INTRODUCTION

Since 2001 Bergen Pipe Supports has become one of the main sources of design, innovation and cost-effective supply of pipe supports and restraints for use in plant operating at cold and cryogenic temperatures.

Many petrochemical processes, gas handling, storage and transportation cause or use very low temperatures which results in the need for very specialist materials and design to be able to effectively carry the piping and plant.

Bergen Pipe Supports 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.

Bergen Pipe Supports 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.

In 2017 Bergen Pipe Supports relocated their polyurethane plant to modern facilities in India while at the same time embarking on a focussed development program to extend the range of specialist materials we offer and to remove our reliance on sub-suppliers.

The result of 3 years of development was our Bergatherm composite load bearing insulation which is a material that uses high-strength glass fabrics held in a matrix of a specially formulated synthetic resin.

The primary application for cryogenic pipe supports and restraints is the LNG industry; extraction, liquefaction, transportation, storage and regassification all need supports and restraints in some form.

The two key functions are to insulate while carrying the piping and to isolate while restraining the piping and key items of plant. These tasks are met by using our high-density polyurethane foam with its good strength and low thermal conductivity to maintain the integrity of the insulation system together with Bergatherm to handle the very high loads while providing good thermal protection to the surrounding structure.

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.

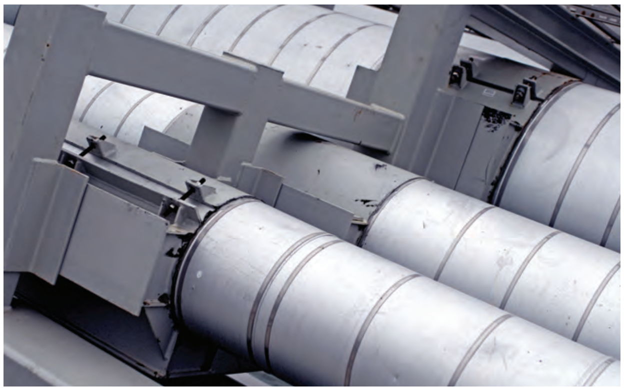
Low temperature causes normal carbon steel to become brittle and steels to withstand very low temperatures are expensive and sometimes difficult to process.

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.



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COMPARISON OF PROPERTIES:

The following table compares the insulation and isolation performance of HD PUF with both Bergatherm and Densified Wood.

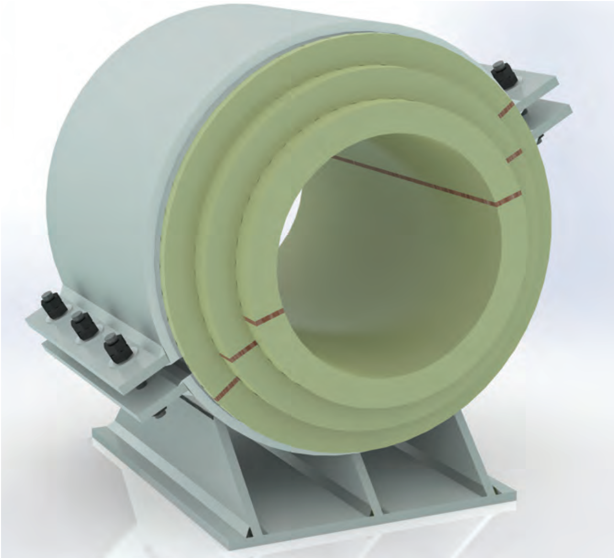
Mnaterial	Density (kg/m3)	Thermal Conductivity (W/mK at 22oC)	Compressive Strength (MPa at 23°C)	Working Temperature Range (oC)
High Density Polyurethane Foam	160 to 500	0.02 to 0.08	2.23 to 17.75	-196 to 140
Bergatherm Composite	1800	<0.3	>250	-196 to 225
Bergatherm HTS Composite	1800	<0.3	>250	-196 to 350
Laminated Wood	1350	<0.3	>270	-196 to 100

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

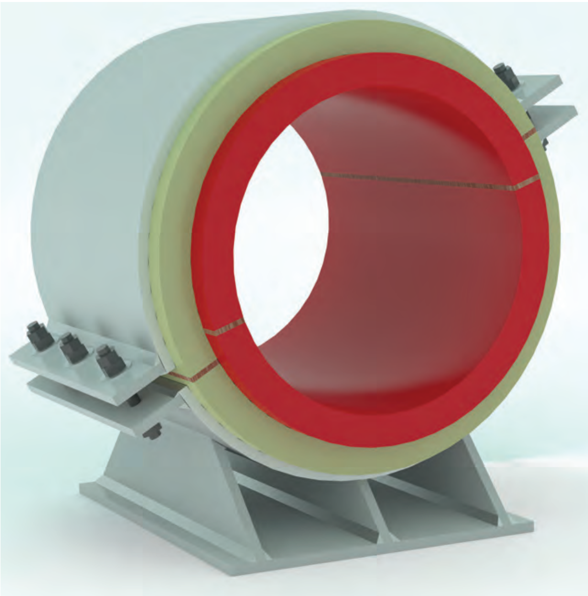
Comparing Bergatherm to HD PUF the allowable compressive load for Bergatherm is approximately 50N/mm2 whereas for HD PUF it is a fraction of that value at approximately 0.7N/mm2. Densified Wood by comparison is capable of sustaining compressive stresses up to 58N/mm2. Therefore it is clear that where 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 Bergatherm which allows acceptable insulation properties to be achieved and yet sustain very high loading.

The advantages of HD PUF as an insulator are clear. As a simple example of the material's load carrying capability, if we consider a 600NB pipe being carried in a cradle that is 300mm long. In a simple resting type cradle the PUF could carry a vertical load of 29,000kg. While we may think of HD PUF as a relatively weak material, it is surprising how much force it is able to safely sustain.



Insulated pipe shoe using moulded, 180° segments of HD PUF



Insulated pipe shoe using inner layer of Bergatherm & outer layer of HD PUF

HIGH DENSITY POLYURETHANE SUPPORTS

Our High Density Polyurethane materials 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 sheet 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.

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 ---

- 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.

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

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.

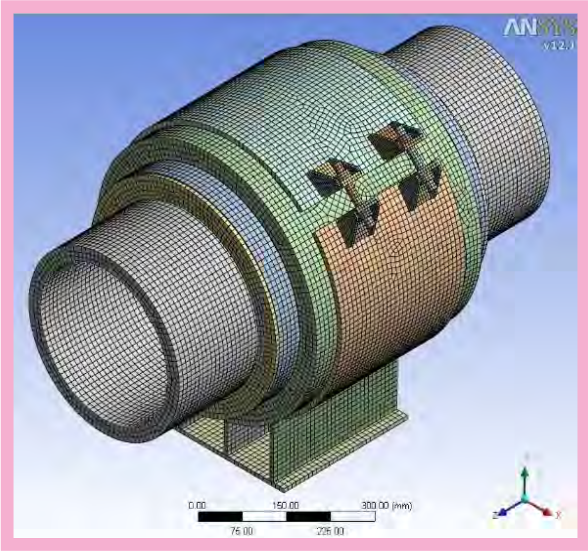
HD PUF is supplied in the following densities —

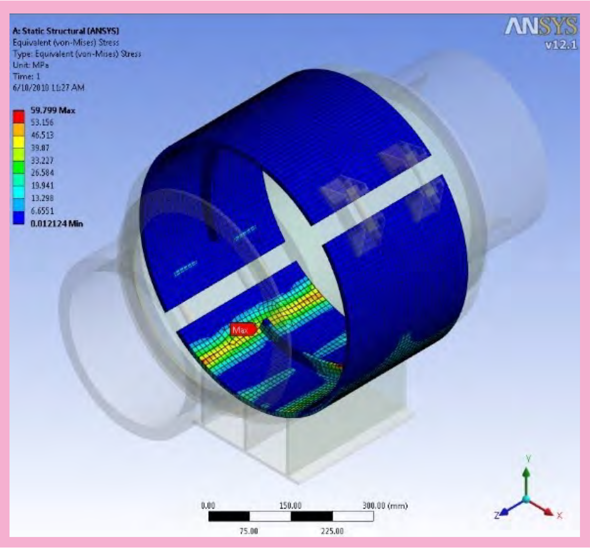
Pipe Size (NB)	Lower Cradle (kg/m³)	Upper Cradle (kg/m³) Resting type	Upper Cradle (kg/m³) Line Stops and Anchors
Up to 150	160 (Natural)	160	160
200 to 600	224 (Red)	160	224
Over 600	320 (Green)	160	320
Special Needs	500 (Natural)	500	500

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.





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 –

(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

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

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610 < Pipe O/D < 1016mm	Clearance = 12mm
Pipe O/D > 914mm	Clearance = 20mm

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/m^2K)
Wind Velocity = 3m/second

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

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

Rate of Heat Transfer q(W/m^2) = $(T_1-T_m).R$

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

Where
- d_o = Pipe O/Dia.
- d_n = Insulation O/Dia.
- T_1 = Pipe Temperature.
- T_m = The ambient temperature of the air.
- T_2 = Surface temperature of the insulation.

