APPENDIX K - MANUFACTURERS' SPECIFICATIONS

The following pages are manufacturers' specifications for parts provided in the Official Kit of Parts.

Additional booklets are in the Kit.

Be sure to read these spec sheets in order to properly allocate and use components.

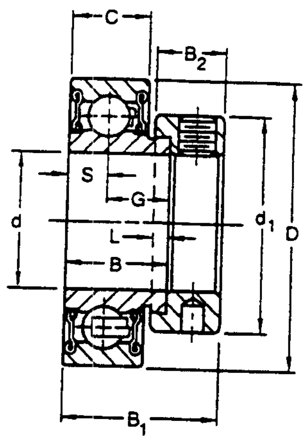
RA-RR, RA-RRB Series Non-Relubricatable Types

The RA-RR Series bearings are extended inner ring type with self-locking collar. A positive contact, land riding R-seal provides improved protection against harmful contaminants and effectively retains the lubricant under severe operating conditions. A 6/6 molded nylon retainer has proven extremely effective under conditions of misalignment. RA-RR Series bearings are factory prelubricated.

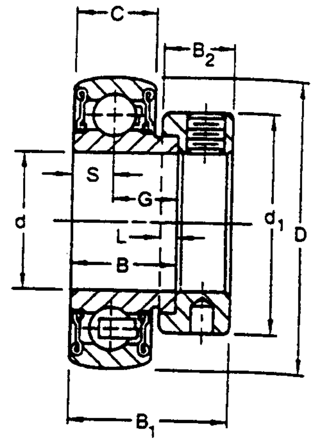
The RA-RR Series has cylindrical outside diameters.

The RA-RRB Series has spherical-outside diameters for use in housings with corresponding spherical inside surfaces to provide unrestricted initial self-alignment.

Recommended shaft tolerances: 1/2"-1 15/16", nominal to -.0005", -.013mm; 2"-2 3/16", nominal to -.0010", -.025mm.



RA-RR Two Seals Cylindrical O.D.



RA-RRB Two Seals Spherical O.D.

TO ORDER, SPECIFY BEARING NUMBER FOLLOWED BY "AND COLLAR". EXAMPLE: RA100RRB AND COLLAR.

Bearing Number Cylindrical O.D.	Bearing Number Spherical O.D.	Collar Number	Basic Outer Size	Bore[1] d in.	Bore[1] d mm	O.D. D in. / mm	Ring Widths B Inner in. / mm	Ring Widths C Outer in. / mm	S in. / mm	G in. / mm	L in. / mm	d_1 in. / mm	B_2 in. / mm	B_1 in. / mm	Brg. & Collar Wt. lbs	Brg. & Collar Wt. kg	Static Load C_O lbs / N	Extended Dynamic Rating C_E lbs / N
RA008RR	RA008RRB	S1008K	203	1/2	17	1.5748 / 40	0.750 / 19.05	0.512[2] / 13	0.256 / 6.5	0.494 / 12.55	5/32 / 4.0	1 1/8 / 28.6	17/32 / 13.5	1 1/8 / 28.6	0.34	0.154	1000 / 4400	2360 / 10600
RA009RR	RA009RRB	S1009K		9/16											0.32	0.145		
RA010RR	RA010RRB	S1010K		5/8											0.28	0.127		
RAE17RR	RAE17RRB	SE17K													0.28	0.127		
RA012RR	RA012RRB	S1012K	204	3/4	20	1.8504 / 47	0.844 / 21.44	0.591[3] / 15	0.295 / 7.49	0.548 / 13.92	5/32 / 4.0	1 5/16 / 33.3	17/32 / 13.5	1 7/32 / 31	0.29	0.132	1400 / 6200	3200 / 14300
RAE20RR	RAE20RRB	SE20K													0.29	0.132		
RA013RR	RA013RRB	S1013K	205	13/16	25	2.0472 / 52	0.844 / 21.44	0.591 / 15	0.295 / 7.49	0.548 / 13.92	5/32 / 4.0	1 1/2 / 38.1	17/32 / 13.5	1 7/32 / 31	0.51	0.231	1560 / 6950	3450 / 15600
RA014RR	RA014RRB	S1014K		7/8											0.47	0.213		
RA015RR	RA015RRB	S1015K		15/16											0.44	0.2		
RA100RR	RA100RRB	S1100K		1											0.41	0.186		
RAE25RR	RAE25RRB	SE25K													0.41	0.186		
RA101RR	RA101RRB	S1101K	206	1 1/16	30	2.4409 / 62	0.938 / 23.82	0.709 / 18	0.354 / 8.99	0.583 / 14.81	5/32 / 4.0	1 47/64 / 44.1	5/8 / 15.9	1 13/32 / 35.7	0.77	0.349	2280 / 10000	4800 / 21600
RA102RR	RA102RRB	S1102K		1 1/8											0.72	0.327		
RA103RR	RA103RRB	S1103K		1 3/16											0.7	0.318		
RA103RR2	RA103RRB2	S1103K3		1 1/4											0.65	0.295		
RAE30RR	RAE30RRB	SE30K													0.7	0.318		
RA104RR	RA104RRB	S1104K	207	1 1/4	35	2.8346 / 72	1.000 / 25.4	0.748 / 19	0.374 / 9.5	0.626 / 15.9	5/32 / 4.0	2 1/8 / 54.40	43/64 / 17.1	1 17/32 / 38.9	1.24	0.562	3050 / 13700	6400 / 28500
RA105RR	RA105RRB	S1105K		1 5/16											1.19	0.54		
RA106RR	RA106RRB	S1106K		1 3/8											1.13	0.513		
RA107RR	RA107RRB	S1107K		1 7/16											1.05	0.476		
RAE35RR	RAE35RRB	SE35K													1.13	0.513		
RA108RR	RA108RRB	S1108KT	208	1 1/2	40	3.1496 / 80	1.188 / 30.18	0.866[4] / 22	0.433 / 11	0.755 / 19.18	3/16 / 4.8	2 3/8 / 60.3	23/32 / 18.3	1 23/32 / 43.7	1.53	0.694	4000 / 17600	8150 / 36000
RA109RR	RA109RRB	S1109KT		1 9/16											1.43	0.649		
RAE40RR	RAE40RRB	SE40K													1.43	0.649		
RA110RR	RA110RRB	S1110K	209	1 5/8	45	3.3465 / 85	1.188 / 30.18	0.866 / 22	0.433 / 11	0.755 / 19.18	3/16 / 4.8	2 1/2 / 63.5	23/32 / 18.3	1 23/32 / 43.7	1.72	0.78	4000 / 17600	8150 / 36000
RA111RR	RA111RRB	S1111K		1 11/16											1.62	0.735		
RA112RR	RA112RRB	S1112K		1 3/4											1.5	0.68		
RAE45RR	RAE45RRB	SE45K													1.5	0.68		
RA113RR	RA113RRB	S1113K	210	1 13/16	50	3.5433 / 90	1.188 / 30.18	0.866 / 22	0.433 / 11	0.755 / 19.18	3/16 / 4.8	2 3/4 / 69.9	23/32 / 18.3	1 23/32 / 43.7	1.94	0.88	4500 / 19600	8800 / 3900
RA114RR	RA114RRB	S1114K		1 7/8											1.83	0.83		
RA115RR	RA115RRB	S1115K		1 15/16											1.70	0.771		
RA115RR2	RA115RRB2	S1115K2		2											1.58	0.717		
RAE50RR	RAE50RRB	SE50K													1.79	0.771		
RA200RR	RA200RRB	S1200K	211	2	55	3.9370 / 100	1.281 / 32.54	0.945 / 24	0.472 / 11.99	0.809 / 20.55	3/16 / 4.8	3 / 76.2	13/16 / 20.6	1 29/32 / 48.4	2.12	0.962	5630 / 25000	10800 / 48000
RA201RR	RA201RRB	S1201K		2 1/16											1.98	0.898		
RA202RR	RA202RRB	S1202K		2 1/8											1.89	0.857		
RA203RR	RA203RRB	S1203K		2 3/16											1.78	0.807		
RAE55RR	RAE55RRB	SE55K													1.78	0.807		

[1] Bore tolerance is nominal to +.0005", .013mm

[2] Spherical O.D. outer ring width is .472", 12mm

[3] Spherical O.D. outer ring width is .551", 14mm

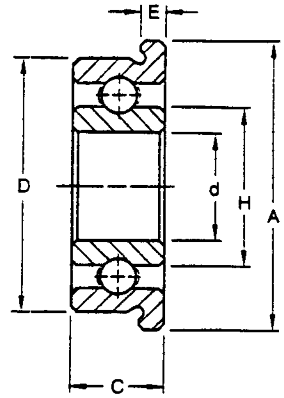
[4] Spherical O.D. outer ring width is .827", 21mm

Flanged Series

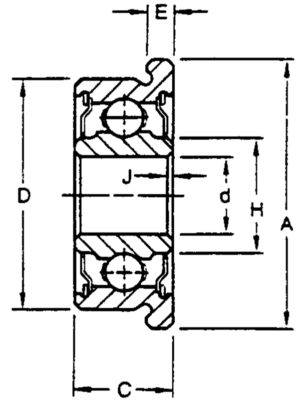
CYLINDRICAL O.D.

Four sizes in the cylindrical O.D. series are offered in a flanged construction. Flanged bearings have integral shoulders for mounting in through-bored housings. These flanged bearings have straight outside diameters and are interchangable with the corresponding unflanged sizes. The flanged group is available with double shields.

These bearings are electric motor quality for applications where extra quietness is a requirement.



Open Type



Shielded Type

DIMENSIONS – TOLERANCES

Bearing Number open	Bearing Number shielded*	Bore d +0.0000" -0.0003" +0.000" mm -0.008 mm		chamfer J x 45° +0.010" -0.000" +0.25 mm -0.00 mm		Outside Diameter D +0.000" -0.0004 +0.000 mm -0.010 mm.		Width C +0.000" -0.005" +0.00 mm -0.13 mm		Inner Ring Shoulder H min		Flange* A +0.005" -0.002" +0.13 mm -0.05 mm		Flange* E ±0.002" ±0.05 mm		Shielded Type Overall Width +0.000" -0.005" +0.00 mm -0.13 mm		Shielded Type H min		Wt		Static Load Rating C_o		Extended Dynamic Load Rating C_E	
		in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	lbs.	kg.	lbs.	N	lbs.	N
F33K3	F33KDD3	0.1250	3.175	0.012	0.30	0.3750	9.525	0.156	3.96	0.202	5.13	0.440	11.18	0.030	0.76	0.156	3.96	0.183	4.65	0.01	0.005	48	212	160	710
F33K5	F33KDD5	0.1875	4.762	0.012	0.30	0.5000	12.700	0.156	3.96	0.270	6.86	0.565	14.35	0.042	1.07	0.196	4.98	0.248	6.30	0.01	0.005	110	490	325	1430
FS1K7	FS1KDD7[1]	0.2500	6.350	0.012	0.30	0.6250	15.875	0.196	4.98	0.349	8.86	0.690	17.53	0.042	1.07	0.196	4.98	0.332	8.43	0.01	0.005	125	560	365	1630
FS3K	FS3KDD[1]	0.3750	9.525	0.016	0.41	0.8750	22.225	0.219	5.56	0.517	13.13	0.969	24.61	0.062	1.57	0.281	7.14	0.475	12.06	0.02	0.009	310	1400	830	3650

(1) Also available in stainless steel. To specify, add prefix "A" before bearing number.

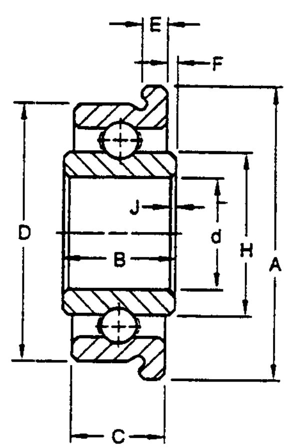
* Also available with two contact seals. To specify, replace "KDD" in part number with "PP".

