568.82Nm			
168.3	M12	202.82Nm				270.44Nm				338.06Nm				413.71Nm				613.71Nm				813.71Nm			
193.7	M12	268.66Nm				357.43Nm				446.82Nm				546.61Nm				816.61Nm				1086.61Nm			
219.1	M12	343.74Nm				459.06Nm				574.38Nm				699.70Nm				1049.70Nm				1409.70Nm			
244.5	M12	400.68Nm				533.68Nm				667.68Nm				801.68Nm				1201.68Nm				1601.68Nm			
273	M12	447.39Nm				593.99Nm				747.39Nm				901.39Nm				1351.39Nm				1801.39Nm			
323.9	M16	751.25Nm				996Nm				1240.9Nm				1485.8Nm				2225.8Nm				2970.8Nm			
355.6	M16	911kNm				1.09kNm				1.09kNm				1.09kNm				1.63kNm				2.17kNm			
406.4	M16	1.18kNm				1.24kNm				1.24kNm				1.24kNm				1.86kNm				2.42kNm			
457	M16	1.39kNm				1.39kNm				1.39kNm				1.39kNm				2.09kNm				2.65kNm			
508	M16	1.55kNm				1.55kNm				1.55kNm				1.55kNm				2.33kNm				3.09kNm			
559	M16	1.71kNm				1.71kNm				1.71kNm				1.71kNm				2.56kNm				3.41kNm			
610	M16	1.86kNm				1.86kNm				1.86kNm				1.86kNm				2.79kNm				3.72kNm			
660	M20	3.12kNm				3.14kNm				3.14kNm				3.14kNm				4.72kNm				6.30kNm			
711.2	M20	3.39kNm				3.39kNm				3.39kNm				3.39kNm				5.08kNm				6.76kNm			
762	M20	3.63kNm				3.63kNm				3.63kNm				3.63kNm				5.44kNm				7.29kNm			
813	M20	3.87kNm				3.87kNm				3.87kNm				3.87kNm				5.81kNm				7.76kNm			
864	M20	4.12kNm				4.12kNm				4.12kNm				4.12kNm				6.17kNm				8.22kNm			
914	M20	4.35kNm				4.35kNm				4.35kNm				4.35kNm				6.53kNm				8.76kNm			
965.2	M20	4.60kNm				4.60kNm				4.60kNm				4.60kNm				6.90kNm				9.29kNm			
1016	M20	4.84kNm				4.84kNm				4.84kNm				4.84kNm				7.26kNm				9.76kNm			
1066.8	M24	7.32kNm				7.32kNm				7.32kNm				7.32kNm				10.98kNm				14.64kNm			
1219.2	M24	8.37kNm				8.37kNm				8.37kNm				8.37kNm				12.55kNm				16.73kNm			
1422.4	M24	9.76kNm				9.76kNm				9.76kNm				9.76kNm				14.64kNm				19.52kNm			
1625.6	M24	11.16kNm				11.16kNm				11.16kNm				11.16kNm				16.73kNm				22.30kNm			

NB. The above figures are calculated on the basis of the following torque settings within the clamp bolts —

M10	2.5Nm
M12	6.0Nm
M16	15.84Nm
M20	31.0Nm
M24	53.76Nm

These figures are offered for guidance only; the use of adhesives or thrust flanges may allow higher values to be achieved. The designer should assure himself that the proposed arrangement will function effectively.