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/m^2K)
Wind Velocity = 3m/second

Surface Coefficient (f W/m^2K) 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

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

Rate of Heat Transfer q(W/m^2) $= (T_1-T_m).R$

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

Where
d_o = Pipe O/Dia.
d_n = Insulation O/Dia.
T_1 = Pipe Temperature.
T_m = The ambient temperature of the air.
T_2 = Surface temperature of the insulation.

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/m^2K)
Wind Velocity = 3m/second

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

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

Rate of Heat Transfer q(W/m^2) $= (T_1-T_m).R$

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

Where d_o = Pipe O/Dia.
d_n = Insulation O/Dia.
T_1 = Pipe Temperature.
T_m = The ambient temperature of the air.

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	22.55	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/m^{2}K)
Wind Velocity = 3m/second

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

Thermal Resistance R(m^{2}K/W) $= d_o/(f.d_n)+\{(d_o/k).\ln(d_n/d_o)\times10^{-3}\}$

Rate of Heat Transfer q(W/m^2) $= (T_1-T_m).R$

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

Where
- d_o = Pipe O/Dia.
- d_n = Insulation O/Dia.
- T_1 = Pipe Temperature.
- T_m = The ambient temperature of the air.
- T_2 = Surface temperature of the insulation.

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	15.80	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/m^2K)
Wind Velocity = 3m/second

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

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

Rate of Heat Transfer q(W/m^2) $= (T_1-T_m).R$

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

Where
d_o = Pipe O/Dia.
d_n = Insulation O/Dia.
T_1 = Pipe Temperature.
T_m = The ambient temperature of the air.
T_2 = Surface temperature of the insulation.

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/m^{2}K)
Wind Velocity = 3m/second

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

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

Rate of Heat Transfer q(W/m^2) $= (T_1-T_m).R$

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

Where
d_o = Pipe O/Dia.
d_n = Insulation O/Dia.
T_1 = Pipe Temperature.
T_m = The ambient temperature of the air.
T_2 = Surface temperature of the insulation.

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/m^2K)
Wind Velocity = 3m/second

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

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

Rate of Heat Transfer q(W/m^2) $= (T_1-T_m).R$

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

Where d_o = Pipe O/Dia.
d_n = Insulation O/Dia.
T_1 = Pipe Temperature.
T_m = The ambient temperature of the air.
T_2 = Surface temperature of the insulation.

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	22.88	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/m^{2}K)
Wind Velocity = 3m/second

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

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

Rate of Heat Transfer q(W/m^2) $= (T_1-T_m).R$

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

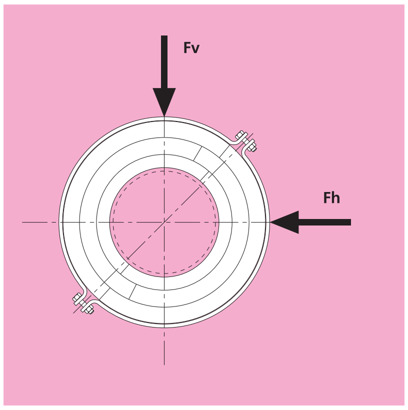
Where
- d_o = Pipe O/Dia.
- d_n = Insulation O/Dia.
- T_1 = Pipe Temperature.
- T_m = The ambient temperature of the air.
- T_2 = Surface temperature of the insulation.

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 —

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

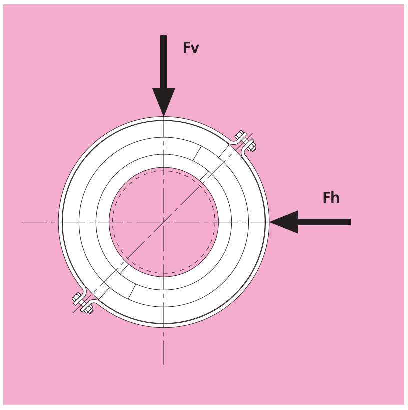


MAXIMUM RADIAL APPLIED LOADING

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	690.03	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 —

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



MAXIMUM AXIAL TORSION

Shoe Length		150	200	250	300	450	600
Pipe O/D	No. of Layers	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
	Clamp Bolt	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	22.27Nm	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	280.97Nm
139.7	M12	139.75Nm	186.32Nm	228.94Nm	228.94Nm	343.41Nm	343.41Nm
168.3	M12	202.82Nm	270.44Nm	275.81Nm	275.81Nm	413.71Nm	413.71Nm
193.7	M12	268.66Nm	317.43Nm	317.43Nm	317.43Nm	476.15Nm	476.15Nm
219.1	M12	343.74Nm	359.06Nm	359.06Nm	359.06Nm	538.59Nm	538.59Nm
244.5	M12	400.68Nm	400.68Nm	400.68Nm	400.68Nm	601.03Nm	601.03Nm
273	M12	447.39Nm	447.39Nm	447.39Nm	447.39Nm	671.09Nm	671.09Nm
323.9	M16	751.25Nm	0.99kNm	0.99kNm	0.99kNm	1.48kNm	1.48kNm
355.6	M16	0.91kNm	1.09kNm	1.09kNm	1.09kNm	1.63kNm	1.63kNm
406.4	M16	1.18kNm	1.24kNm	1.24kNm	1.24kNm	1.86kNm	1.86kNm
457	M16	1.39kNm	1.39kNm	1.39kNm	1.39kNm	2.09kNm	2.09kNm
508	M16	1.55kNm	1.55kNm	1.55kNm	1.55kNm	2.33kNm	2.33kNm
559	M16	1.71kNm	1.71kNm	1.71kNm	1.71kNm	2.56kNm	2.56kNm
610	M16	1.86kNm	1.86kNm	1.86kNm	1.86kNm	2.79kNm	2.79kNm
660	M20	3.12kNm	3.14kNm	3.14kNm	3.14kNm	4.72kNm	4.72kNm
711.2	M20	3.39kNm	3.39kNm	3.39kNm	3.39kNm	5.08kNm	5.08kNm
762	M20	3.63kNm	3.63kNm	3.63kNm	3.63kNm	5.44kNm	5.44kNm
813	M20	3.87kNm	3.87kNm	3.87kNm	3.87kNm	5.81kNm	5.81kNm
864	M20	4.12kNm	4.12kNm	4.12kNm	4.12kNm	6.17kNm	6.17kNm
914	M20	4.35kNm	4.35kNm	4.35kNm	4.35kNm	6.53kNm	6.53kNm
965.2	M20	4.60kNm	4.60kNm	4.60kNm	4.60kNm	6.90kNm	6.90kNm
1016	M20	4.84kNm	4.84kNm	4.84kNm	4.84kNm	7.26kNm	7.26kNm
1066.8	M24	7.32kNm	7.32kNm	7.32kNm	7.32kNm	10.98kNm	10.98kNm
1219.2	M24	8.37kNm	8.37kNm	8.37kNm	8.37kNm	12.55kNm	12.55kNm
1422.4	M24	9.76kNm	9.76kNm	9.76kNm	9.76kNm	14.64kNm	14.64kNm
1625.6	M24	11.16kNm	11.16kNm	11.16kNm	11.16kNm	16.73kNm	16.73kNm

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.

MAXIMUM AXIAL THRUST

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

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.

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	Pr = Maximum Allowable Radial Force
Ft = Applied Axial Torsion	Pt = Maximum Allowable Axial Torsion
Fa = Applied Axial Thrust	Pa = Maximum Allowable Axial Thrust

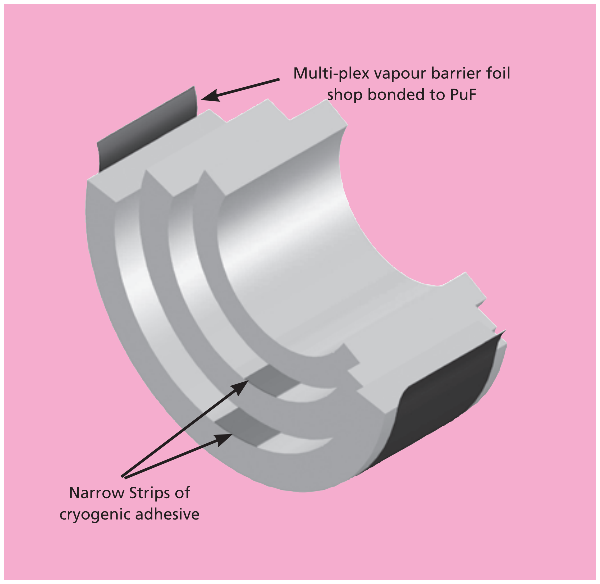
Validation of Design of HD PUF Cradle :

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.