TAPERED O.D.

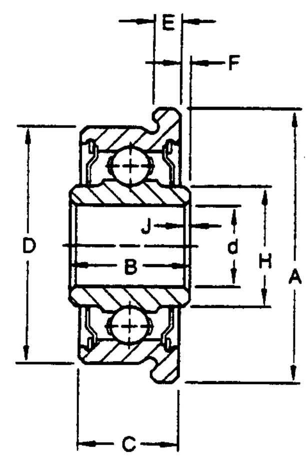
The F Flanged Series has shoulders integral with the bearings for mounting in through-bored housings. They are used where compactness is essential or where it is not desirable to machine housing shoulders. All sizes in this series have tapered outside diameters, and all are available with double shields.

These bearings are particularly suitable for such applications as precision instruments, packaging machinery, motion picture projectors and the like. Several sizes in this series are manufactured in both standard bearing quality, chromium-alloy, high carbon steel and stainless steel, as indicated in the tables. To specify stainless steel, use the prefix A before the basic bearing number. Example: AF4.

These bearings are electric motor quality for applications where extra quietness is a requirement.



Open Type



Shielded Type

DIMENSIONS – TOLERANCES

Bearing Number open	Bearing Number shielded	Bore d +0.0003" -0.0000" +0.008 mm -0.000 mm"		chamfer J x 45° +0.010" -0.000" +0.025 mm -.00 mm		Outside Diameter D +0.000" -0.0004" +0.000 mm -.010" mm		Inner Width B ±0.010" ±.03 mm		Ring Widths – Inner – Project F +0.005" ±.13 mm		Ring Widths – Inner – H[3] min		Ring Widths – Outer Width C +0.000" -0.004" +.00 mm -0.10 mm		taper per foot		Flange A +0.005" -0.002" +0.13 mm -0.05 mm		Flange E ±0.002" ±0.05 mm		Wt		Static Load Rating C_o		Extended Dynamic Load C_E	
		in.	mm	in	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	lbs.	kg.	lbs.	N	lbs.	N
F2[1]	—	0.1875	4.762	0.010	0.25	0.4382	11.130	0.189	4.80	0.016	0.41	0.273	6.93	0.163	4.14	0.080	2.03	0.500	12.70	0.042	1.07	0.01	0.005	106	465	260	1160
—	F2DD-2	0.1250	3.175	0.010	0.25	0.3757	9.534	0.188	4.77	0.015	0.38	0.181	4.60	0.163	4.14	0.075	1.90	0.438	11.13	0.037	0.94	0.01	0.005	48	212	160	710
F3	—	0.1875	4.762	0.010	0.25	0.5632	14.305	0.218	5.54	0.015	0.38	0.273	6.93	0.195	4.95	0.080	2.03	0.625	15.88	0.042	1.07	0.01	0.005	110	490	325	1430
—	F3DD	0.1875	4.762	0.010	0.25	0.5632	14.305	0.250	6.35	0.015	0.38	0.245	6.22	0.226	5.74	0.068	1.73	0.625	15.88	0.042	1.07	0.01	0.005	110	490	325	1430
F4	F4DD	0.2500	6.350	0.010	0.25	0.6257	15.893	0.250	6.35	0.015	0.38	0.331	8.41	0.226	5.74	0.068	1.73	0.687	17.45	0.042	1.07	0.01	0.005	125	560	365	1630
F5	F5DD	0.3125	7.938	0.010	0.25	0.6882	17.480	0.250	6.35	0.015	0.38	0.410[2]	10.41	0.226	5.74	0.068	1.73	0.750	19.05	0.042	1.07	0.01	0.005	196	865	540	2400

(1) Full type, no retainer. Not recommended for speeds over 500 RPM.

(2) H dimension is .381" (9.68 mm) for F5DD.

(3) Land dimension of the inner ring.

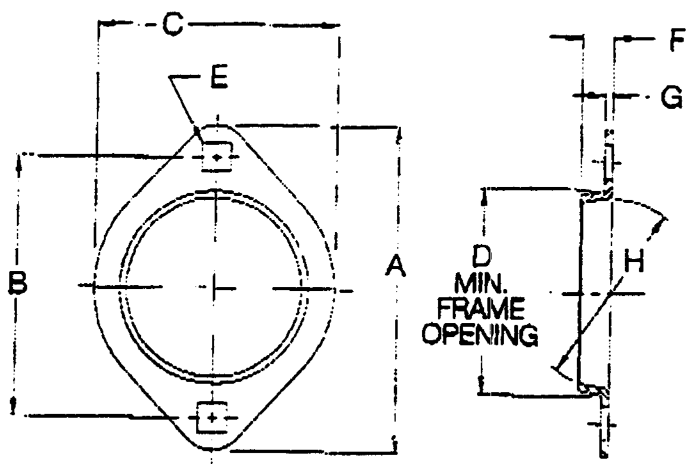
General Flangette Information

LUTCO is the largest manufacturer of precision flangettes in North America. With an extensive tooling inventory, we are able to offer a wide variety of standard and custom units.

Fit and surface contact between the flangettes and the bearing contribute to the life of the assembly. By allowing the bearing to misalign in the housing under a predetermined torque, premature failure can be eliminated. Sophisticated measuring and torque rating equipment are employed to provide statistical process control, through charting and minimum 1.0 CPK values.

For more specific information on the processes utilized, please contact the factory.

2 Bolt Self-Aligning Flangettes



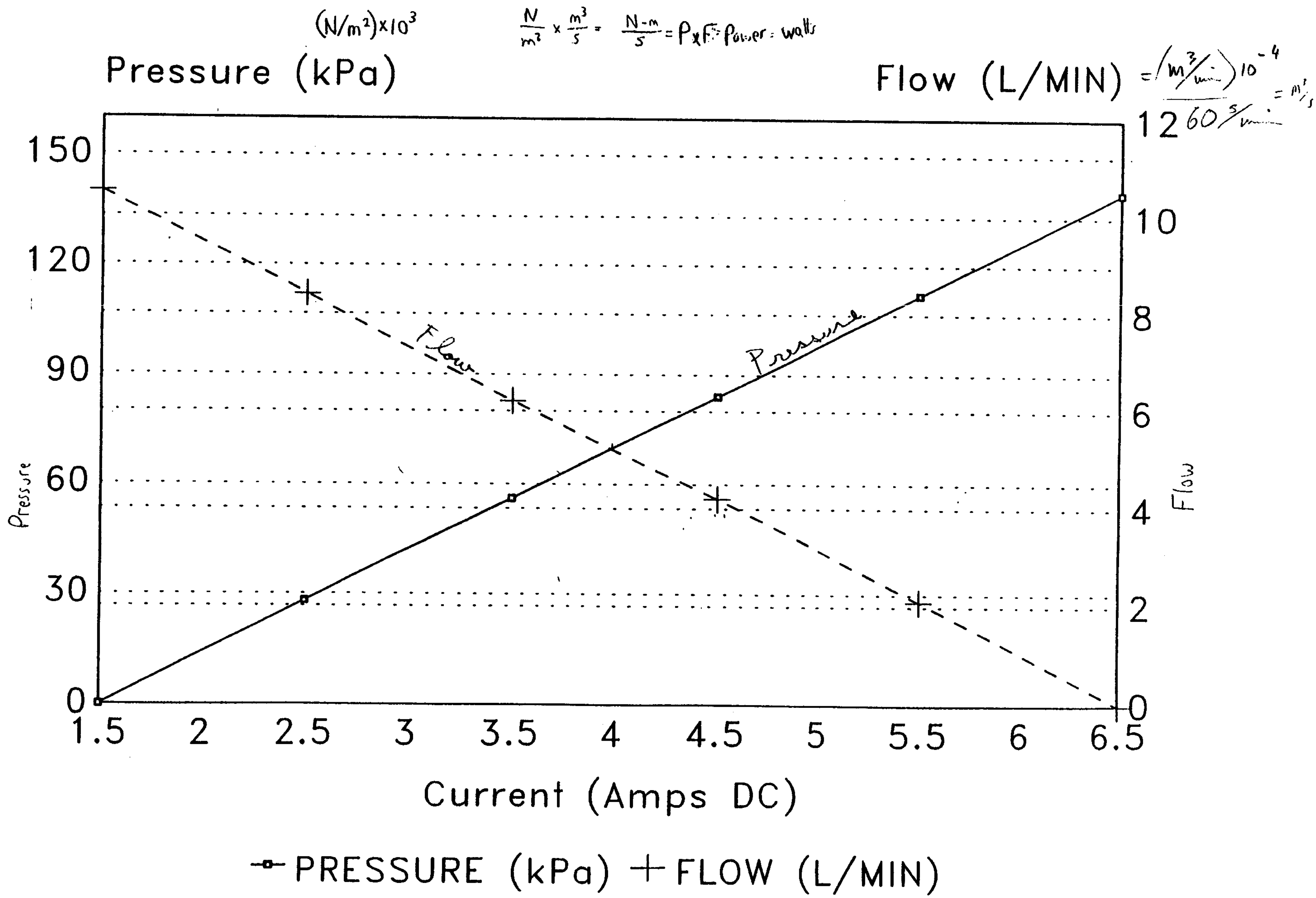
PART NUMBER	A In. mm	B In. mm	C In. mm	D In. mm	E In. mm	F In. mm	G In. mm	H nom. mm	RADIAL LOAD LBS. N	UNIT WT. LBS.
2 BOLT										
35MST	2 7/8 73.0	2 1/2 63.50	2 5/16 58.74	1 5/8 41.28	9/32 7.14	7/32 5.54	0.054 1.37	35	350 1556	0.06
40MST	3 3/16 80.96	2 1/2 63.50	2 5/16 58.74	1 7/8 47.63	9/32 7.14	9/32 7.14	0.075 1.905	40	750 3100	0.08
47MST	3 5/16 90.49	2 13/16 71.44	2 5/8 66.68	2 3/16 55.56	11/32 8.73	5/16 7.94	0.083 2.11	47	900 3900	0.10
52MST	3 3/4 95.25	3 76.20	2 51/64 71.04	2 3/8 60.33	11/32 8.73	11/32 8.73	0.083 2.11	52	1000 4450	0.11
62MST	4 7/16 112.71	3 9/16 90.49	3 5/16 84.14	2 13/16 71.44	13/32 10.31	3/8 9.53	0.104 2.64	62	1400 6200	.0.33
72MST	4 15/16 125.41	3 15/16 100.01	3 11/16 93.66	3 3/16 80.96	13/32 10.31	13/32 10.31	0.104 2.64	72	1750 7500	0.40

For Torque rated flangettes, add the prefix "T".
Add, "ZP" for standard zinc plate and "YZP" for yellow chromate finishes.
Special designs available upon request.