CRYOGENIC SUPPORTS

MAXIMUM AXIAL THRUST

Pipe O/D	Shoe Length	No. of Layers	150			200			250			300			450			600							
			4 Bolts			4 Bolts			4 Bolts			4 Bolts			6 Bolts			6 Bolts							
			1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
21.3	M10		0.31kN		0.41kN		0.51kN		0.51kN		0.51kN		0.61kN		0.92kN		1.22kN		1.22kN						
26.9	M10		0.39kN		0.51kN		0.64kN		0.77kN		0.77kN		1.16kN		1.16kN		1.54kN		1.54kN						
33.7	M10		0.48kN		0.64kN		0.80kN		0.97kN		0.97kN		1.45kN		1.45kN		1.93kN		1.93kN						
42.4	M10		0.61kN		0.81kN		1.01kN		1.21kN		1.21kN		1.82kN		1.82kN		2.43kN		2.43kN						
48.3	M10		0.69kN		0.92kN		1.15kN		1.38kN		1.38kN		2.08kN		2.08kN		2.77kN		2.77kN						
60.3	M10		0.86kN		1.15kN		1.44kN		1.73kN		1.73kN		2.59kN		2.59kN		3.38kN		3.38kN						
76.1	M12		1.09kN		1.45kN		1.82kN		2.18kN		2.18kN		3.27kN		3.27kN		4.36kN		4.36kN						
88.9	M12		1.27kN		1.70kN		2.12kN		2.55kN		2.55kN		3.82kN		3.82kN		4.92kN		4.92kN						
114.3	M12		1.64kN		2.18kN		2.73kN		3.27kN		3.27kN		4.91kN		4.91kN		6.42kN		6.42kN						
139.7	M12		2.00kN		2.67kN		3.28kN		3.28kN		3.28kN		4.92kN		4.92kN		6.42kN		6.42kN						
168.3	M12		2.41kN		3.21kN		3.28kN		3.28kN		3.28kN		4.92kN		4.92kN		6.42kN		6.42kN						
193.7	M12		2.77kN		3.28kN		3.28kN		3.28kN		3.28kN		4.92kN		4.92kN		6.42kN		6.42kN						
219.1	M12		3.14kN		3.28kN		3.28kN		3.28kN		3.28kN		4.92kN		4.92kN		6.42kN		6.42kN						
244.5	M12		3.28kN		3.28kN		3.28kN		3.28kN		3.28kN		4.92kN		4.92kN		6.42kN		6.42kN						
273	M12		3.28kN		3.28kN		3.28kN		3.28kN		3.28kN		4.92kN		4.92kN		6.42kN		6.42kN						
323.9	M16		4.64kN		6.10kN		6.10kN		6.10kN		6.10kN		9.16kN		9.16kN		11.6kN		11.6kN						
355.6	M16		5.09kN		6.10kN		6.10kN		6.10kN		6.10kN		9.16kN		9.16kN		11.6kN		11.6kN						
406.4	M16		5.82kN		6.10kN		6.10kN		6.10kN		6.10kN		9.16kN		9.16kN		11.6kN		11.6kN						
457	M16		6.10kN		6.10kN		6.10kN		6.10kN		6.10kN		9.16kN		9.16kN		11.6kN		11.6kN						
508	M16		6.10kN		6.10kN		6.10kN		6.10kN		6.10kN		9.16kN		9.16kN		11.6kN		11.6kN						
559	M16		6.10kN		6.10kN		6.10kN		6.10kN		6.10kN		9.16kN		9.16kN		11.6kN		11.6kN						
610	M16		6.10kN		6.10kN		6.10kN		6.10kN		6.10kN		9.16kN		9.16kN		11.6kN		11.6kN						
660	M20		9.45kN		9.53kN		9.53kN		9.53kN		9.53kN		14.29kN		14.29kN		18.48kN		18.48kN						
711.2	M20		9.53kN		9.53kN		9.53kN		9.53kN		9.53kN		14.29kN		14.29kN		18.48kN		18.48kN						
762	M20		9.53kN		9.53kN		9.53kN		9.53kN		9.53kN		14.29kN		14.29kN		18.48kN		18.48kN						
813	M20		9.53kN		9.53kN		9.53kN		9.53kN		9.53kN		14.29kN		14.29kN		18.48kN		18.48kN						
864	M20		9.53kN		9.53kN		9.53kN		9.53kN		9.53kN		14.29kN		14.29kN		18.48kN		18.48kN						
914	M20		9.53kN		9.53kN		9.53kN		9.53kN		9.53kN		14.29kN		14.29kN		18.48kN		18.48kN						
965.2	M20		9.53kN		9.53kN		9.53kN		9.53kN		9.53kN		14.29kN		14.29kN		18.48kN		18.48kN						
1016	M20		9.53kN		9.53kN		9.53kN		9.53kN		9.53kN		14.29kN		14.29kN		18.48kN		18.48kN						
1066.8	M24		13.72kN		13.72kN		13.72kN		13.72kN		13.72kN		20.59kN		20.59kN		26.99kN		26.99kN						
1219.2	M24		13.72kN		13.72kN		13.72kN		13.72kN		13.72kN		20.59kN		20.59kN		26.99kN		26.99kN						
1422.4	M24		13.72kN		13.72kN		13.72kN		13.72kN		13.72kN		20.59kN		20.59kN		26.99kN		26.99kN						
1625.6	M24		13.72kN		13.72kN		13.72kN		13.72kN		13.72kN		20.59kN		20.59kN		26.99kN		26.99kN						

NB. The above figures are calculated on the basis of the following torque settings within the clamp bolts —

M10	2.5Nm
M12	6.0Nm
M16	15.84Nm
M20	31.0Nm
M24	53.76Nm

These figures are offered for guidance only; the use of adhesives or thrust flanges may allow higher values to be achieved. The designer should assure himself that the proposed arrangement will function effectively.