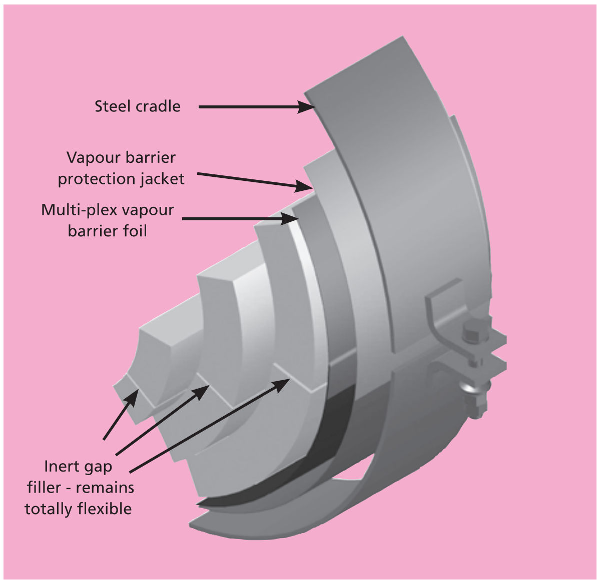
However by bonding the layers together with a narrow band of adhesive positioned along the quadrant of the moulding the multiple layers can flex and shear relative to one another thereby allowing the cradle to adjust its shape to suit geometric or dimensional anomalies.

The diagram shown on the right illustrates this principle ---



Strip bonding of lower insulation segments.

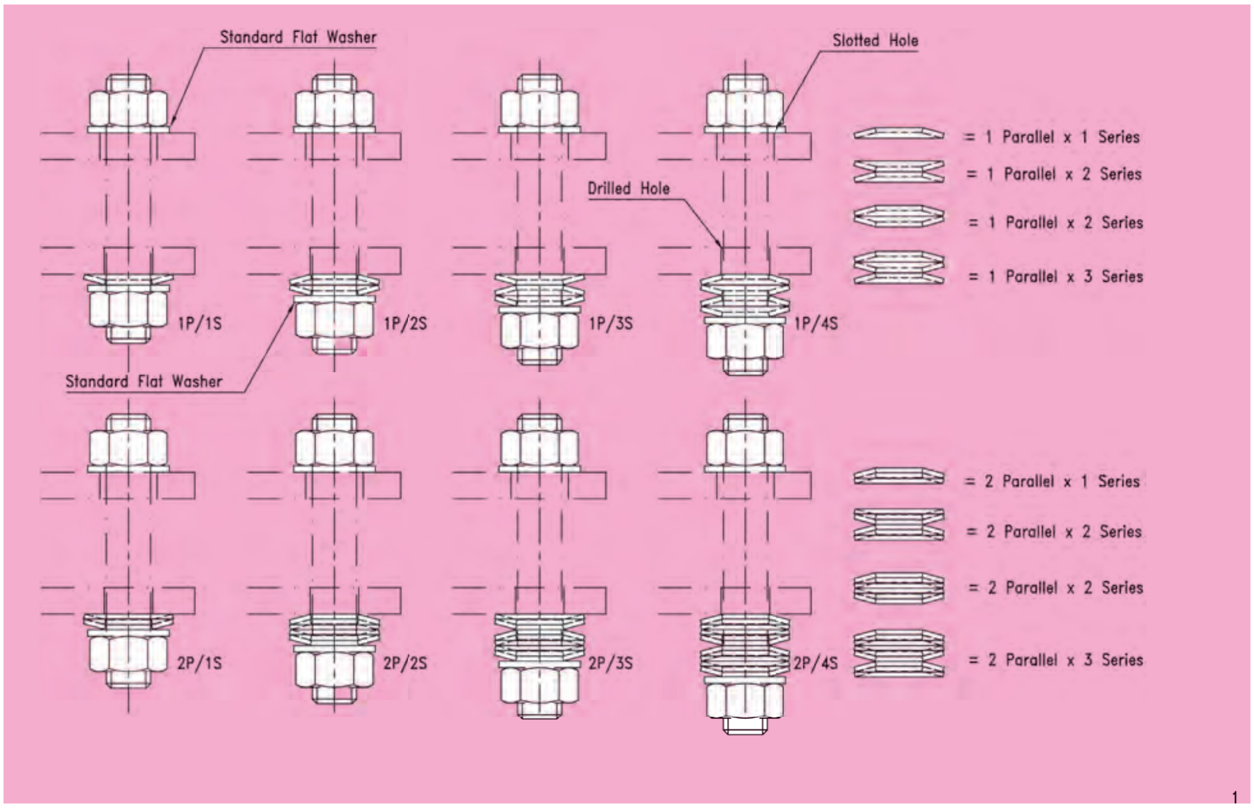
Full scale test of 30 " (750 NB) cryogenic pipe shoe at -165°C for client approval



Mutli-layer construction.

Bergen Pipe Supports has many years of experience of designing cold and cryogenic pipe supports and restraints using high-density polyurethane foam. We would be happy to discuss your specific requirements and work with your engineers to develop optimum solutions for your business needs.

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.

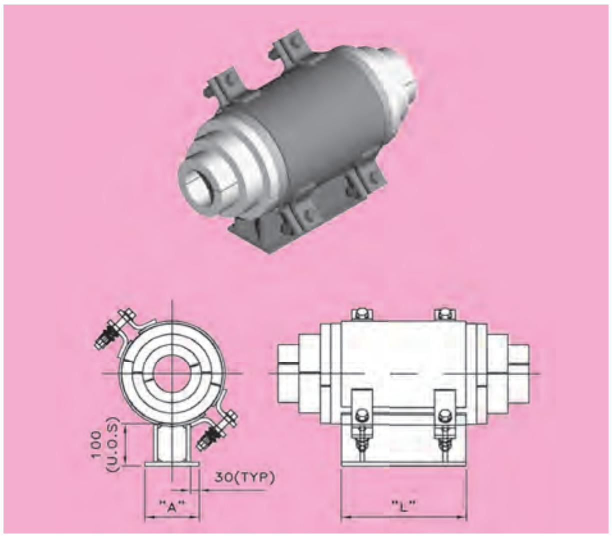
In practice the pipe cools to the same temperature of the fluid it carries. The inside face of the insulation will also cool to this temperature but the outer face of the PUF, exposed to the ambient conditions of the local environment will be held at a much higher temperature.

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.

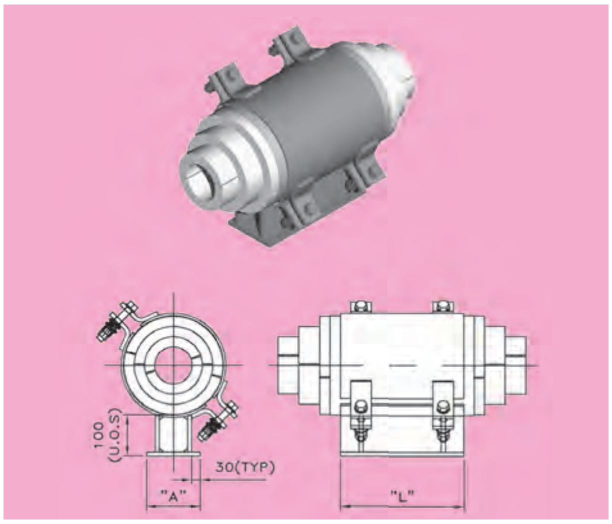
The above diagram explains the terminology used and shows how disc springs should be installed. We will provide bolt torque values on a contract by contract basis since this must take in to account the thickness of the insulation.

TYPE CS01 CRYOGENIC PIPE SHOE

PIPE SIZE		PIPE	DIMENSIONS		SWL (N)	
		OD	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



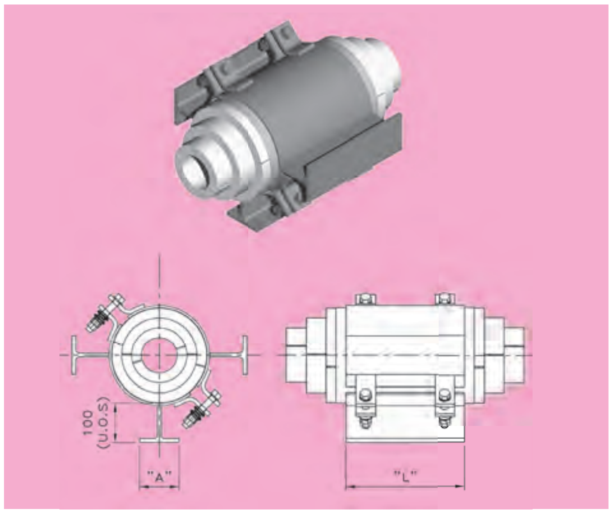
CS-01
For pipe sizes ½" to 3" NB.



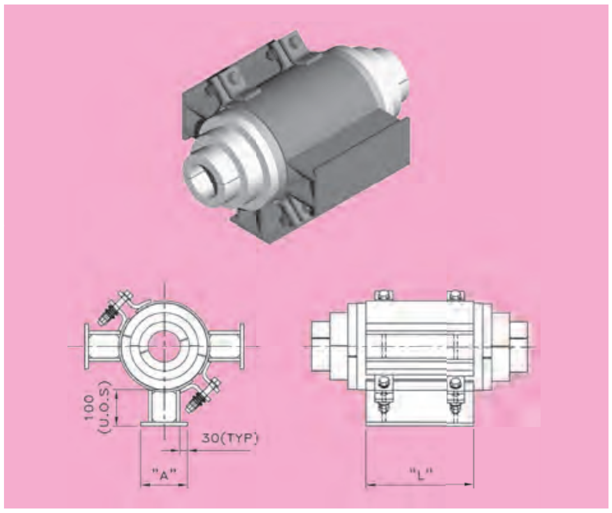
CS-01
For pipe sizes over 3" NB.