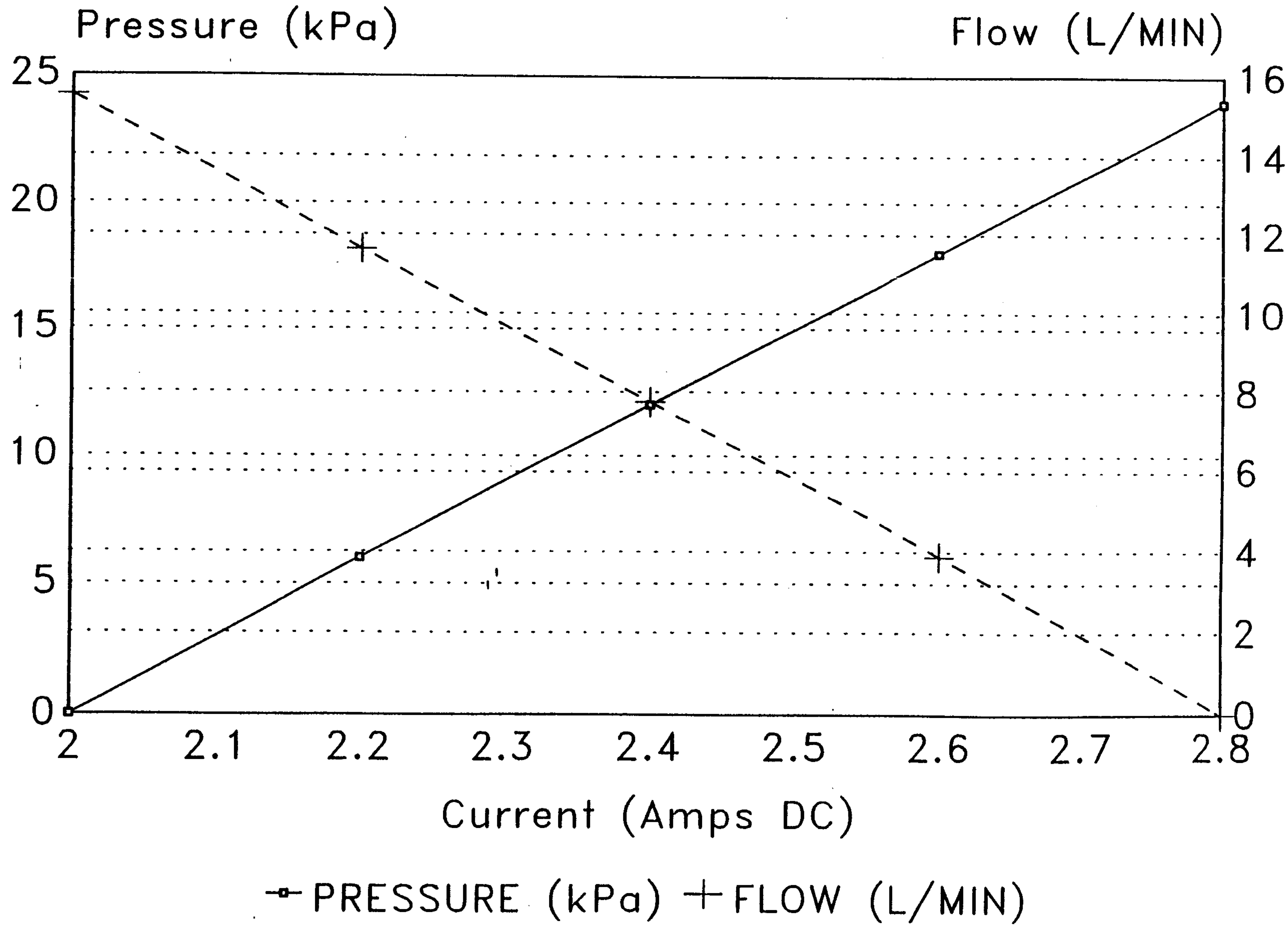
McCord Winn TEXTRON

High Output Air Pump

12 Vdc Performance



McCord Winn TEXTRON
Low Pressure Pump
12.6 Vdc Performance



- Magnetic piston optional on all double acting 1 1/16" bore cylinders (except in combination with viton option).

Division of numatics®

1-1/16" BORE CYLINDER

1062D04-00A

Double Acting

Double Nose or Rear Pivot Mount

Available Stroke Lengths:

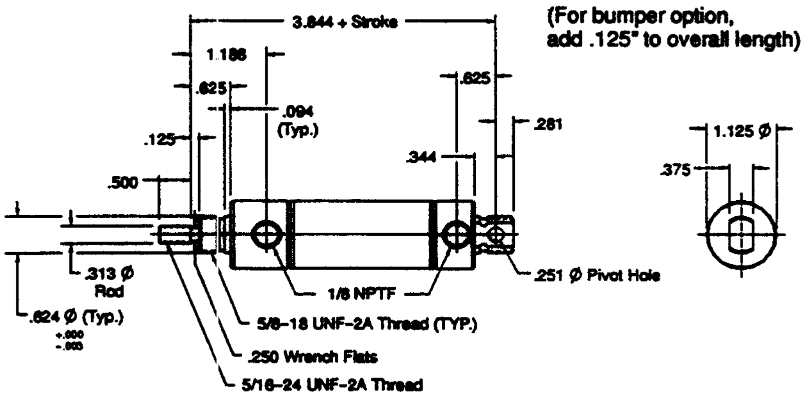
1/2", 1", 1-1/2", 2", 2-1/2", and 1" increments from 3" to 12"

Maximum Stroke: 32"

* Optional Accessories:

M117005 Mounting Bracket
M129003 Pivot Bracket
M127004 Rod Clevis

(For bumper option, add .125" to overall length)



7/16" BORE CYLINDER

0438D02-00A

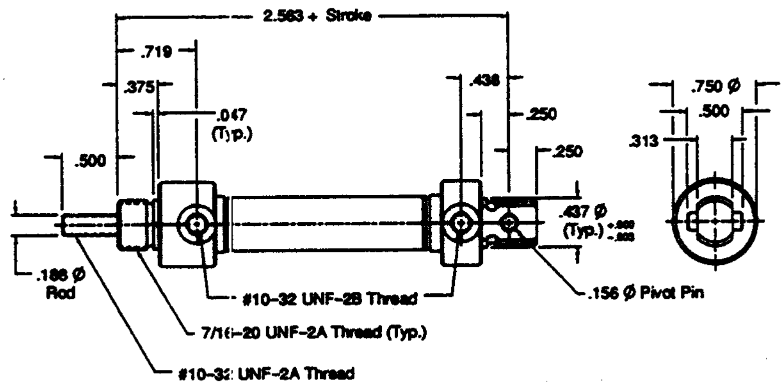
Double Acting

Rear Pivot Mount

Available Stroke Lengths:
1/2", 1", 1-1/2", 2", 2-1/2", 3", 4"

Maximum Stroke: 12"

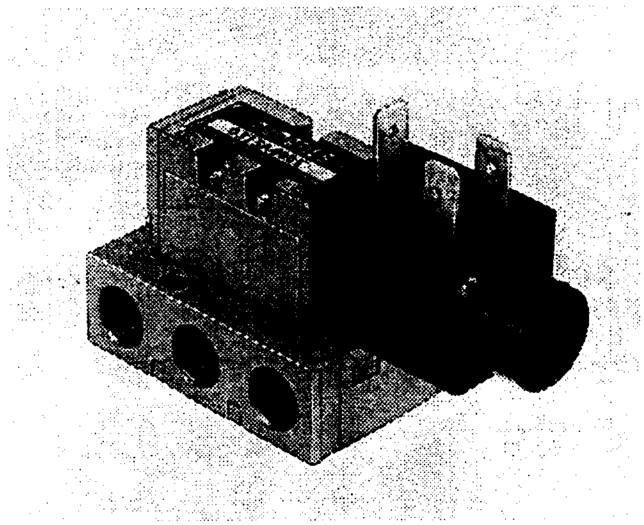
* **Optional Accessories:**
  M029002 Pivot Bracket
  M127002 Rod Clevis



numatics®
1450 North Milford Rd., Highland, Mi 48357, Phone: (810) 887–4111, Fax: (810) 887–9190

MARK 3 Series

030SA4414 and 030SS4414 Direct Acting Solenoid Valves

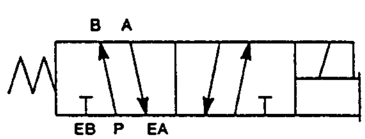


DESCRIPTION

MARK 3 miniature power valves have all of the quality features of larger Numatics valves. They contain a multi–purpose floating spool and sleeve with no dynamic rubber seals to wear out. All valves are 5–ported, 4–way, 2–position valves that may be used as 2–way, 3–way, 4–way, selector or diverter valves. They are fully balanced and pressures through the valve do not affect the solenoid force required to shift the spool.

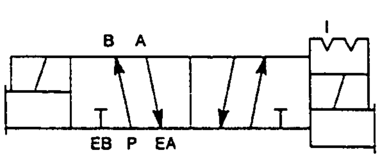
Direct solenoid actuated valves are available in two configuration:

Single solenoid, spring return valves are actuated by a "maintained" electrical signal. The spring returns the spool to the original position when the electrical signal is released.



2–Position
Single Solenoid
Spring Return

Double solenoid, detented valves are actuated by either a "momentary" or "maintained" electrical signal alternately on each solenoid. The detent holds the spool in position after electrical power is removed and prevents inadvertent spool shift due to vibration or shock.



2–Position
Double Solenoid
Detented

OPERATING DATA

TEMPERATURE RANGE:
Solenoid Valves: −10° F to +115° F ambient

PRESSURE RANGE:
Main Valve: 28" Hg. vacuum to 150 PSIG.
Pilot Pressures:
Spring Return: 15−100 PSIG
Detented: 10−100 PSIG

FLOW CAPACITY:
10−32 Ports with .109 I.D. Fitting Installed: Cv = .18

SERVICE:
Valves can be used on the following properly filtered media:
Lubricated air, dry (oil−free) air, vacuum, and noncorrosive, nontoxic, nonflammable dry gases.

ELECTRICAL:
Solenoids are continuous duty rated.