CRYOGENIC SUPPORTS

Combined Forces

Where deadweight is combined with lateral forces, axial torsion and thrust the following method should be used to determine the suitability of the support to sustain the combination of forces.

$$\sum \frac{Fr}{Pr} + \frac{Ft}{Pt} + \frac{Fa}{Pa} \leq 1$$

Where:

Fr = Applied Radial Force
 Ft = Applied Axial Torsion
 Fa = Applied Axial Thrust

Pr = Maximum Allowable Radial Force
 Pt = Maximum Allowable Axial Torsion
 Pa = Maximum Allowable Axial Thrust

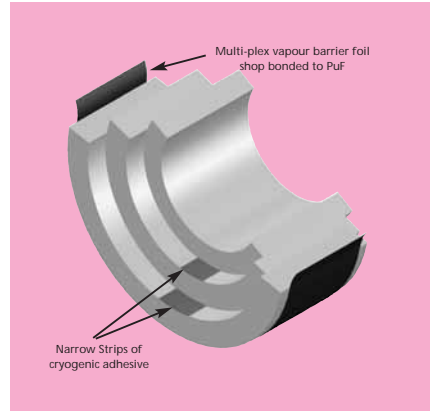
Construction Principles and Materials:

We have shown by full-scale testing at cryogenic temperatures that bonding between the layers of HD PUF can be kept to an absolute minimum and from these tests have concluded that in simple resting, hanging and guided supports the upper layers of HD PUF do not require any bonding.

It can be shown that by fully bonding the multiple layers of HD PUF together the PUF cradle becomes more rigid than the steel cradle surrounding it and will not flex to suit any irregularity or tolerance in the shape and diameter of the pipe.

However by bonding the layers together with a narrow band of adhesive positioned along the quadrant of the moulding the multiple layers can flex and shear relative to one another thereby allowing the cradle to adjust its shape to suit geometric or dimensional anomalies.

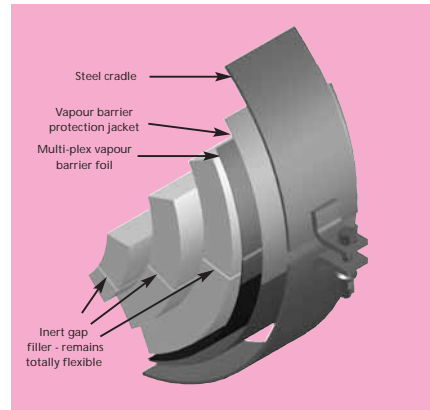
The diagram shown on the right illustrates this principle —



Strip bonding of lower insulation segments.



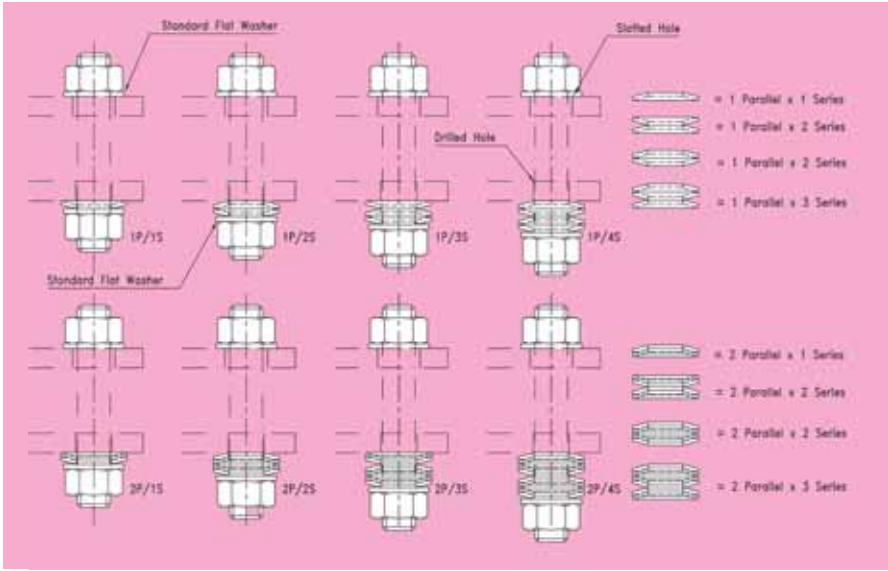
Full scale test of 24" NB (600NB) cryogenic pipe shoe at -165°C for client approval.



Multi-layer construction.

CRYOGENIC SUPPORTS

DISC SPRING CONFIGURATION



The use of disc springs will maintain a nominal compressive force between the PUF ensuring that regardless of applied vertical loading there will always be positive force between the PUF and the Pipe thereby eliminating the possibility of the pipe 'floating' inside the insulation.