TYPE CG01, CG02 & CG03 SHOES

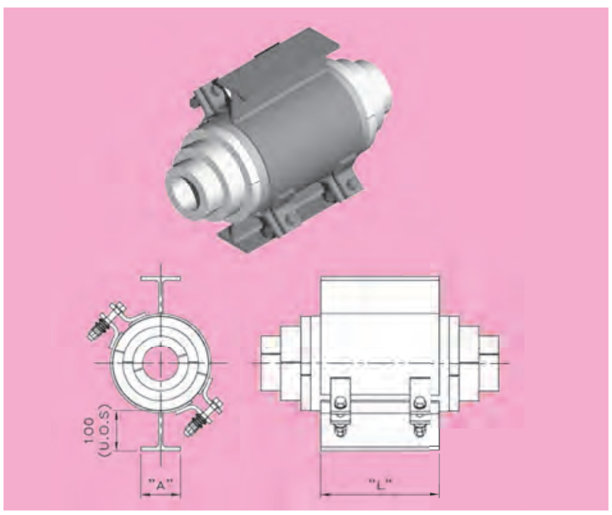
PIPE SIZE		SWL (N)		
		VERT	HOR	AXIAL
½"	15	1176	679	150
¾"	20	1485	857	150
1"	25	1861	1074	170
1½"	40	2667	1540	470
2"	50	6660	3845	610
2½"	65	8406	4853	770
3"	80	9820	5670	970
4"	100	12626	7290	1210
6"	150	18591	10734	1380
8"	200	59152	34153	2180
10"	250	73705	42555	2550
12"	300	87447	50489	3270
14"	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



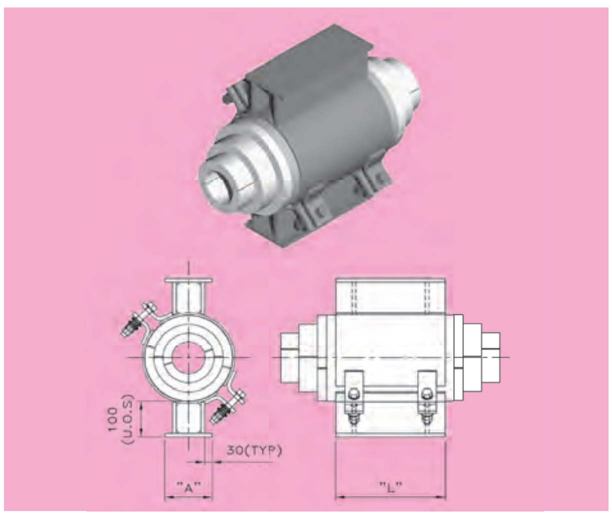
CG-01
For pipe sizes ½" to 3" NB.



CG-01
For pipe sizes over 3" NB.

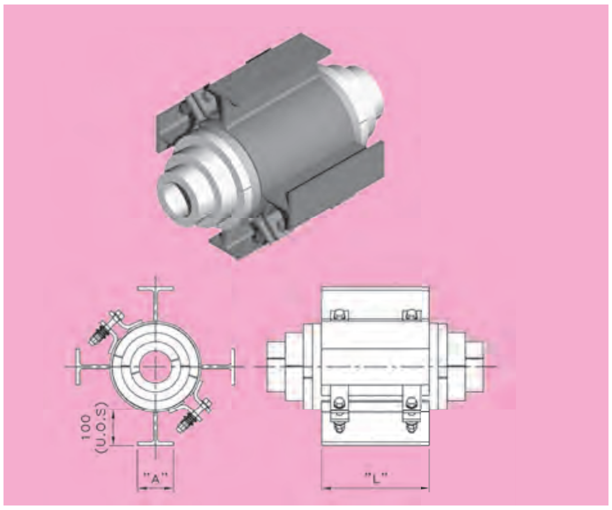


CG-02
For pipe sizes ½" to 3" NB.

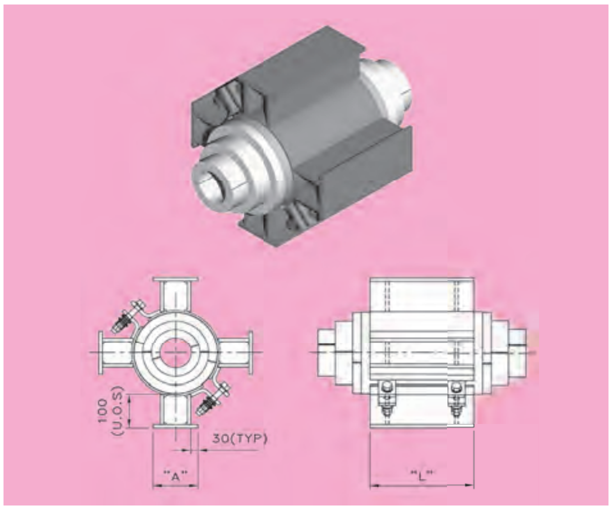


CG-02
For pipe sizes over 3" NB.

TYPE CG01, CG02 & CG03 SHOES



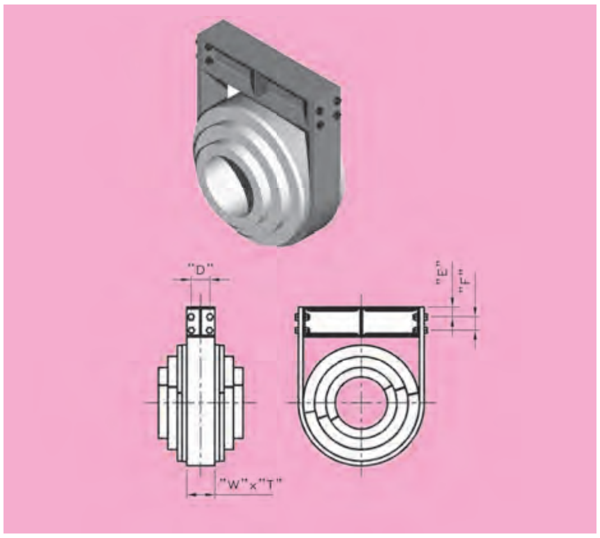
CG-03
For pipe sizes ½” to 3” NB.



CG-03
For pipe sizes over 3” NB.

TYPE CH01 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

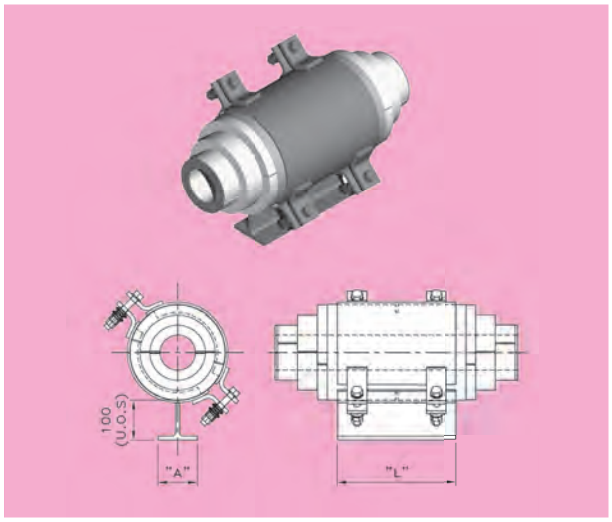


CH-01

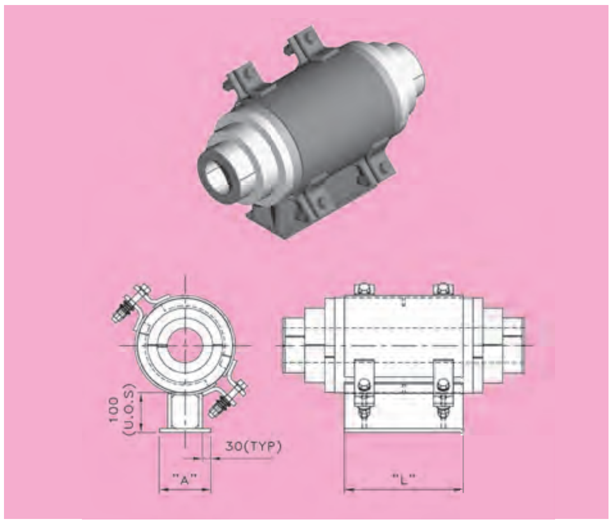
TYPE CL01 & CL03 SHOES

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	59152	34153	17745
10”	250	73705	42555	22111
12”	300	87447	50489	26234
14”	350	96005	55430	28801
16”	400	109721	63349	32916
18”	450	123382	71237	30714
20”	500	137151	78187	41145
22”	550	15866	87105	45259
24”	600	274483	158478	82344
26”	650	534891	308829	160467
28”	700	675038	332585	172811
30”	750	617183	356341	185154
32”	800	658328	380097	197498
34”	850	699474	403853	209842
36”	900	740295	427422	222088
38”	950	781765	451366	234529
40”	1000	822911	475122	246873
42”	1050	864056	498878	259216
44”	1100	905202	522634	271560
46”	1150	946348	546390	283904
48”	1200	987493	570146	296247
50”	1250	1028639	593902	308591
52”	1300	1069784	617658	320935
56”	1400	1152076	665171	345622
58”	1450	1193221	688927	357966
64”	1600	1416658	760195	394997
66”	1650	1357803	783951	407340
70”	1750	1440094	831463	432028
72”	1800	1481241	855220	444372