Voltage: 12 VDC

Wattage: 6.0

Time to energize:
030SA4414 .012
030SS4414 .012

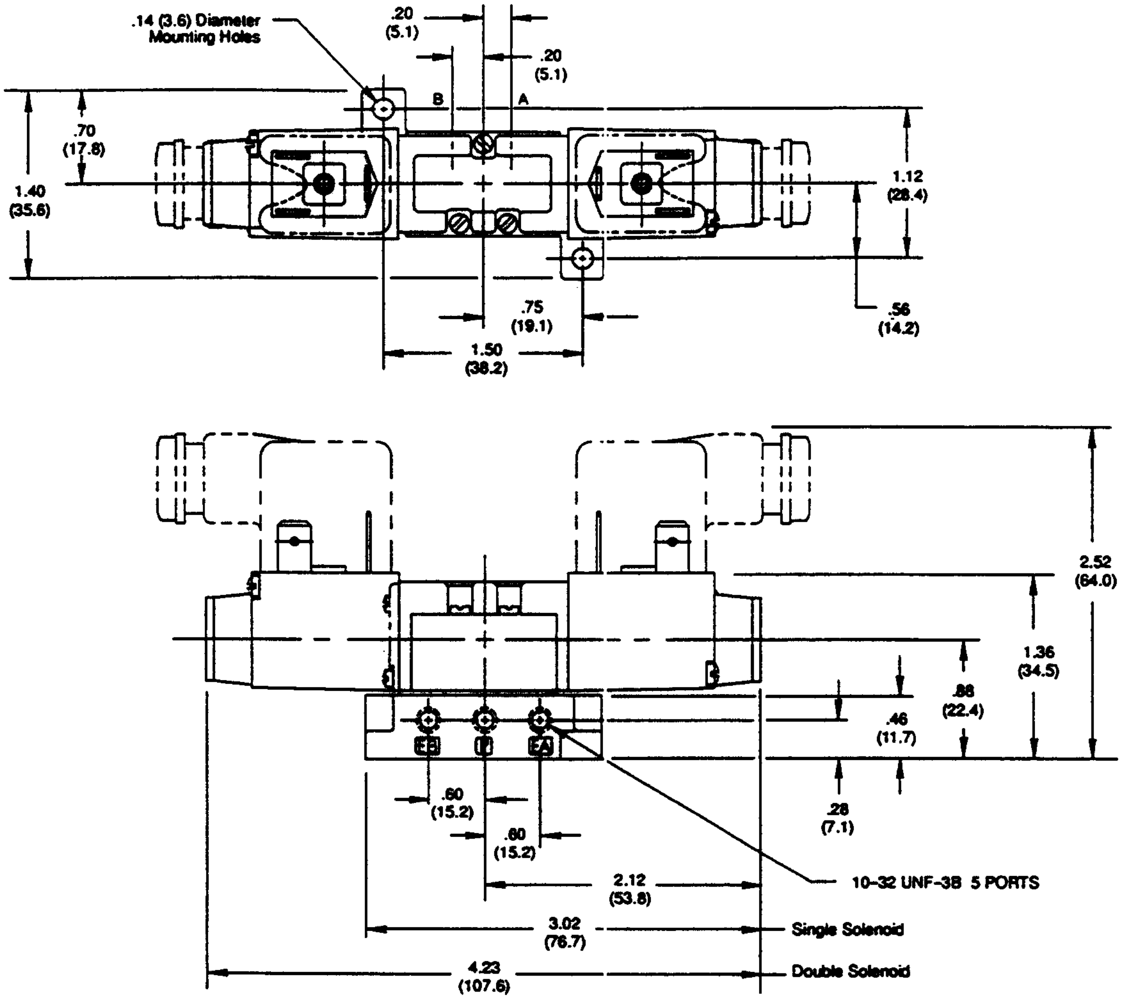
Time to de–energize:
030SA4414 .006

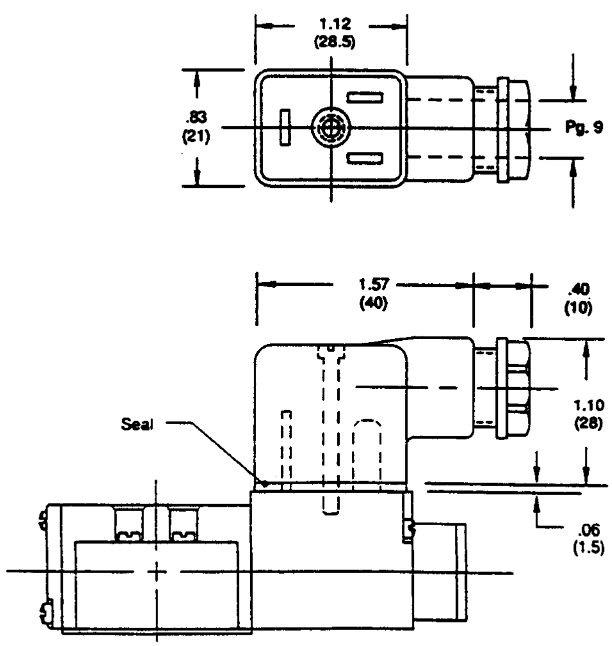
Maximum Cycle Rate (continuous):
030SA4414 500 cpm
030SS4414 500 cpm

NUMATICS MARK 3 Series

10–32 UNF–3B
Side Ported Base

Top Dimension = Inches
Bottom Dimension (In parenthesis) = Millimeters





PLUG ASSEMBLIES
ACCEPTS CABLE DIA. .240 TO .310

The electrical plug assembly provides a strain relief gland nut size Pg.9. This accepts cables with diameter of .240 to .310 inches. All plugs provide a degree of protection that complies with DIN 40050. They also comply with 1P65 for dust tightness and water resistance. Plugs are available either black, grey, or translucent with a built–in indicator light.

Plug assemblies are supplied, as shown, with the cord hub exiting away from the valve. The plug insert is reversible. This allows the assembly to be reversed 180°, if desired.

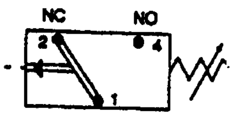
PRESSURE SWITCHES

▶ APPLICATION

Numatics PS180 is a new line of pressure switches designed for accurate indication that proper system pressure is being achieved. Available in 1/8 or 1/4 threads, it is easily incorporated into an air system using a Flexiblok® diverter plate or other manifold.

With its rugged housing made from zinc coated steel, the PS180 is designed for industrial multi-million cycle life applications. The four pin connector plug is included and contains a key way preventing accidental misconnection. Pressure adjustment is tamper resistant hindering unauthorized changes. It can be wired in either normally open or normally closed configurations and includes a case ground pin.

normally open or normally closed



ANSI SYMBOL

▶ SPECIFICATIONS

- Contact Rating: 4 A @ 250 VAC
- Protection: IP 65, terminals IP00
- Maximum Operation: 200/min.
- Temperature Range: 0°F to 190°F / -15°C to 85°C
- Maximum Pressure: 300 PSI / 20 BAR
- Maximum Voltage: 250 VAC / 200 DC
- Hysteresis Adjustment: 15%
- Connector Material: Polyamid
- Diaphragm Material: Buna N
- Housing Material: Zinc Plated Steel

▶ MODEL SELECTION

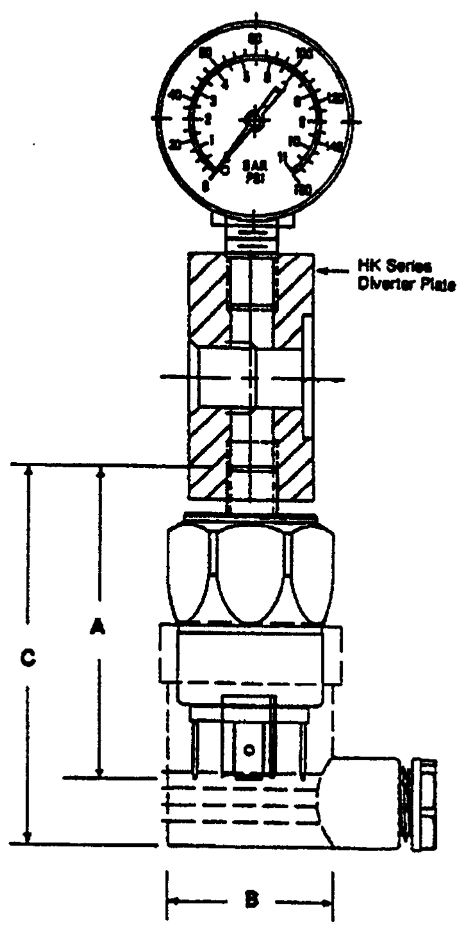
Part number includes connector cap.

thread NPT	model no. PS180	PSIG	dimensions A	B	C
* 1/8	PS180BAN01	4-20 (0.3-1.5 bar)	2.5 (64)	1.0 (27)	3.1 (79)
1/8	PS180CAN01	14-150 (1-10 bar)	2.5 (64)	1.0 (27)	3.1 (79)
1/4	PS180BAN02	4-20 (0.3-1.5 bar)	2.5 (64)	1.0 (27)	3.1 (79)
1/4	PS180CAN02	14-150 (1-10 bar)	2.5 (64)	1.0 (27)	3.1 (79)

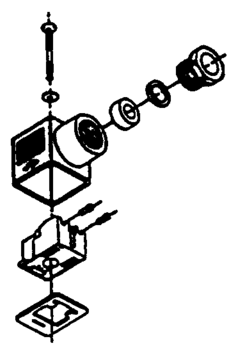
thread G	model PS180CAG	PSIG	dimensions A	B	C
1/4	PS180BAG02	4-20 (0.3-1.5 bar)	2.3 (58)	1.0 (27)	2.9 (74)
1/4	PS180CAG02	14-150 (1-10 bar)	2.3 (58)	1.0 (27)	2.9 (74)

Replacement Connector Cap: Model No. PSC180

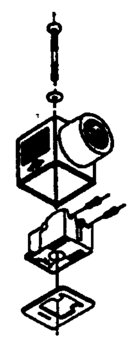
dimension = inches; (in parentheses) = millimeters



SOLENOID CONNECTOR



STRAIN RELIEF



CONDUIT

WIRING

NO. 1 TERMINAL POWER (+)
NO. 2 TERMINAL NEUTRAL (−)
THIRD TERMINAL IS FOR GROUND ⏚

F-2804 Series
Check Valves

The F-2804 Series Check Valves permit flow in one direction only. The operation of the check valve is based on the movement of a small disc. The disc shifts within the housing as the pressure differential changes from forward to reverse. A flat surface on one side of the disc seals off flow, while the other side allows flow to pass.

Two models are available from the Standard Units, F-2804-401, 402 & 403 to the High Flow Unit, F-2804-404.

The advantages of the check valve design is the low "cracking pressure", minimum differential required for forward flow, which is less than 0.005 PSI differential in the Standard Units. Secondly, there is no residual pressure difference across the check valve once flow has ceased. Flow in the forward direction is relatively unrestricted, approximately equivalent to the restriction of a 0.040 inch orifice in the Standard Units. The amount of flow permitted in the reverse direction, which is the sealing side, and the forward direction, which is full flow, is shown in the graphs below.

ORDERING INFORMATION (Order by model number and specify accessory letters required.)

F-2804 — 404 — B85

[illegible]	[illegible]	[illegible]
F-2804-401	Orange	B80—Barbs for 1/16" I.D. tubing B85—Barbs for 1/8" I.D. tubing No accessory numbers required for straight ports
F-2804-402	Green	
F-2804-403	Blue	
F-2804-404	Black	B80—Barbs for 1/16" I.D. tubing B85—Barbs for 1/8" I.D. tubing 10-32 threads. No accessory numbers required.

FEATURES

- Minimum Cracking Pressure
- Miniature Size
- Low Cost

SPECIFICATIONS

Maximum Supply:
- F-2804-401 • 10 PSI
- F-2804-402 • 10 PSI
- F-2804-403 • 10 PSI
- F-2804-404 • 75 PSI

Operating Temperature: 40° to 120°F. (5° to 48°C.)

Recommended Filtration: 5 micron

Cracking Pressure:
- F-2804-401 • Less than .8" H_2O
- F-2804-402 • Less than .8" H_2O
- F-2804-403 • Less than .8" H_2O
- F-2804-404 • Less than 10" H_2O

MATERIALS

Housing: Polysulfone

Disc:
- F-2804-401 • Celcon Disc
- F-2804-402 • Celcon Disc
- F-2804-403 • Silicone
- F-2804-404 • Silicone

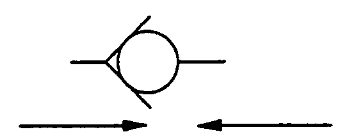
MOUNTING

Inline

PORT CONNECTIONS

Straight ports for 1/16" I.D. flexible tubing
Barbs for 1/16" or 1/8" I.D. flexible tubing
The F-2804-404 has 10-32 Threads

FLOW



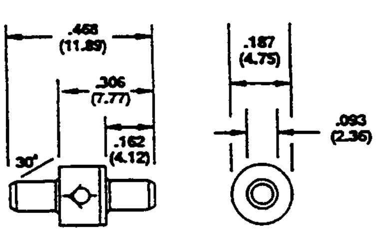
FORWARD FLOW   REVERSE FLOW

TYPICAL FLOW CHARACTERISTICS

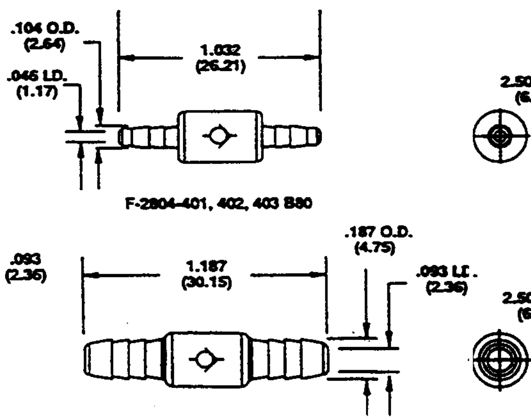
[illegible]	[illegible]	Forward Flow @ PSI Differential
F-2804-401	Less than 2.98 SCIM	0.12 SCFM 1 PSI Supply
F-2804-402	Less than 1.00 SCIM	
F-2804-403	Less than 0.20 SCIM	
F-2804-404	Less than 0.06 SCIM	2.0 SCFM 75 PSI Supply