In practice the pipe cools to the same temperature of the fluid it carries. The inside face of the insulation will also cool to this temperature but the outer face of the PUF, exposed to the ambient conditions of the local environment will be held at a much higher temperature.

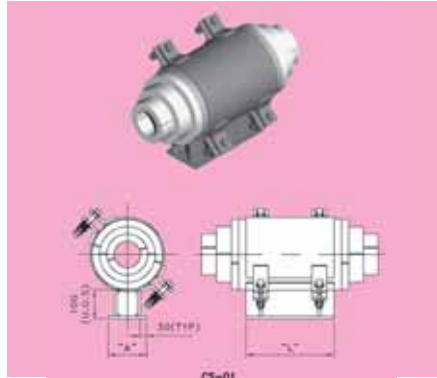
The PUF therefore has a large temperature gradient through its thickness causing the inside face to contract and effectively pulling it away from the shrinking pipe. Installed correctly, using appropriate mastics, adhesives and gap filling materials the PUF insulation will contract under the pressure exerted by the disc springs and remain in contact with the pipe.

The above diagram explains the terminology used and shows how disc springs should be installed. We will provide bolt torque values on a contract by contract basis since this must take in to account the thickness of the insulation.

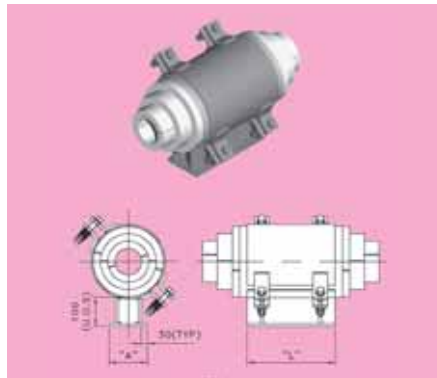
CRYOGENIC SUPPORTS

TYPE CS01 CRYOGENIC PIPE SHOE

PIPE SIZE		PIPE OD	DIMENSIONS		SWL (N)	
			A	L	VERT	HOR
½"	15	21.3	100	150	1176	679
¾"	20	26.9	100	150	1485	857
1"	25	33.7	100	150	1861	1074
1½"	40	48.3	100	150	2667	1540
2"	50	60.3	100	300	6660	3845
2½"	65	76.1	100	300	8406	4853
3"	80	88.9	100	300	9820	5670
4"	100	114.3	150	300	12626	7290
6"	150	168.3	150	300	18591	10734
8"	200	219.1	200	450	59152	34153
10"	250	273	250	450	73705	42555
12"	300	323.9	300	450	87447	50489
14"	350	355.6	330	450	96005	55430
16"	400	406.4	350	450	109721	63349
18"	450	457	350	450	123382	71237
20"	500	508	400	450	137151	78187
22"	550	558.8	400	450	15866	87105
24"	600	610	500	750	274483	158478
26"	650	660.4	500	750	534891	308829
28"	700	711.2	500	750	675038	332585
30"	750	762	600	750	617183	356341
32"	800	812.8	600	750	658328	380097
34"	850	863.6	600	750	699474	403853
36"	900	914	650	750	740295	427422
38"	950	965.2	650	750	781765	451366
40"	1000	1016	650	750	822911	475122
42"	1050	1066.8	810	750	864056	498878
44"	1100	1117.6	840	750	905202	522634
46"	1150	1168.4	880	750	946348	546390
48"	1200	1219.2	880	750	987493	570146
50"	1250	1270	960	750	1028639	593902
52"	1300	1320.8	1000	750	1069784	617658
56"	1400	1422.4	1080	750	1152076	665171
58"	1450	1473.2	1080	750	1193221	688927
64"	1600	1625.6	1080	750	1416658	760195
66"	1650	1676.4	1200	750	1357803	783951
70"	1750	1778	1200	750	1440094	831463
72"	1800	1828.8	1200	750	1481241	855220



CS-01
For pipe sizes ½" to 3" NB.

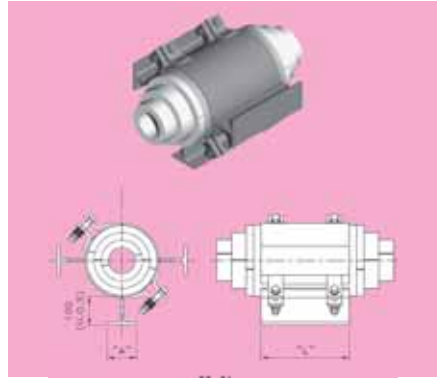


CS-01
For pipe sizes over 3" NB.