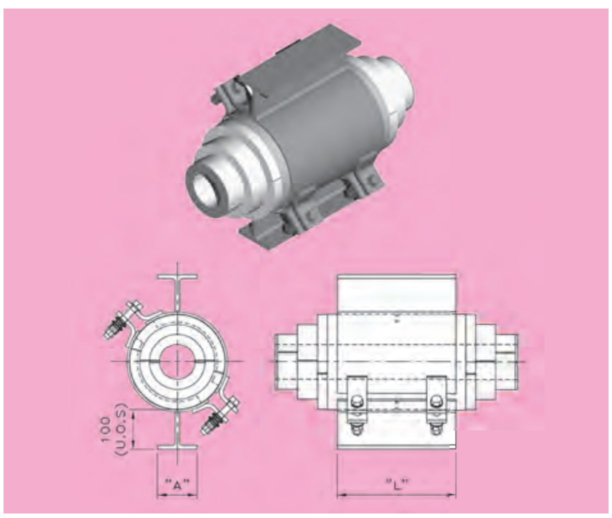
Please provide full piping specification & design conditions.



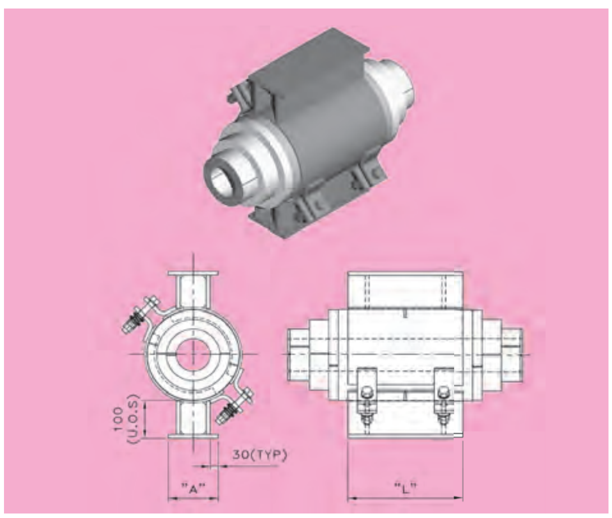
CL-01
For pipe sizes ½” to 3” NB.



CL-01
For pipe sizes over 3” NB.



CL-03
For pipe sizes ½” to 3” NB.

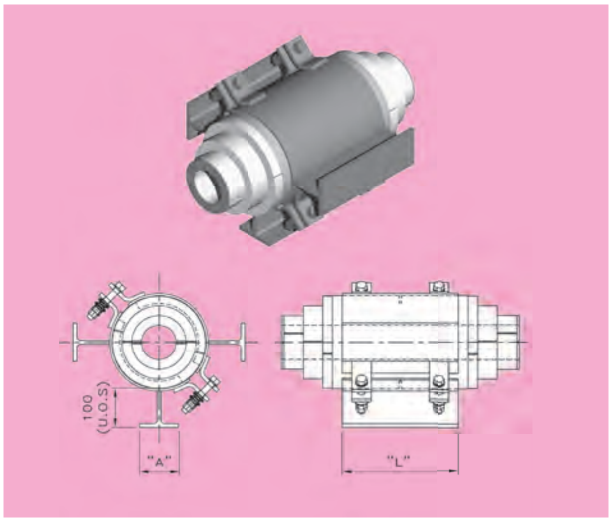


CL-03
For pipe sizes over 3” NB.

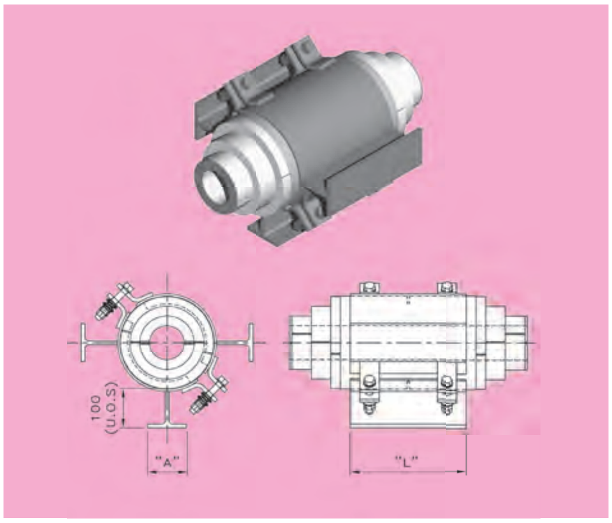
TYPE CL02 & CL04 SHOES

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	59152	34153	17745
10”	250	73705	42555	22111
12”	300	87447	50489	26234
14”	350	96005	55430	28801
16”	400	109721	63349	32916
18”	450	123382	71237	30714
20”	500	137151	78187	41145
22”	550	15866	87105	45259
24”	600	274483	158478	82344
26”	650	534891	308829	160467
28”	700	675038	332585	172811
30”	750	617183	356341	185154
32”	800	658328	380097	197498
34”	850	699474	403853	209842
36”	900	740295	427422	222088
38”	950	781765	451366	234529
40”	1000	822911	475122	246873
42”	1050	864056	498878	259216
44”	1100	905202	522634	271560
46”	1150	946348	546390	283904
48”	1200	987493	570146	296247
50”	1250	1028639	593902	308591
52”	1300	1069784	617658	320935
56”	1400	1152076	665171	345622
58”	1450	1193221	688927	357966
64”	1600	1416658	760195	394997
66”	1650	1357803	783951	407340
70”	1750	1440094	831463	432028
72”	1800	1481241	855220	444372

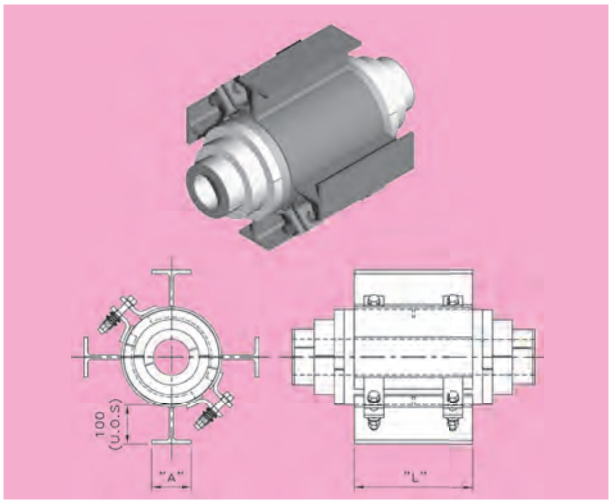
Please provide full piping specification & design conditions.



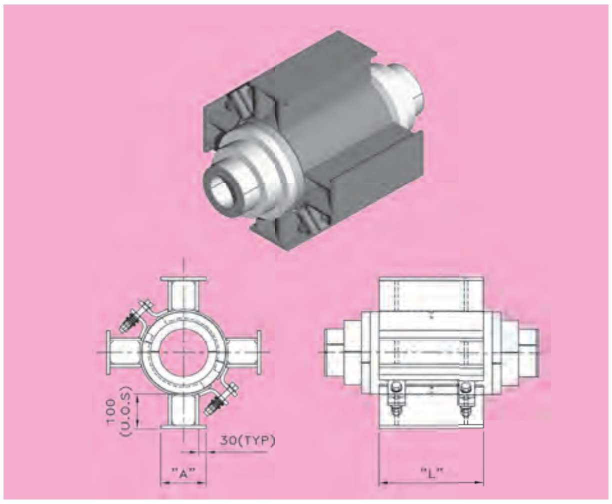
CL-02
For pipe sizes ½” to 3” NB.



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.

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.