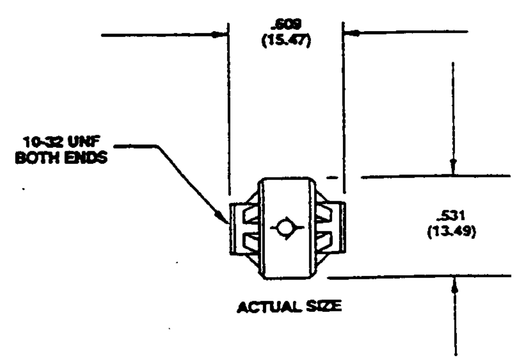
DIMENSIONS

( )= Metric Dimensions



F-2804-401, 402, 403

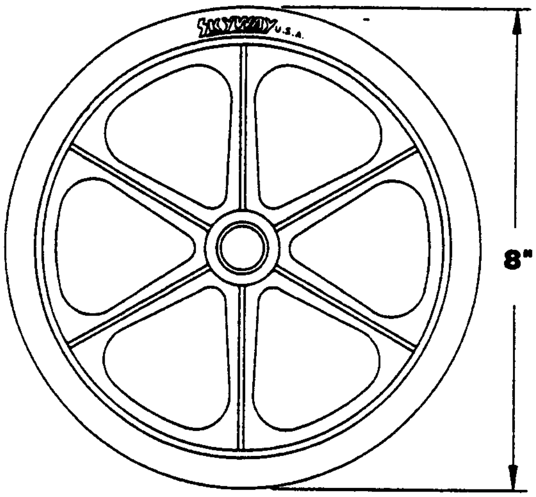


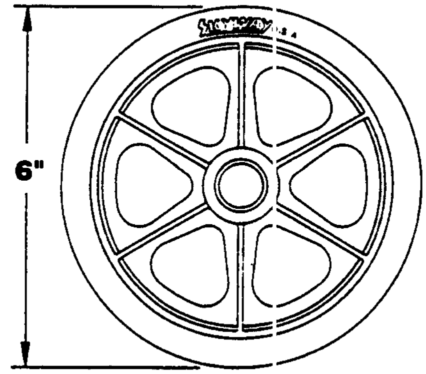


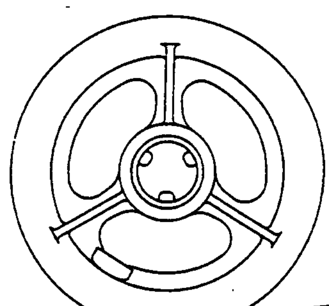
ACTUAL SIZE

4451 Caterpillar Rd., Redding, CA 96003
916/243-5151 (FAX 916/243-5104)

STANDARD UTILITY WHEELS
WHEELCHAIR WHEEL ACCESSORIES
WHEELCHAIR WHEELS
CASTER WHEELS







NEW

8" CASTER NON-PNEUMATIC

6" CASTER NON-PNEUMATIC

SKYWAY 6" and 8" Non-Pneumatic caster wheels feature a molded DuPont ZYTEL® nylon wheel with a coinjected Monsanto Santoprene® thermoplastic rubber molded-on tire.

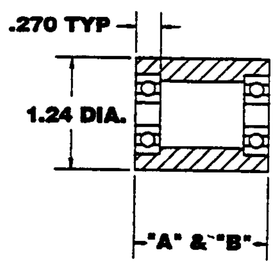
5" CASTER PNEUMATIC OR NON-PNEUMATIC

Accepts 6" x 1-1/4" Pneumatic Tires. Also Accepts Various 5" & 6" Non-Pneumatic Snap-On Tires. Available Only In Hub #1. 1" Precision Bearing.

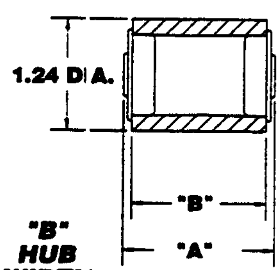
CASTER HUB SPECIFICATIONS

Hub configurations shown are SKYWAY standards, however, if you require a custom design, we stand ready to work with you to create a special hub to suit your needs.

5" Caster Only Available with Standard Hub #1, 1" Overall Width.



HUB #1
Precision Bearing Hub
7/8" O.D. Maximum x 5/16" and 3/8" I.D.'s



HUB #2
Unground, Flanged Bearing Hub
.906 O.D. Maximum x 1/4", 5/16", 3/8" and 7/16" I.D.'s

	BASIC OVERALL	"A" ACROSS BEARING REFERENCE	"B" HUB WIDTH
PRECISION BEARING			
HUB #1 For 5", 6" & 8" casters only	1"	.99	.98
HUB #1 For 6" & 8" casters only	1-1/2"	1.50	1.48
HUB #1 For 6" & 8" casters only	2-3/16"	2.18	2.17
UNGROUND, FLANGED BEARING			
HUB #2 For 6" & 8" casters only	1"	1.23	.98
HUB #2 For 6" & 8" casters only	2-3/16"	2.43	2.17
HUB #2 For 6" & 8" casters only	1-1/2"	1.73	1.48

While we recommend uses for our products based on tests done in laboratories we in no way guarantee particular methods of use or applications or performance when installed or made to operate under special conditions. Skyway has a policy of continuous improvement of products and reserves the right to make improvements or changes on products without notice.

NATWELD

CARBON & LOW ALLOY BARE STEEL WELDING WIRE

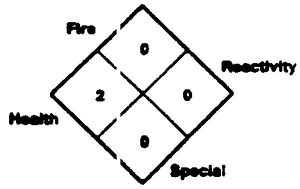
NO: 119

Material Safety Data Sheet

IN COMPLIANCE WITH OSHA'S HAZARD COMMUNICATION STANDARD 29CFR 1910.1200

Manufacturers Name:
National Welding Alloys, Inc.
1600 South Canal Street
Pittsburgh, PA 15215

HAZARD RATING
4 = EXTREME
3 = HIGH
2 = MODERATE
1 = SLIGHT
0 = INSIGNIFICANT



Date Issued: 8/1/90
Date Revised:
Emergency Phone Numbers:
Natweld: (412) 781-4255
Chemtrec: 800-424-9300

This Material Safety Data Sheet (MSDS) provides information on a specific group of manufactured metal products. The following alloys can be found on this MSDS: See Section II and Section VI for important health hazard data.

SECTION I — MATERIAL IDENTIFICATION

APPROXIMATE CHEMICAL COMPOSITION - % (Single figures are maximum)

TRADE NAME	Al	C	Cu	Fe	Mn	P	Si	S	Ti	Zr
Bare Wire RG 45	0.02	0.08	0.30	Balance	0.50	.035	0.10	0.04	---	---
Bare Wire RG 60	0.02	---	0.30	Balance	0.90-1.40	.035	0.10-0.35	.035	---	---
Bare Wire RG 65	0.02	---	---	Balance	---	.035	---	.035	---	---
Bare Wire ER70S-2	0.05-0.15	0.07	0.50	Balance	0.90-1.40	.025	0.40-0.70	.035	0.05-0.15	0.02-0.12
Bare Wire ER70S-3	---	0.06-0.15	0.50	Balance	0.90-1.40	.025	0.45-0.70	.035	---	---
Bare Wire ER70S-6	---	0.07-0.15	0.50	Balance	1.40-1.85	.025	0.80-1.15	.035	---	---

APPROXIMATE CHEMICAL COMPOSITION - % (Single figures are maximum)

TRADE NAME	C	Cr	Fe	Mn	Mo	Ni	P	Si	S	V
Bare Wire 4130	0.31	0.93	Balance	0.52	0.20	---	.012	0.28	.023	---
Bare Wire 4140	0.40	1.03	Balance	0.87	0.20	0.09	.007	0.26	---	---
Bare Wire 8620	0.20	0.51	Balance	0.81	0.22	0.52	.015	0.25	.023	---

APPROXIMATE CHEMICAL COMPOSITION - % (Single figures are maximum)

TRADE NAME	C	Cr	Cu	Fe	Mn	Mo	Ni	P	Si	S
Bare Wire ER80S-B2	0.07-0.12	1.20-1.50	0.35	Balance	0.40-0.70	0.40-0.65	0.20	.025	0.40-0.70	.025
Bare Wire ER80S-B2L	0.05	1.20-1.50	0.35	Balance	0.40-0.70	0.40-0.65	0.20	.025	0.40-0.70	.025
Bare Wire ER90S-B3	0.07-0.12	2.30-2.70	0.35	Balance	0.40-0.70	0.90-1.20	0.20	.025	0.40-0.70	.025
Bare Wire ER90S-B3L	0.05	2.30-2.70	0.35	Balance	0.40-0.70	0.90-1.20	0.20	.025	0.40-0.70	.025
Bare Wire ER80S-D2	0.07-0.12	---	0.50	Balance	1.60-2.10	0.40-0.60	0.15	.025	0.50-0.80	.025
Bare Wire ER100S-1	0.08	0.30	0.25	Balance	1.25-1.80	0.25-0.55	1.40-2.10	0.01	0.20-0.50	0.01
Bare Wire ER110S-1	0.09	0.50	0.25	Balance	1.40-1.80	0.25-0.55	1.95-2.60	0.01	0.20-0.55	0.01
Bare Wire ER120S-1	0.10	0.60	0.25	Balance	1.40-1.80	0.30-0.65	2.00-2.80	0.01	0.25-0.60	0.01

sds9-a)

SECTION II — HAZARDOUS CONSTITUENTS

IMPORTANT — Welding electrodes are a non-hazardous solid at ambient temperatures. This section covers the materials from which these products are manufactured. The fumes and gases produced while welding during normal use of these products are covered in Sections V and VI.

BARE WIRE

HAZARDOUS COMPONENTS	*CAS NO.*	*OSHA PEL mg/m³*	*ACGIH TLV mg/m³*	*STEL mg/m³*
*Chromium (VI)	7440-47-3	1.00	0.50	— — —
*Nickel	7440-02-0	1.00	1.00	— — —
Aluminum	7429-80-5	15.0	10.0	— — —
Carbon	1333-86-4	3.50	3.50	— — —
Manganese	7439-96-5	5.00 (ceiling)	5.00 (ceiling)	— — —
Molybdenum (soluble)	7439-98-7	5.00	5.00	— — —
Iron (oxide fume)	1309-37-1	10.0	5.00	— — —
Phosphorus	7723-14-0	0.10	0.10	— — —
Zirconium	7440-67-7	5.00	5.00	10.0
Silicon	7440-21-3	15.0	10.0	— — —
Sulfur	7446-09-05	13.0	5.00	13.0
Copper (fume)	7440-50-8	1.00	1.00	— — —
Thallium	7440-28-0	0.10	0.10	— — —
Vanadium	1314-62-1	0.50 (ceiling)	0.05	— — —

SUBSTANCES OF VARIABLE COMPOSITION

HAZARDOUS COMPONENTS	*CAS NO.*	*OSHA PEL mg/m³*	*ACGIH TLV mg/m³*	*STEL mg/m³*
Welding Fume	NOC	— — —	5.00	— — —

** SUBSTANCE IDENTIFIED BY OTHER SOURCES AS A SUSPECTED OR CONFIRMED HUMAN CARCINOGEN*

SECTION III — PHYSICAL DATA

Solid wire or rod, grey to copper in color.

SECTION IV — FIRE AND EXPLOSION DATA

FLASH POINT (WITH TEST METHOD): None **FLAMMABLE (EXPLOSIVE) LIMITS V/V%** **LEL:** None **UEL:** None

EXTINGUISHING MEDIA: This alloy is noncombustible. Use extinguishing media appropriate to the surrounding fire.

SPECIAL FIRE FIGHTING PROCEDURES: If this material is reduced to powder form, caution must be used to prevent fire or explosion. To extinguish a metal powder fire use dry sand, dry graphite or other class "D" fire extinguishing powder.

UNUSUAL FIRE AND EXPLOSION HAZARD: No unusual fire or explosion hazards are associated with this material.

INCOMPATIBILITY (MATERIALS TO AVOID): Avoid contact with mineral acids and oxidizing agents which may generate hydrogen gas; the evolution of hydrogen may be an explosion hazard.

HAZARDOUS DECOMPOSITION PRODUCTS: Various elemental metals and metal oxides may be generated from melting or dross handling operations. Refer to Section II for permissable exposure limits.

SECTION V — HEALTH HAZARD DATA — CARBON & LOW ALLOY BARE STEEL WELDING WIRE

Welding generates fumes, gases and electromagnetic radiation with known adverse health effects. The composition of welding emissions varies substantially with the welding process.