CRYOGENIC SUPPORTS

TYPE CG01, CG02 & CG03 SHOES

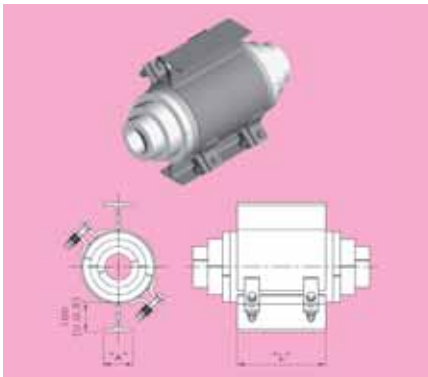
PIPE SIZE		SWL (N)		
		VERT	HOR	AXIAL
½"	15	1176	679	150
¾"	20	1485	857	150
1"	25	1861	1074	170
1½"	40	2667	1540	470
2"	50	6660	3845	610
2½"	65	8406	4853	770
3"	80	9820	5670	970
4"	100	12626	7290	1210
6"	150	18591	10734	1380
8"	200	59152	34153	2180
10"	250	73705	42555	2950
12"	300	87447	50489	3270
14"	350	96005	55430	3280
16"	400	109721	63349	3280
18"	450	123382	71237	3280
20"	500	137151	78187	3280
22"	550	150866	87105	3280
24"	600	274483	158478	4920
26"	650	534891	308829	4920
28"	700	568038	332585	9160
30"	750	617183	356341	9160
32"	800	658328	380097	9160
34"	850	699474	403853	9160
36"	900	740295	427422	9160
38"	950	781765	451366	9160
40"	1000	822911	475122	9160
42"	1050	864056	498878	14290
44"	1100	905202	522634	14290
46"	1150	946348	546390	14290
48"	1200	987493	570146	14290
50"	1250	1028639	593902	14290
52"	1300	1069784	617658	14290
56"	1400	1152076	665171	14290
58"	1450	1193221	688927	14290
64"	1600	1416658	760195	20590
66"	1650	1357803	783951	20590
70"	1750	1440094	831463	20590
72"	1800	1481241	855220	20590



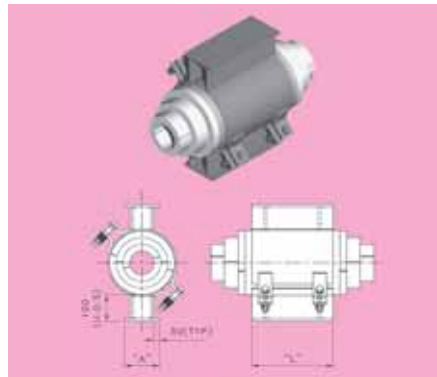
CG-01
For pipe sizes ½" to 3" NB.



CG-01
For pipe sizes over 3" NB.



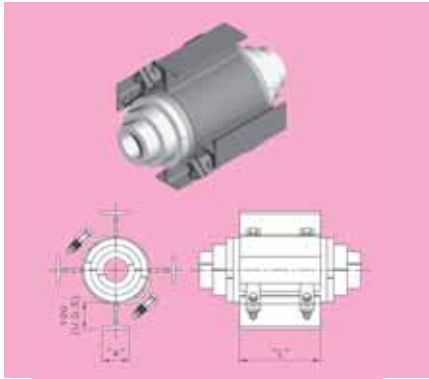
CG-02
For pipe sizes ½" to 3" NB.



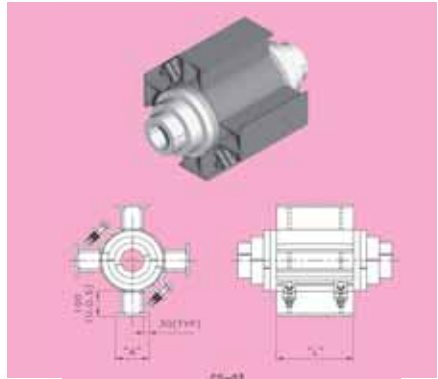
CG-02
For pipe sizes over 3" NB.

CRYOGENIC SUPPORTS

TYPE CG01, CG02 & CG03 SHOES



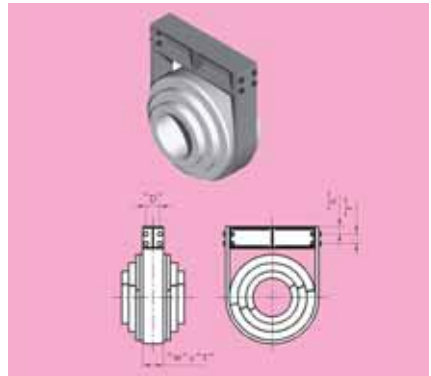
CG-03
For pipe sizes 1/2" to 3" NB.



CG-03
For pipe sizes over 3" NB.