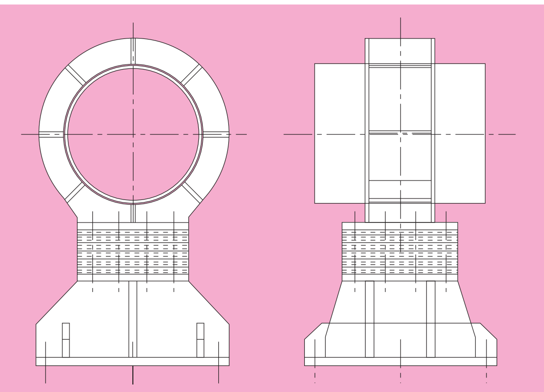
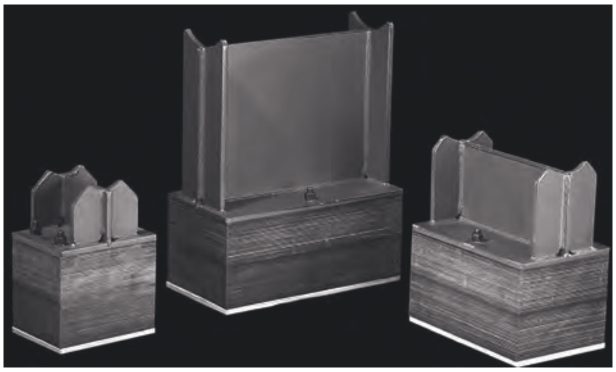


Figure 1



Simple weld-on shoes.

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.

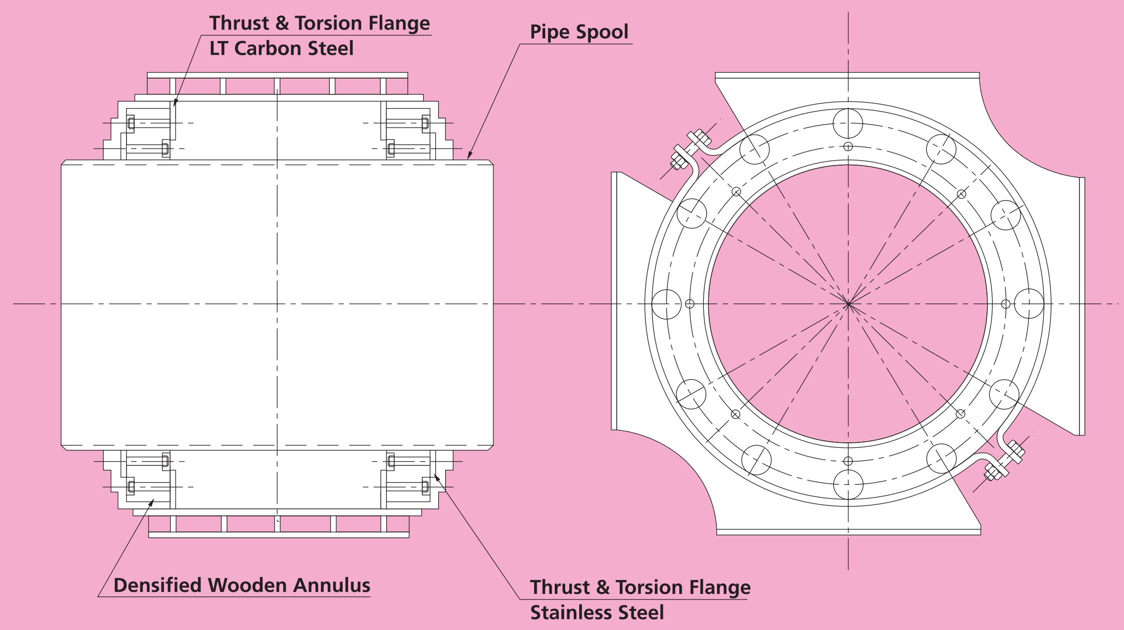


Figure 2

CRYOGENIC SUPPORTS AND RESTRAINTS

Due to the wide and varying range of support requirements we have not shown a 'standard' product for this material. Bergen Pipe Supports 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/cm³	DIN 53 479
Modulous Of Elasticity In Flexure		14000 N/mm²	DIN 53 452
Compressive Strength	⊥	250 N/mm²	DIN 53 454
Compressive Strength	‖	170 N/mm²	DIN 53 454
Flexural Strength	⊥ and ‖	120 N/mm²	DIN 53 452
Tensile Strength	‖	70 N/mm²	DIN 53 455
Impact Strength	⊥	25 kJ/m²	DIN 53 453
Impact Strength	‖	20 kJ/m²	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 ∂	DIN 53 483
Insulation Resistance		10^8 Ω × cm	IEC 93/ VDE 0303T.30
Track Resistance		CT 100	IEC 112/ VDE 0303T.1

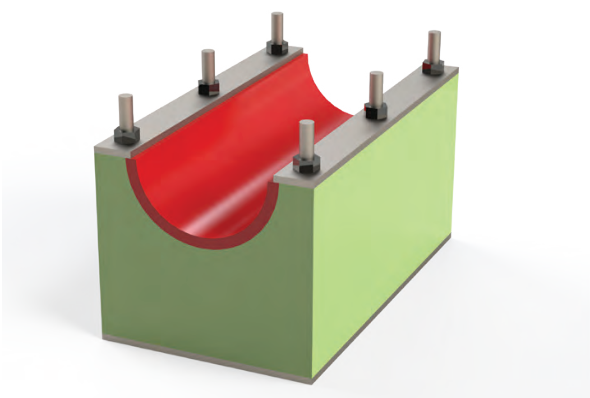
Note: The data mentioned in the table gives average values obtained by statistical examination of laboratory results. This data is provided purely for information and shall not be regarded as binding.

Bergatherm composite load-bearing insulation / isolation supports

Bergatherm is a composite material that uses high-strength glass fabrics held in a matrix of a specially formulated synthetic resin to produce a high-load bearing product, suitable for use in cryogenic and similar demanding applications.

Bergatherm has been developed to meet a significant market demand for this type of product. It follows in our tried and tested philosophy of horizontal integration, with which we aim to bring to our Customers the most advanced engineering solution for such applications with significantly reduced delivery lead times. These formulations have been carefully engineered and incorporated into our designs to provide solutions for our Customer’s requirements.

With our own product, Bergatherm, we can engineer the composition to give us the optimum properties and production method to suit the end use. We no longer have to accept compromise; Bergatherm gives our Customers the desired properties and allows us the most economic manufacturing method to minimise waste and reduce production lead-times.



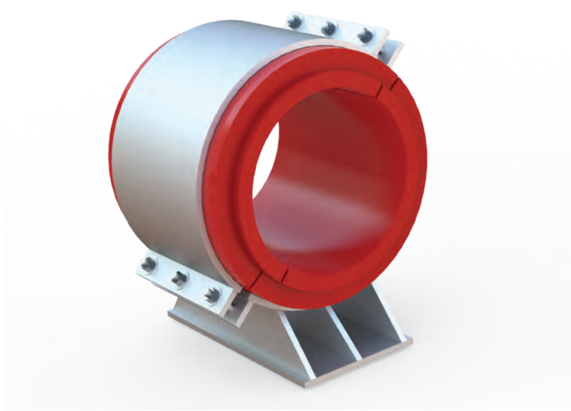
Applications

Bergatherm has been developed as an environmentally friendly replacement for hardwoods such as Oak, Iroko, Sapele, Cedar, Ash, Maple and Beech. These woods have been commonly used as supports for cold and cryogenic pipe work in refineries, gas handling and chemical plant where the operational parameters require both high strength and good insulation properties.

Over time wooden supports deteriorate, can leach acid leading to corrosion of the pipe, moisture absorption into the local insulation, degradation of the support and inefficiency in the process.

Other similar products such as laminated, resin impregnated woods are costly, have very long lead times and can be uneconomic to produce in some of the shapes that are required for supporting pipes. There are also significant physical limitations in which wood and laminated wood products can be used, especially at higher temperatures and in very wet conditions.

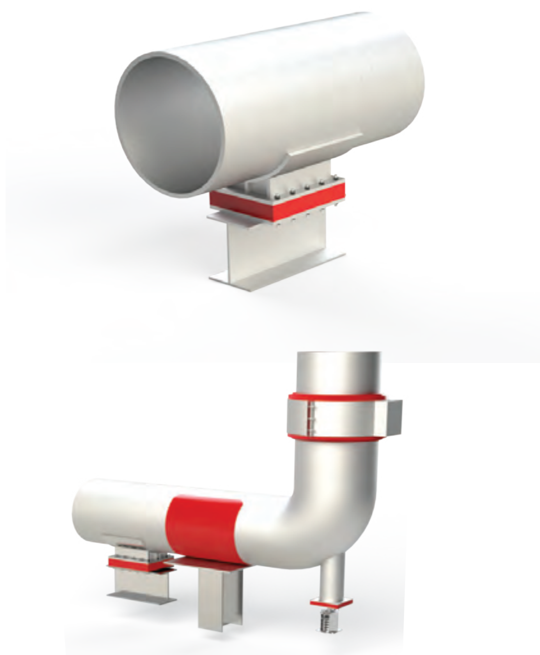
Bergatherm is used as a high-load capacity, cold isolation block typically found in situations where the cold temperature of the fluid within the pipe would cause potential embrittlement or damage to the surrounding structure. Such blocks are used as a thermal barrier between support structures and vessels or beneath trunnions or at line stops and anchors.



Bergatherm can be used to completely isolate a pipe, supplied in cylindrical form, moulded to shape to avoid waste and give increased strength over similar machined composites. Such product is used on flare lines where dual temperatures are often a feature.