Exposure: Section I lists normal composition of aluminum welding wire. Section II lists exposure limits for hazardous decomposition products which might be present in fume generated during welding or brazing. Actual exposure should be determined by monitoring fume in the operator's breathing zone.

Possible Effects of Exposure: Short term exposure to welding fume may result in discomfort, dizziness, nausea and dryness or irritation of the throat. Long term exposure to welding fume, gases or dust may contribute to pulmonary irritation or pneumoconiosis. Long term exposure to iron fume may produce siderosis, which is generally regarded as benign. Nickel and chromium should be considered a possible carcinogen per OSHA 29CFR 1910.1200. Certain nickel compounds have been implicated based on experience in some nickel refining operations. The specific compounds, however, have not been determined and a direct association between nickel in welding fume and cancer has not been demonstrated. Some compounds of hexavalent chromium have been reported to be carcinogenic. No clear association, however, has been established between chromium in welding fume and the development of cancer. Exposure limits should be maintained below the levels listed in Section II.

Routes of Entry: **(1)** Inhalation of Fume **(2)** Burns from Electromagnetic Radiation

Pre-existing Medical Condition: Individuals with impaired pulmonary function or illness may have symptoms exacerbated by irritants contained in welding fumes.

SECTION VI — REACTIVITY DATA

Hazardous Decomposition Products

Exposure Limits: Welding fumes and gases cannot be classified simply. The composition and quantity of both are dependent upon the metal being welded, the process, procedure and electrodes used. Other conditions which also influence the composition and quantity of the fumes and gases to which workers may be exposed include: coatings on the metal being welded (such as paint, plating or galvanizing), the number of welders and the volume of work area, the quality and amount of ventilation, the position of the welder's head with respect to the fume plume, as well as the presence of contaminants in the atmosphere (such as chlorinated hydrocarbon vapors from cleaning and degreasing activities).

When the electrode is consumed, the fume and gas decomposition products generated are different in percent and form from the ingredients listed in Section II. Fume and gas decomposition products, and not the ingredients in the electrode, are important. The concentration of a given fume or gas component may decrease or increase by many times the original concentration in the electrode. Also, new compounds not in the electrodes may form. Decomposition products of normal operation include those originating from the volatilization, reaction or oxidation of the materials shown in Section II, plus those from the base metal and coating, etc., as noted above.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5mg/m³. That which does, should be controlled.

SECTION VII — SPILL OR LEAK PROCEDURES

NOT APPLICABLE

SECTION VIII — SPECIAL PROTECTION INFORMATION

Ventilation: Use enough ventilation, local exhaust at the arc (or flame), or both, to keep the fumes and gases below PEL's, TLV's or STEL's in the worker's breathing zone and the general area. Train the employee to keep his head out of the fumes. See ANSI/ASC Z49.1 Section 5.

Respiratory Protection: Use respirable fume respirator or air supplied respirator when welding, brazing or soldering in confined space or where local exhaust or ventilation does not keep exposure below PEL, TLV or STEL.

Eye Protection: Wear helmet or use face shield with filter lens of appropriate shade number (see ANSI/ASC Z49.1 Section 4.2). Provide protective screens and flash goggles, if necessary, to shield others.

Protective Clothing: Wear head and body protection which help to prevent injury from radiation, sparks, flame and electrical shock. See ANSI Z49.1. At a minimum this includes welder's gloves and a protective face shield, and may include arm protectors, aprons, hats, shoulder protection, as well as dark substantial clothing. Train the employee not to touch live electrical parts and to insulate himself from work and ground. Welders should not wear short sleeve shirts, short pants or cutoffs.

Waste Disposal Method: Prevent waste from contaminating surrounding environment. Discard any product, residue, disposable container or liner in an environmentally acceptable manner, in full compliance with federal, state and local regulations.

Emergency First Aid: Remove from dust or fume exposure. If breathing has stopped perform artificial respiration. Summon medical aid immediately.

Read and understand the manufacturer's instructions and the precautionary label on the product. See American National Standard Z49.1, *Safety in Welding and Cutting* published by the American Welding Society, P.O. Box 351040, Miami, FL 33135 and OSHA publication 2206 (29CFR 1910), U.S. Goverment Printing Office, Washington D.C. 20402 for more detailed information.

SECTION IX — SPECIAL PRECAUTIONS

Other Precautions: Use exhaust system to clear welding fumes Make sure that inhaled air does not contain fume constituents above permissable levels.

NOTE: For other precautions or additional safety information on welding and cutting, see American Standard Z49.1-1980, *Safety In Welding and Cutting*, and the *Welding Handbook*, Volume 1, Chapter 9, Safe Practices In Welding and Cutting, both available from the American Welding Society, Inc. 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135, Telephone number (305) 443-9353.

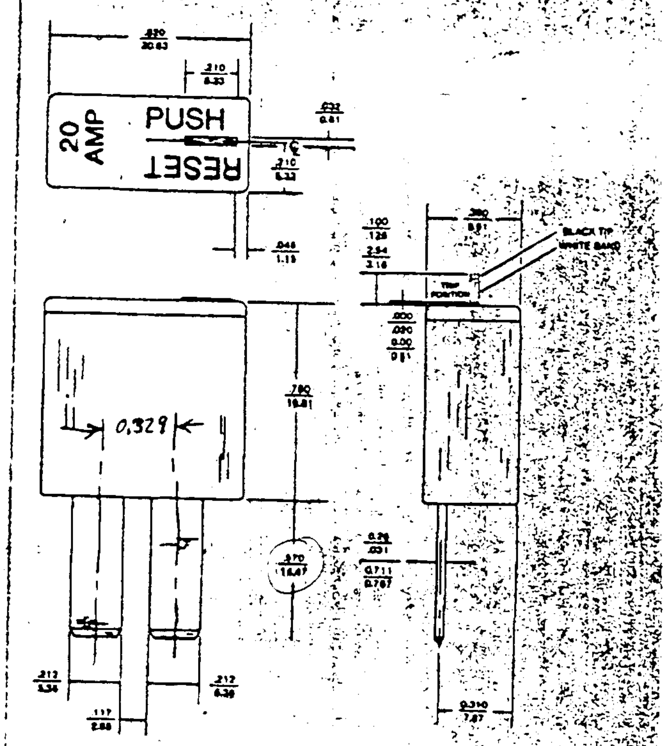
TOMORROWS STANDARD – AVAILABLE TODAY

QUALITY:

- Snap Action sensor provides increasing contact pressure to effect trip, and promotes wiping action of contacts.
- Trip time of 2.6 to 6.5 seconds with 200% over-load for all ratings.
- Precise correlation of trip time to rating in any unit.
- Must hold 100% — must trip 135%
- Withstands normal start-up and short duration surges without nuisance tripping.
- Fast response time.
- Unusual tolerance to vibration and shock environment.
- 100% final inspection test before the name goes on.

FEATURES:

- Housed in engineering plastic (non-corrosive - U.L. rated 94VO).
- Visual trip indicator is push to rest (Model VB3-M).
- SAE Type (self-resetting) has well defined open/close cycle on over-load. (Model VB3-A)
- Cannot be held manually closed (trip free).
- Ambient compensated (to 40°C).
- Introduces new convenience and quality to circuit protection.



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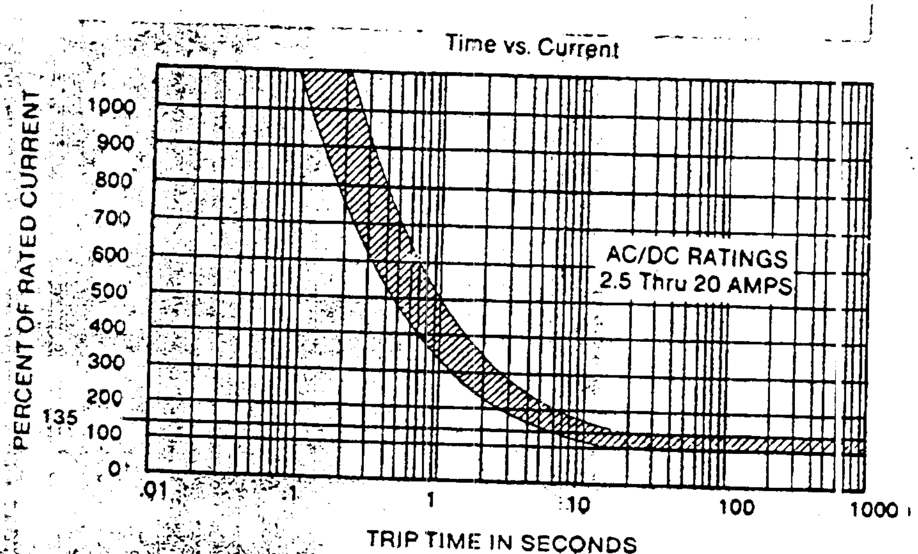


SPECIFICATIONS

MODELS: VB3-A Cycling (SAE Type I), VB3-M Manual, reset non-cycling new concept (SAE Type II)

VOLTAGE: Up to 50 V.D.C.

RATINGS: 3 thru 20 AMPS

TEMPERATURE COMPENSATION: To 40°C

CALIBRATION: Must carry rated current at 25°C & 40°C. Must trip 135% of rating within ten minutes.

RESET TIME: Less than 15 seconds.

25 & 30 AMPS. NOW AVAILABLE

ORDERING INFORMATION

EXAMPLE: VB3- M20 -F57

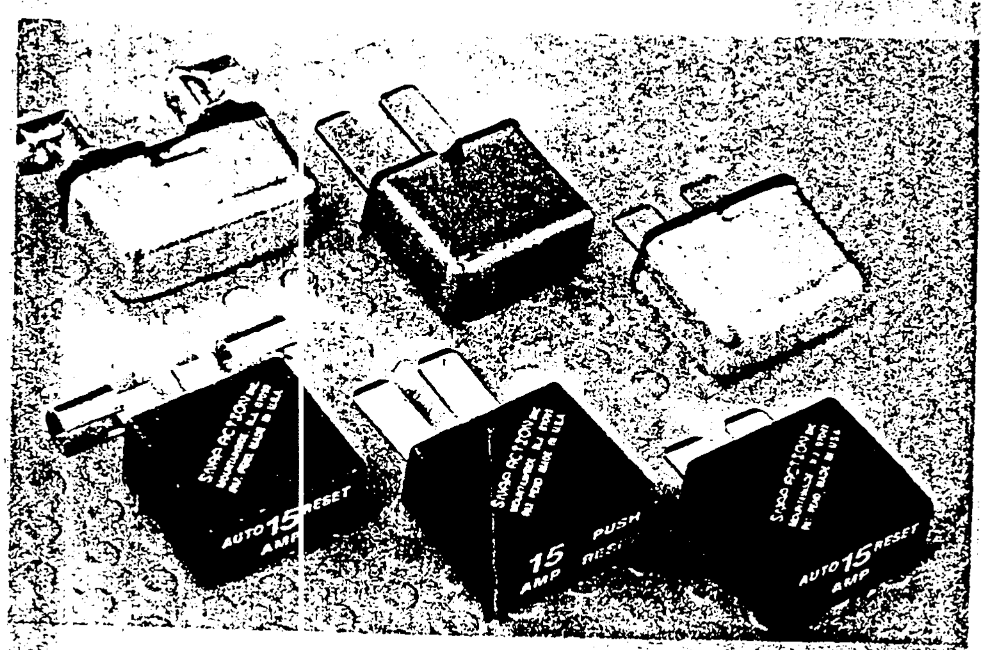
SERIES NUMBER:

TYPE RESET: A (automatic), M (manual)

AMP RATING: 3 thru 20

TERMINAL CONFIGURATION: F57 standard (flat .570x.110x.032). Consult factory for other terminal designs and modifications.