TYPE CHO1 HANGER

PIPE SIZE	D	E	F	W	T	SWL (kN)	
6"	150	90	40	70	150	25	10.73
8"	200	90	40	70	150	25	22.76
10"	250	90	40	70	150	25	28.37
12"	300	90	40	70	150	25	33.65
14"	350	90	40	70	150	25	36.95
16"	400	90	40	70	150	25	42.23
18"	450	90	40	70	150	25	47.49
20"	500	90	40	70	150	25	52.79
22"	550	90	40	70	150	25	58.07
24"	600	90	40	70	150	25	63.39
26"	650	140	50	100	200	25	164.70
28"	700	140	50	100	200	25	177.37
30"	750	140	50	100	200	25	190.04
32"	800	140	50	100	200	25	202.71
34"	850	140	50	100	200	25	215.38
36"	900	140	50	100	200	25	227.95
38"	950	140	50	100	200	25	240.72
40"	1000	140	50	100	200	25	253.39



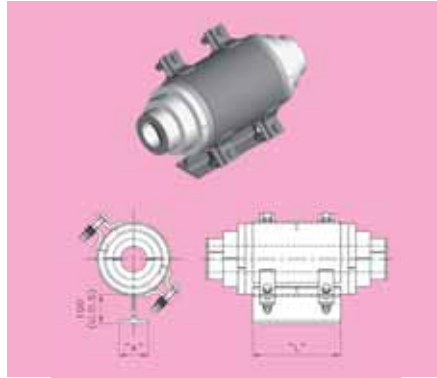
CH-01

CRYOGENIC SUPPORTS

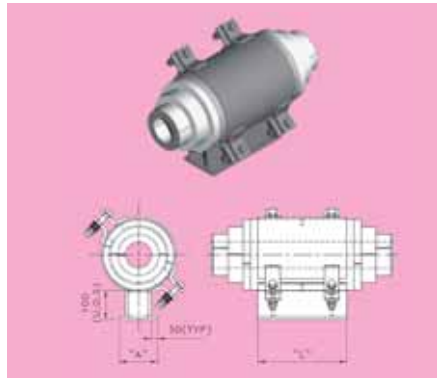
TYPE CLO1 & CLO3 SHOES

PIPE SIZE		SWL (N)		
		VERT	HOR	AXIAL
2"	50	6660	3845	1998
2½"	65	8406	4853	2521
3"	80	9820	5670	2946
4"	100	12626	7290	3787
6"	150	18591	10734	5577
8"	200	25915	14153	7745
10"	250	33705	18555	10111
12"	300	42447	23489	12634
14"	350	52005	28940	15381
16"	400	62471	35000	18266
18"	450	73842	41777	21291
20"	500	86115	49280	25446
22"	550	99390	57500	29741
24"	600	113667	66430	34176
26"	650	128946	76070	38751
28"	700	145227	86420	44476
30"	750	162510	97480	50351
32"	800	180800	109250	56376
34"	850	199995	121750	62551
36"	900	220095	134970	68876
38"	950	241200	148900	75351
40"	1000	263415	163550	82076
42"	1050	286740	178920	89051
44"	1100	311175	195000	96276
46"	1150	336720	211800	103751
48"	1200	363375	229320	111476
50"	1250	391140	247570	119451
52"	1300	420015	266550	127676
56"	1400	488880	306300	153451
58"	1450	519855	327000	163876
64"	1600	616650	381000	194451
66"	1650	645525	402750	205876
70"	1750	734400	456750	236451
72"	1800	765375	479250	248876

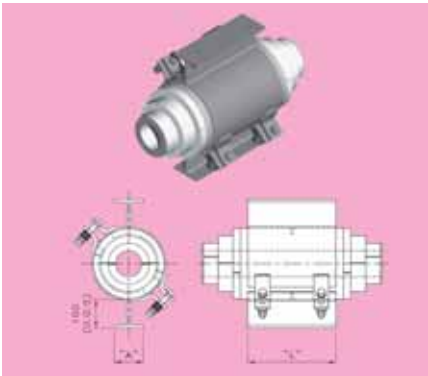
Please provide full piping specification & design conditions.



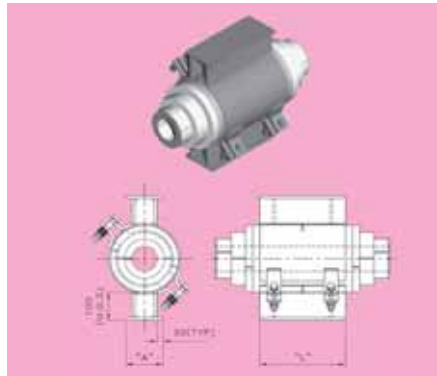
CL-01
For pipe sizes ½" to 3" NB.