Bergatherm not only possesses excellent low temperature properties but can also be used at temperatures far exceeding the limitations of wood, laminated wood and other commercial composite blocks while still retaining its mechanical properties.

Bergatherm can be used in combination with high-density polyurethane foam to provide a composite material with the insulation properties of polyurethane foam but the flexural strength and/or temperature resistance of Bergatherm. In this form we call the material Bergalite® because of the significant reduction in overall weight of the material.



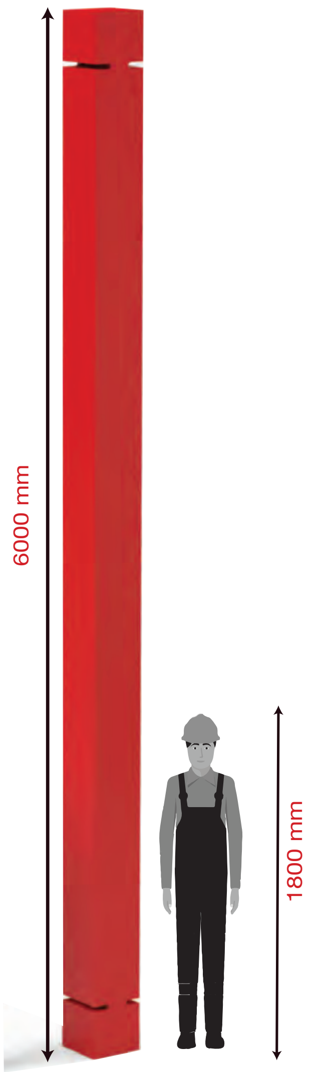
Typical illustration of Bergatherm applications in Piping Design

CRYOGENIC SUPPORTS AND RESTRAINTS

Key mechanical and physical properties of Bergatherm

Property	Unit of Measurement	Applicable Standard	Specifications
Specific gravity	gm/cm3	ISO 1183	1.80
Water absorption	%	ISO 62	< 0.40
Glass content	% by Weight	ISO 11358	60 ~ 70
Tensile strength	N/mm²	ISO 527 -4/5	>100
Compressive strength (Perpendicular to fibre direction) @ 23oC	N/mm²	ISO 14126	>250
Compressive strength Perpendicular to fibre direction) @ 225oC	N/mm²	IS 1998	>180
Impact strength un-notched	kJ / m2	ISO 179	>80
Thermal conductivity RT 23oC	W/mK	ASTM E 1530/ ASTM C 518	<0.30
Flammability	Seconds	UL-94	V0/<50
Thermal classification (Contact Surface Temperature)	°C	-	-196 to 225

*The above table lists the general properties of this material and are for reference purpose only. These have been achieved under controlled laboratory conditions and are subject to revision without notice. The user should obtain latest applicable information about the product prior to ordering and check, evaluate and ensure the suitability of the material for use in specific environment and conditions.



Our manufacturing know-how enables us to achieve product sizes which will be very difficult to meet using commercial timber sizes. Above product was designed for Gasification Plant.

Bergalite lightweight composite load-bearing insulation / isolation supports

Bergalite is the range of lightweight composite blocks, manufactured by Bergen Pipe Supports India, which combines the excellent insulation properties of high-density polyurethane foam and the superior mechanical properties of Bergatherm. This product has been engineered to be deployed as an effective thermal barrier and isolator in cryogenic and other similar and demanding applications, where temperatures can at times exceed the useful application range of PUF alone.

BPSI uses a highly sophisticated vacuum-assisted manufacturing process for producing Bergalite, which ensures that the resin impregnates fully, and any possibility of air entrapment is totally eliminated. Air entrapment is a common problem in products made using conventional open moulding processes and the vacuum-assisted process adapted by BPSI ensures that engineering parameters are achieved.

Bergalite is a highly engineered product based on sandwich composite construction and design methodology. The resulting product operates on the principle of an "I Beam", where most of the mechanical strength is focused on the outer fibres of the sandwich farthest from the bending axis. This resulting structure delivers superior performance when subjected to shear and buckling loads.

BPSI utilizes a specially formulated high-density foam as the core material for use in Bergalite design and manufacturing. Besides, contributing to the mechanical performance of sandwich construction, foam core also significantly enhances the acoustic and thermal insulation performance of Bergalite with respect to conventional composites.

Bergalite is suitably post-cured and then precision machined on CNC machining centres to ensure extremely accurate drilling location and dimensional accuracy. The edges of the finished component are also suitably protected to ensure that there is no moisture ingress.

Typical properties of Bergalite composite blocks are tabulated below :

Property	Unit of Measurement	Applicable Standard	Specifications
Density (Foam Core)	Kg/m3	ISO 1183	500 +/- 5%
Density (Composite Skin layer)	Kg / m3	ISO 1183	1800 +/- 10%
Water Absorption	%	ISO 62	< 1.5
Compressive Strength (Perpendicular Fiber direction)	kg/cm²	IS 1998	> 150
Thermal conductivity (@23 Deg C)	W/mK	W/mK	<0.3
Thermal Classification (Contact Surface Temperature)	°C	_	-196 to +140/225*

Note *Depending on thickness of Bergatherm composite.

The above table lists the general properties of this material and is for reference purposes only. These have been achieved under controlled laboratory conditions and are subject to revision without notice. The user should obtain the latest applicable information about the product prior to ordering and check, evaluate and ensure the suitability of the material for use in specific environments and conditions.

Bergatherm HTS (High Thermal Stability) composite load-bearing insulation / isolation supports

Bergatherm HTS is the latest development in our range of engineered composite products. It brings our customers a unique, reliable isolation and insulation solution for piping systems, subjected to cold and dual temperature service conditions.

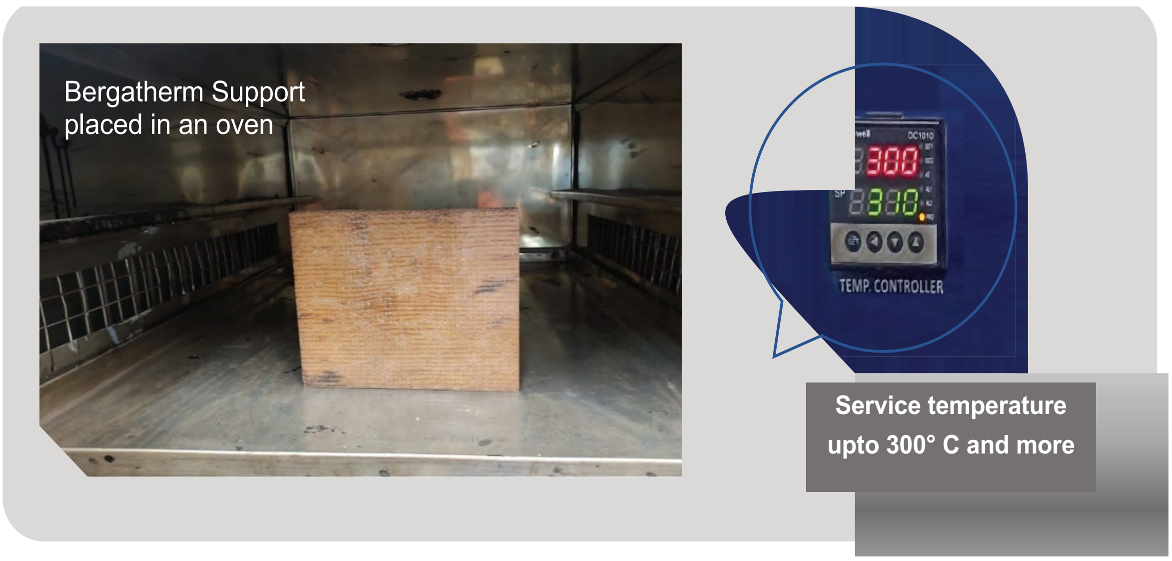
Bergatherm HTS offers vastly enhanced mechanical properties enabling the piping engineer to achieve an optimized insulated support system by eliminating the typical problems associated with the brittle and fragile nature of commercially available materials like cellular glass, which are normally used for cold and dual temperature services.

Bergatherm high-performance composite insulation products are formulated and manufactured by Bergen Pipe Supports India Private Limited (BPSI) using high-strength glass fabrics and thermoset resins, capable of achieving a very high glass transition temperature, to deliver very superior thermal and mechanical properties. They offer excellent thermal stability combined with superior flame, smoke, and toxicity profiles which result in a product, providing enhanced heat-shielding performance in demanding applications like oil, gas, and aerospace technologies where this functionality is often required.

BPSI uses a highly sophisticated vacuum-assisted manufacturing process to ensure that the resin impregnates fully with no air entrapment present. Air entrapment is a common problem in products made using conventional open contact molding processes. The manufacturing process adopted by BPSI ensures consistent and uniform laminate properties across the product.

Bergatherm HTS undergoes a carefully calibrated curing process during and post molding, which ensures that the product properties are uniformly distributed across the product.