AUTO – TRUCK – RV's
AVIATION – MARINE
GENERATORS – BATTERY CHARGES
AND MANY OTHER
AC OR DC APPLICATIONS



MODEL VB3 REPLACES SENSORS WHICH LOSE CONTACT PRESSURE

SECTION X — DISCLAIMER OF LIABILITY

As the conditions or methods of use are beyond our control, we do not assume any responsibility and expressly disclaim any liability for any use of this material. Information contained herein is believed to be true and accurate but all statements or suggestions are made without any warranty, expressed or implied, regarding accuracy of the information, the hazards connected with the use of the material or the results to be obtained from use thereof.

References:

Air Contaminants — Permissible Exposure Limits
Title 29 Code of Federal Regulations Part 1910.1000

Threshold Limit Values and Biological Exposure Indices for 1989-1990 Second Printing
American Conference of Govermental Industrial Hygienists

Code of Federal Regulation
Parts 1900 to 1910 Revised July 1, 1988

Operator's Manual for Oxyfuel Gas Cutting
ANSI/AWS C4.2-90 An American National Standard

Effects of Welding on Health — VI
Prepared for: Safety and Health Committee of the American Welding Society

OSHA: Employee Workplace Rights
U.S. Dept. of Labor, OSHA 3021 Revised

Respiratory Protection
U.S. Dept. of Labor, OSHA 3079 Revised 1988

Modern Welding
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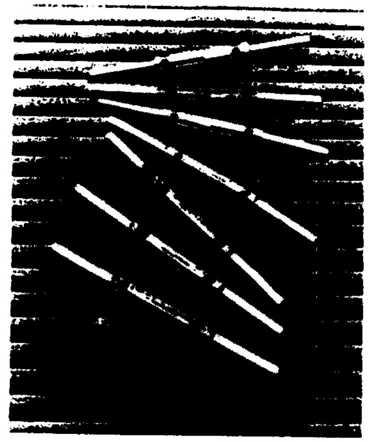
Reed Switch Specification



SERIES FR2

Clare

Over the past three decades, billions of reed switches have been used in hundreds of applications. Operating in microseconds, they are quiet in operation and need little or no energy for actuation. When driven with an electromagnetic coil, reed switches can accumulate millions of fault-free operations at speeds up to 500 Hz continuously. Reed switches actuated by permanent magnets may lay poised for years, even in hostile environments, and operate perfectly when called upon.

Enhancements made by Clare to reed switch design and manufacturing processes have opened exciting new application possibilities. With more than 30 years experience in reed switch manufacturing, Clare is the world leader in glass-sealed contact technology. Clare DYAD reed switches deliver immediate improvements in end user yields and productivity.

The CLARE FR2 series reed switch is trademarked the DYAD. Unique features of the DYAD include:

- Patented glass to metal seal provides a stronger hermetic seal. Glass breakage is virtually eliminated.
- Sputtered ruthenium contacts provide stable contact resistance throughout life.
- Bifurcated contacts reduce bounce on closure offering faster momentary action and longer life.
- Flat glass dampens the kinetic energy of the blades on opening, virtually eliminating reclosure.
- Flat leads offer more reliable solder, weld, or crimp joints.
- Flat glass and flat leads also lend themselves to surface mount processing capability.

Specifications

Clare

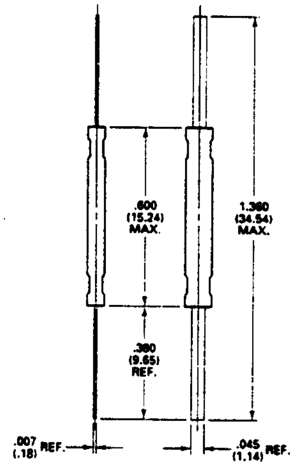
PHYSICAL AND MECHANICAL REQUIREMENTS	
■ Contact Form	SPST, Form A (center gap)
■ Contact Material	Ruthenium
■ Standard Overall Length	1.360 inches (34.54mm)
■ Maximum Glass Length	0.600 inches (15.24mm)
■ Terminals*	Nickel iron alloy 52
■ Test Coil	NARM I test coil: See page 3 for details
CONTACT RATING	
■ Maximum Switching Power	10 VA
■ Maximum Switching Voltage	200 VDC, VAC
■ Maximum Switching Current	0.50 A
■ Maximum Continuous Carry Current	1.50 A
ELECTRICAL RATING	
■ Operate Sensitivity Available in Minimum 5 NI Ranges	5-45 NI
■ Maximum Initial Contact Resistance	150 milliohms
■ Minimum Dielectric Voltage	250 VDC
■ Maximum Capacitance	1.0 pF
■ Minimum Insulation Resistance	10^{11} Ohms
OPERATING CHARACTERISTICS	
■ Maximum Operate Time, Including Bounce	0.50 ms
■ Maximum Release Time	0.20 ms
■ Maximum Operating Frequency	500 Hz
■ Operating Temperature Range	-40°C to +125°C
■ Shock	100g, 11 ms, 1/2 sinewave
■ Vibration	20g, or .125" D.A., 10 - 5000 Hz
■ Solderability	As defined by MIL-STD-202 F, Method 208D
■ Resistance to Solvents	The reed switch operating characteristics shall not be affected by water wash, rinse procedures, the use of mild to semi-active fluxes or conformal coating processes.

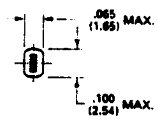
* If the switch is to be soldered in place, a solder plated termir al finish should be specified.

Ordering Information

Dimensions

3





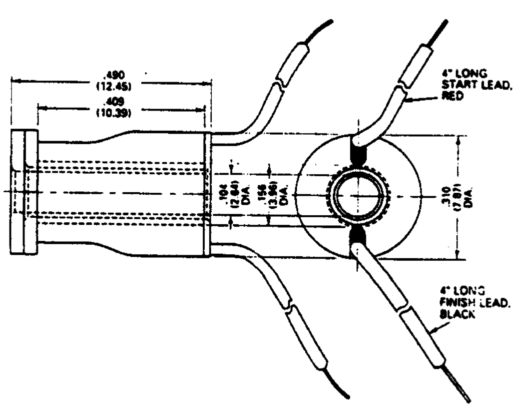
How to Order Clare Reed Switches

FR2 S 05 45—05 35 00

Switch Name
FR2 = Bifurcated Ruthenium Dry Reed
(Form A Contacts - SPST)

Terminal Finish
S= Solder Plated Terminals
W= Oxide Free for Welding
Minimum Operate Value
Maximum Operate Value
Minimum Release Value
Maximum Release Value
Standard Switch

Standard Test Coil



Introduction

The magnetic force (expressed in NI, AT, or Ampere Turns) required to cause the reed switch contacts to close is called the pull-in or operate value.

■ *Coil Definition*	*EIA/NARM I Standard*
■ Wire size	AWG 46
■ Number of turns	5000 ± 5 turns
■ Coil resistance	1200 Ohms ± 10%
■ *Recommended Mounting Conditions*	Vertical, with the coil magnetic field opposing the local earth's magnetic field.

The reed switch shall be placed in the test coil with the gap centered in the core of the coil winding.

Test leads and their clips must be non-magnetic.

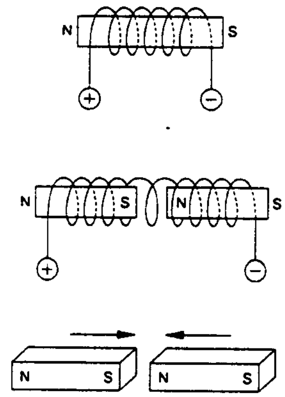
The longitudinal axis of the test coil and test switch shall be vertical.

Clare

Operation of a Reed Switch Permanent Magnet and Electromagnetic Coil Actuation

The reed switch depends upon an induced magnetic field for its operation. Reed switches are activated by the presence of a magnetic field with sufficient flux to pull the reed blades together.

This can be accomplished by either using a permanent magnet—bringing the magnet close to the switch to turn it on—or by energizing a electromagnetic coil that is mounted around or near the switch. The balance of this page will review the actuating characteristics of a reed switch via these two methods.



Coil Actuation

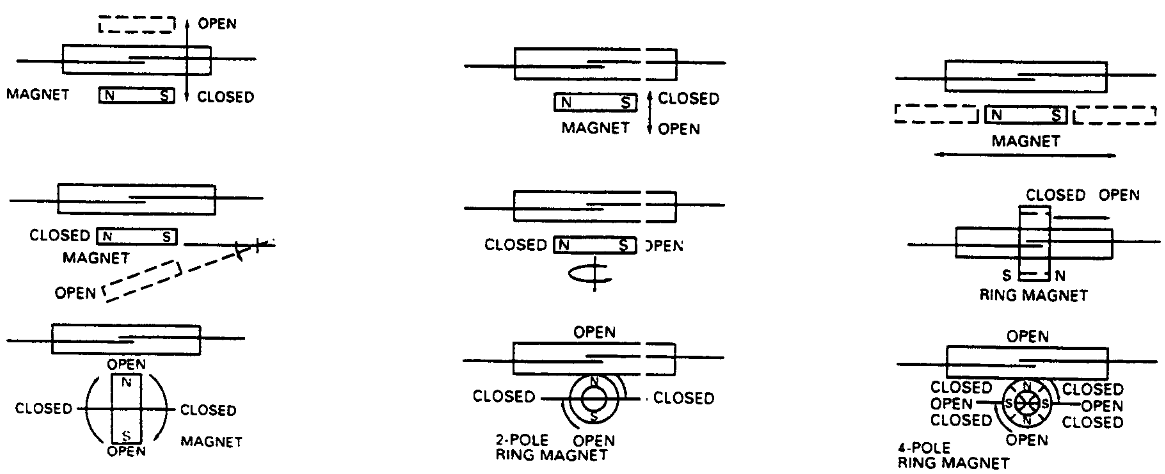
The operation of a reed switch via an electromagnetic coil provides the designer with a method of actuation from a remote source. This is a very simple method of actuation.

When the reed switch is placed inside or close to a coil of wire and a current is passed through the coil, each lead of the reed switch becomes strongly magnetized. One end of the reed switch will become a north pole and the other a south pole. Because the reed blades overlap in the center of the glass housing, with a few thousandths of an inch separating the overlapping ends, each lead will have a north and south pole. The overlapping reed blades come together (close) when the electrical current generates sufficient magnetic flux in the coil. When the current to the coil is turned off, the reed blades return to their open condition.

The efficiency of the reed switch actuation is largely dependent upon the coil. The size, shape, wire type, and the number of turns of wire on the coil determines its efficiency. In addition, the proximity of the switch to the coil determines the efficiency of the coil (ie, if the switch is placed inside or very close to the coil, the coil requires little current to actuate the switch. The farther the switch is from the coil, the more magnetic flux the coil must generate to cause switch closure). Two or more switches can be actuated by a single coil.