CL-01
For pipe sizes over 3" NB.



CL-03
For pipe sizes ½" to 3" NB.



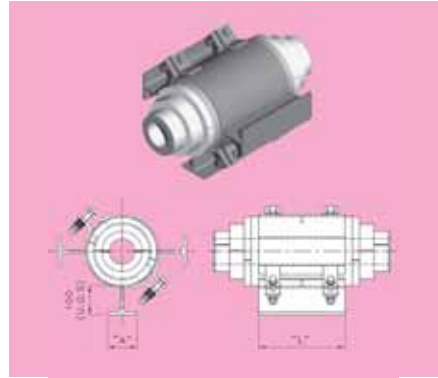
CL-03
For pipe sizes over 3" NB.

CRYOGENIC SUPPORTS

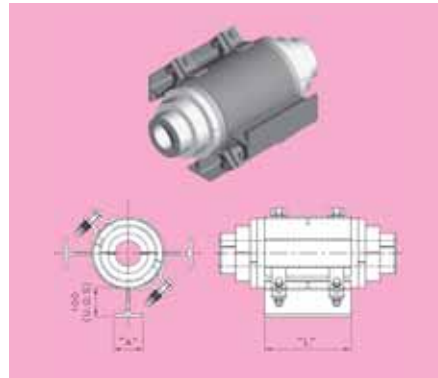
TYPE CLO2 & CLO4 SHOES

PIPE SIZE		SWL (N)		
		VERT	HOR	AXIAL
2"	50	6660	3845	1998
2½"	65	8406	4853	2521
3"	80	9820	5670	2946
4"	100	12626	7290	3787
6"	150	18591	10734	5577
8"	200	25152	14153	7745
10"	250	33705	18555	10111
12"	300	43447	24089	12634
14"	350	56005	31430	16101
16"	400	72721	40349	20516
18"	450	93882	51237	26174
20"	500	119715	65187	33145
22"	550	150866	82705	41529
24"	600	198483	107478	53344
26"	650	263891	141829	70467
28"	700	340308	182585	90811
30"	750	429783	235341	117154
32"	800	543328	300097	149498
34"	850	694474	388853	194842
36"	900	886295	494422	252088
38"	950	112765	61366	30529
40"	1000	142911	75122	37873
42"	1050	184056	98878	49216
44"	1100	239202	12634	63560
46"	1150	306348	16390	82904
48"	1200	387493	21016	106247
50"	1250	493639	27302	13591
52"	1300	619784	34658	17035
56"	1400	802076	44171	22022
58"	1450	1033221	57227	28166
64"	1600	1316658	760195	37497
66"	1650	167803	93951	46340
70"	1750	2140094	121463	59228
72"	1800	271241	155220	76372

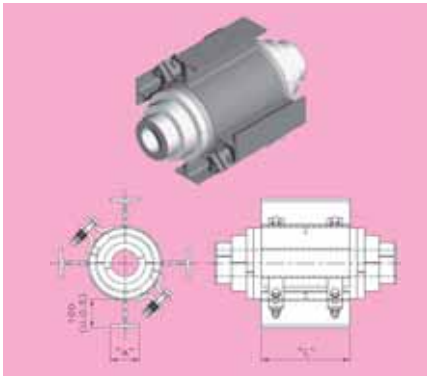
Please provide full piping specification & design conditions.



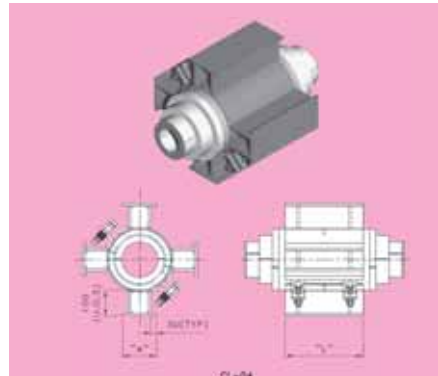
CL-02
For pipe sizes ½" to 3" NB.



CL-02
For pipe sizes over 3" NB.



CL-04
For pipe sizes ½" to 3" NB.



CL-04
For pipe sizes over 3" NB.

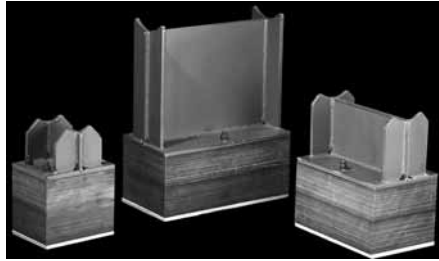
CRYOGENIC SUPPORTS

Densified Wood

Where insulation is not the primary concern and high load carrying capacity is required we recommend the use of Densified Wood as the thermal break.