The support components are machined to close tolerances, ensuring a precise assembly fit at the site. This is necessary to prevent any moisture and condensation ingress into the insulation. This avoids typical problems like corrosion under insulation (CUI) and loss of insulation characteristics.



Typical properties of Bergatherm HTS composite blocks are tabulated below :

Property	Unit of Measurement	Applicable Standard	Specifications
Density	Kg/m3	ISO 1183	1800±5%
Flammability	Seconds	UL-94	V-0
Thermal Conductivity @ 23°C	W/mK	ASTM C 518	<0.3
Compressive Strength (23°C to 350°C)	MPa	IS 1998-1962	>250
Impact Strength (-196°C to + 23°C)	KJ/m2	ASTM D4812	>80
Tensile Strength @ 23°C	MPa	ISO 527-05-2009	>150
Tensile Modulus @ 23°C	GPa	ISO 527-05-2009	>12
Flexural Strength @ 23°C	MPa	ASTM D7264	>100
Shear Strength @ 23°C	MPa	ASTM D5379	>85
Combustibility	%	ASTM E136 - 11	< 10
Limiting Oxygen Index	Response	ASTM D2863 - 13	0
Thermal Classification (Contact Surface Temperature)	°C		-196°C to 350°C

The above table lists this material's general properties and is for reference only. These have been achieved under controlled laboratory conditions and are subject to revision without notice.

The user should obtain the latest applicable information about the product before ordering and check, evaluate and ensure the suitability of the material for use in specific application environment and conditions. Additional tests and testing at different standards can also be conducted by prior agreement to specific customer requirements.

Key Projects

Bergen Pipe Supports Group has 25+ years of continued and successful track record of engineering and supplying cryogenic supports and restraints to customers and projects across the Globe. The diverse geographical and customer base demonstrates the wide acceptance and preference for our engineered solutions. Some of the significant projects serviced by us during this period are listed below.

Country	Project
Algeria	Arzew LNG Terminal Refurbishment
Australia	Australia Pacific LNG Cameron LNG Gorgon LNG Ichthys LNG Moomba LNG
Azerbaijan	Azerikimya Modernization Project
Chile	GNL Quintero LNG Terminal
China	Fujian LNG Terminal and Trunkline Project Guangdong Zhuhai LNG Project Phase 1
Egypt	Damietta LNG Plant expansion
France	Montoir de Bretagne LNG Terminal upgrade
Greece	Revithoussa Island LNG Plant Expansion
India	Dahej LNG Terminal Dhamra LNG Terminal Chhara LNG Terminal LNG Tanks at Mundra LNG Terminal RIL Jamnagar Refinery Project
Israel	Karish Gas Development
Italy	Livorno FSRU
Kuwait	Gas Train 5 project at Mina Al-Ahmadi Refinery Haradh and Hawiyah Gas Project KNPC Clean Fuels Project MAA Refinery GT-5 Project New Gathering Centre For SEK, GG-32
Malaysia	Petronas LNG Train 9 MLNG Rose, Dua, Tiga Petronas Tank 7 & New LNG Jetty - PAF
Mozambique	Mozambique LNG Project
Norway	Hammerfest LNG Project
Oman	Oman LNG Project
Papua New Guinea	PNG LNG Plant
Peru	Peru LNG Terminal
Qatar	KGXX Expansion Ras Laffan Onshore Expansion Phase 2 RGX 6&7 Project North Field Expansion Project QGX2 project
Russian Federation	Arctic LNG 2 project
Saudi Arabia	Barzan Onshore Farabi Project Juaymah Enhanced LPG Piping Network SABIC IBB Reliability Improvement Project
Singapore	Singapore LNG Terminal
Spain	Barcelona LNG Terminal Cartagena LNG Terminal Huelva LNG Terminal
Thailand	PTT LNG Jetty Development and LNG receiving Terminal
UK	South Hook LNG receiving Terminal Isle of Grain LNG receiving Terminal
Yemen	Yemen LNG Plant

NOTES

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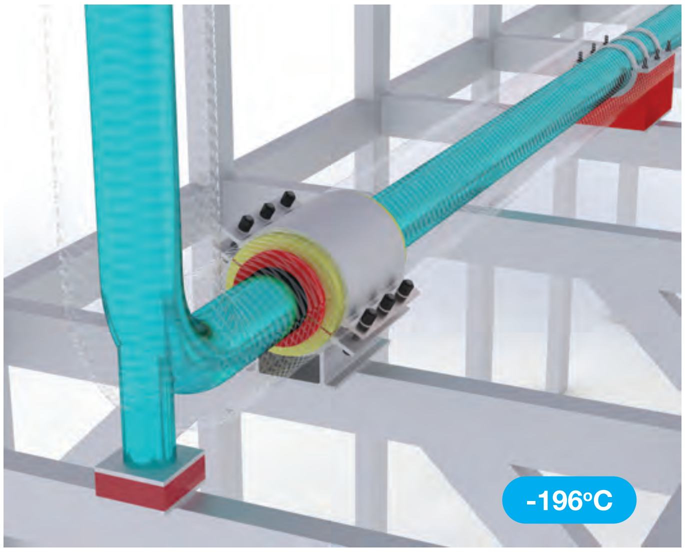
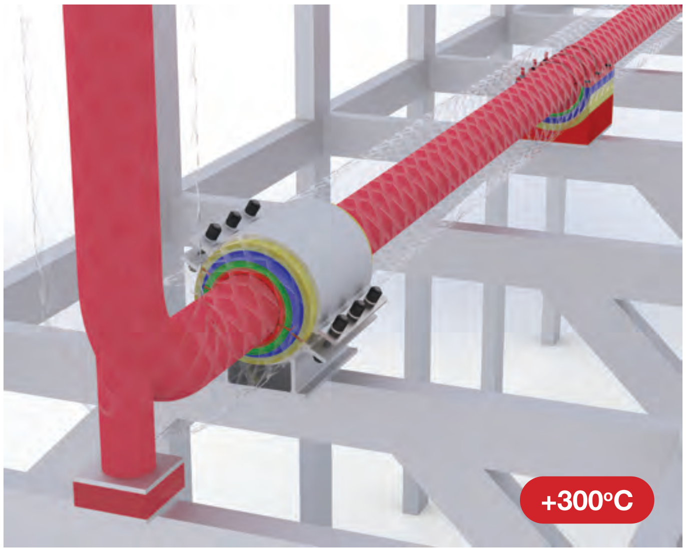
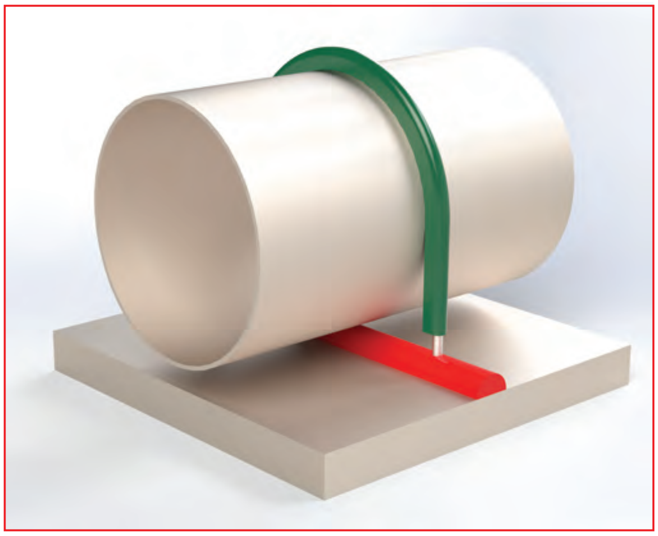
CRYOGENIC SUPPORTS AND RESTRAINTS

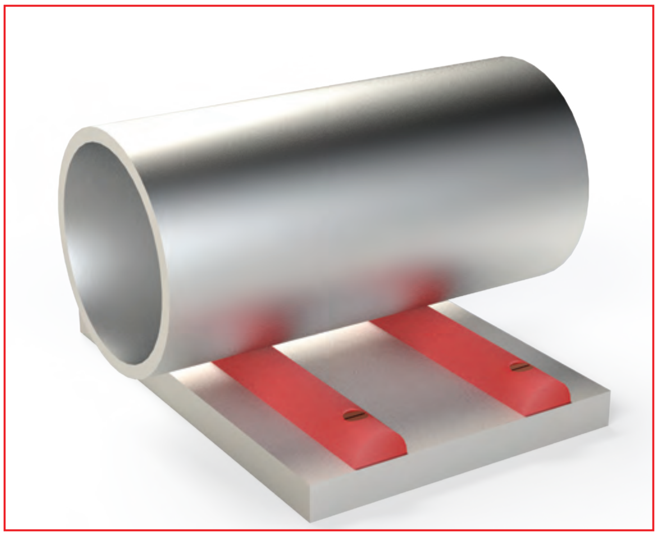




Bergatherm Composite Isolation for dual temperature and/or high-load applications.



Bergatherm Half-Round with insulated U-Bolt



Bergatherm Half-Round

Bergatherm Pipe Wraps