A material that exhibits compressive strength approaching that of carbon steel, is totally resistant to corrosion and will not absorb moisture is ideally suited to the task of both supporting and anchoring cold pipework.

With extremely good screw holding capacity, pipe shoes and sliding plates can be safely fixed to our Densified Wood allowing a wide variety of support configurations to be used in conjunction with this material.



Simple weld-on shoes.

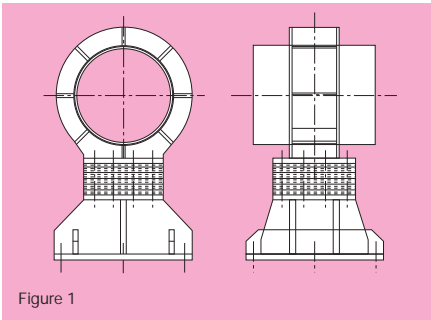


Figure 1

Figure 1 shows a typical cryogenic anchor where the pipe and upper part of the anchor would be insulated using Polyurethane Foam (PUF). The forces are transmitted through the Densified Wooden block into the base structure while the cold temperature is prevented from reaching it.

Such anchors and supports are designed to meet the customer's specific requirements and provide the best solution to a unique set of conditions.

Figure 2 shows a composite anchor using Densified Wood to transfer the forces and HD PUF to insulate the pipe.

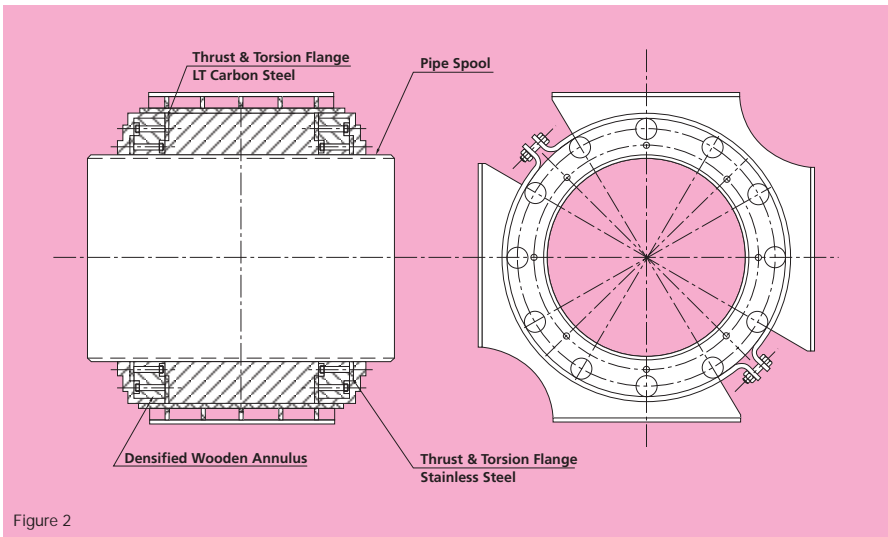


Figure 2

CRYOGENIC SUPPORTS

Due to the wide and varying range of support requirements we have not shown a 'standard' product for this material. Pipe Supports Group will be pleased to design supports that meet your specific requirements based upon the information provided in this catalogue.

Properties of Densified Wood

Specific Gravity		>1,35 g/cm ³	DIN 53 479
Modulus Of Elasticity In Flexure		14000 N/mm ²	DIN 53 452
Compressive Strength	⊥	250 N/mm ²	DIN 53 454
Compressive Strength		170 N/mm ²	DIN 53 454
Flexural Strength	⊥ and	120 N/mm ²	DIN 53 452
Tensile Strength		70 N/mm ²	DIN 53 455
Impact Strength	⊥	25 kJ/m ²	DIN 53 453
Impact Strength		20 kJ/m ²	DIN 53 453
Oil Absorption		Nil	DIN 7 707
Thermal Conductivity At Rt 20 °C		ca.0,30 [w/mK]	DIN 52 612
Operating Temperatures Continuous		90 °C	DIN 7 707
Electric Strength	20 °C	65 kV/25 mm	IEC 243-2/VDE 0303T.21
Electric Strength	90 °C	40 kV/25 mm	ICE 243-2/VDE 0303T.21
Dielectric Loss Factor At 50Hz	20 °C	0,02 tan δ	DIN 53 483
Insulation Resistance		10 ⁶ Ω x cm	IEC 93/ VDE 0303T.30
Track Resistance		CT 100	IEC 112/ VDE 0303T.1

Note: The data mentioned in the table gives average values obtained by statistical examination of laboratory results. This data is provided purely for information and shall not be regarded as binding.