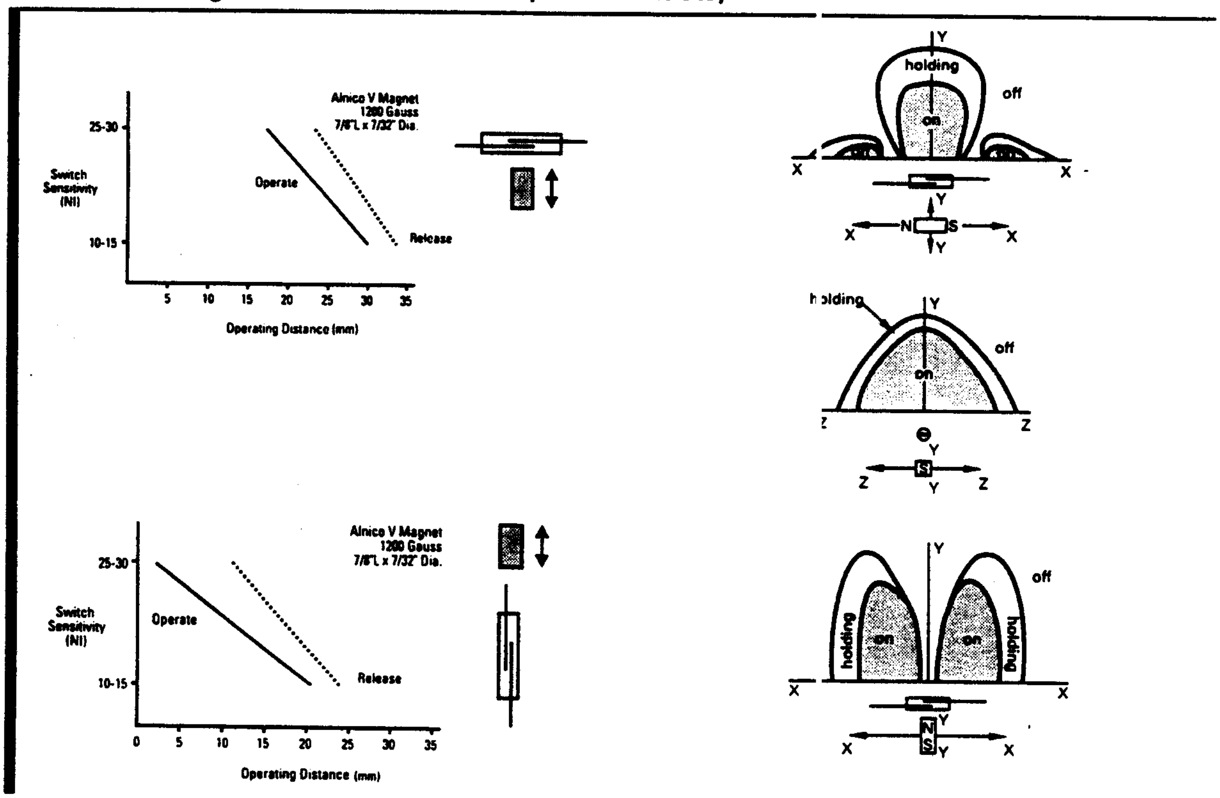
Permanent Magnet Actuation

A permanent magnet is the most common means of operating the reed switch. As with a coil, to actuate the reed switch, a magnet and switch must be positioned within a specific proximity of each other. This distance is related to the sensitivity of the switch and the strength of the magnet. For the normally open reed switch, when the magnetic field is close enough the contacts will close and when the magnetic field is taken away, the contacts will open. There are many ways to use a permanent magnet to actuate the reed switch. Below we have addressed the most popular techniques.



Switch Actuation

Permanent Magnet Actuation Distance (N. O. Contacts)



Form B Reed Switch Actuation

Bias Actuation

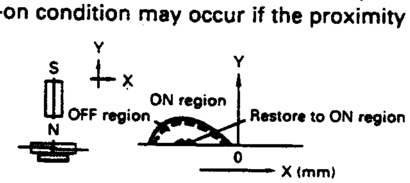
Form B, N. C. contact actuation is achieved by Clare through the use of the standard Form A dry reed switch that is biased closed by mounting a permanent magnet to the switch housing. This magnet is located such that it keeps the switch in the on (or closed) condition.

The switch is turned off (or opened) by bringing another magnet in the proximity of the switch/magnet assembly.

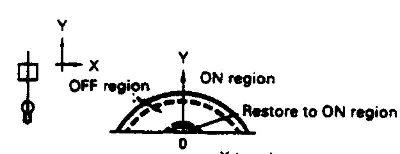
Note in the actuation charts shown below, that an on-off-on condition may occur if the proximity of the actuating magnet s brought very close to the switch/magnet ass embly. This condition is, of course, dependent upon tl e size and strength of the actuating magnet.

Magnets

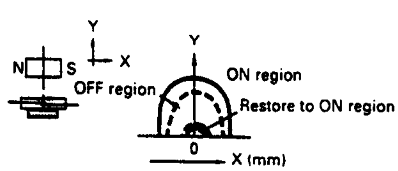
ALNICO V, ALNIC() VIII, Ceramic and Barium ferrite are the most popular ı nagnet materials used. The magnet type is usually chc sen based on size, coercivity, cost, and temperature c ıaracteristics as defined by the application.



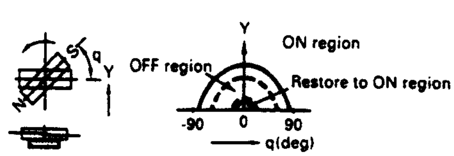
1. Perpendicular



3. Transverse



2. Horizontal

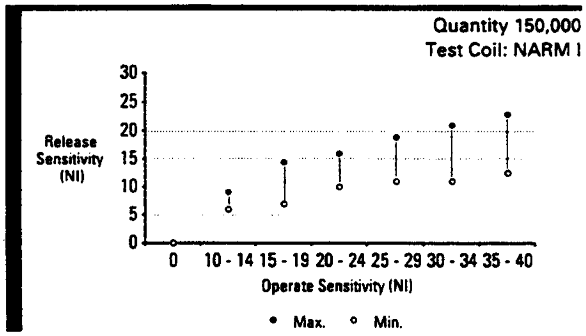


4. Rotational

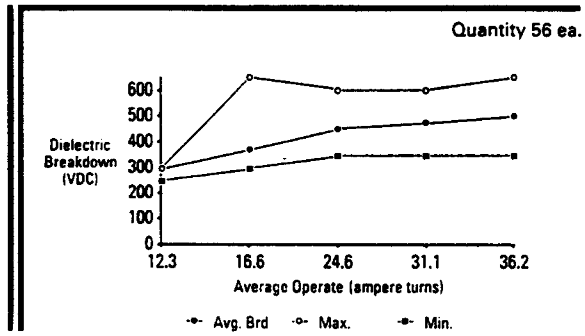
Performance Data

Clare

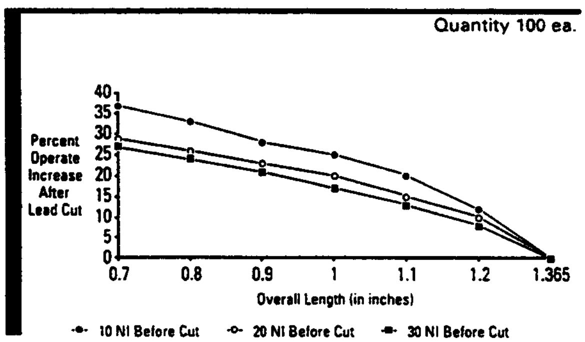
Operate NI vs. Release NI



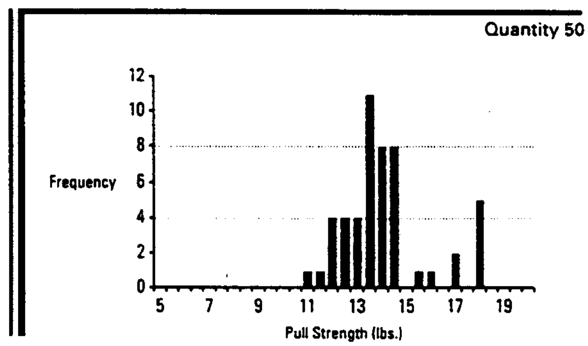
Dielectric Breakdown vs. Operate Sensitivity



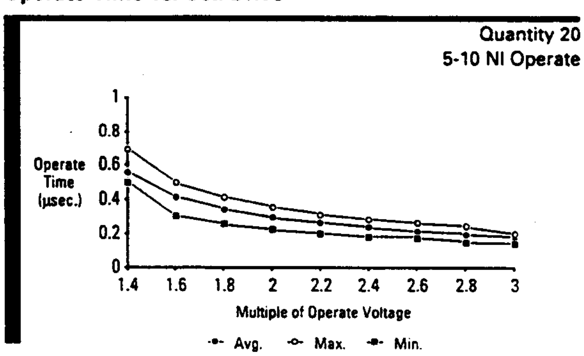
Operate Shift After Lead Trimming



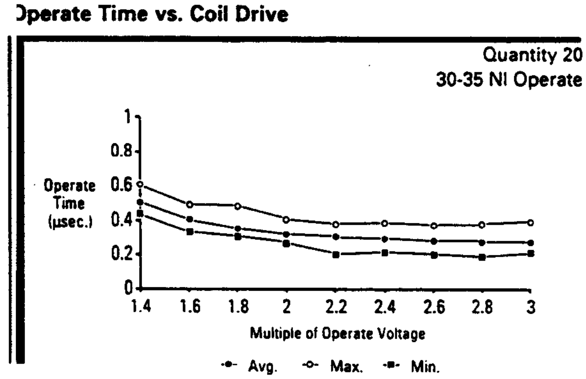
Pull To Fracture Test Distribution



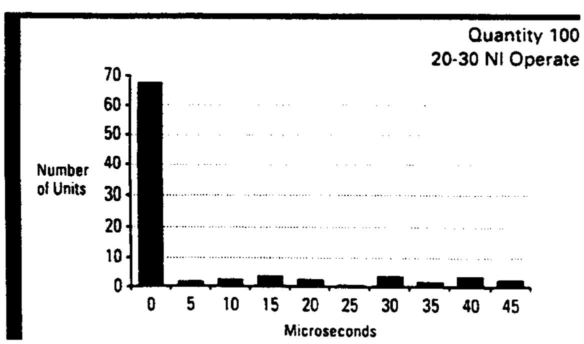
Operate Time vs. Coil Drive



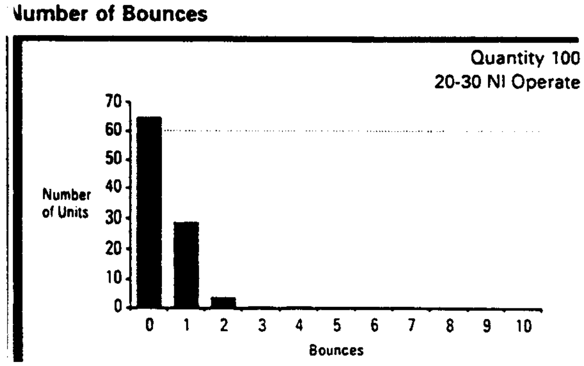
Operate Time vs. Coil Drive



Bounce Time

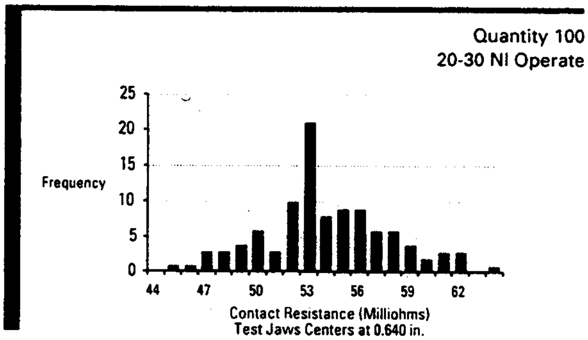


Number of Bounces

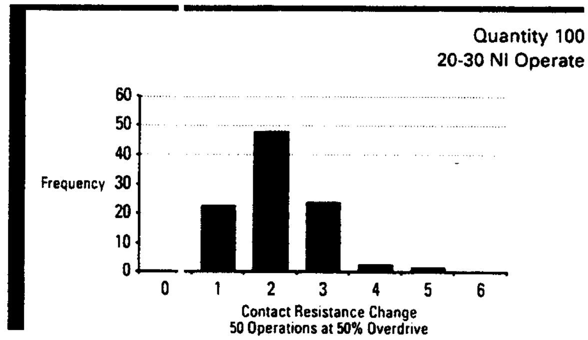


Performance Data

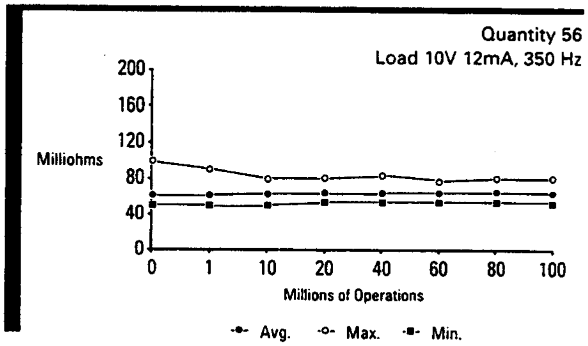
Contact Resistance



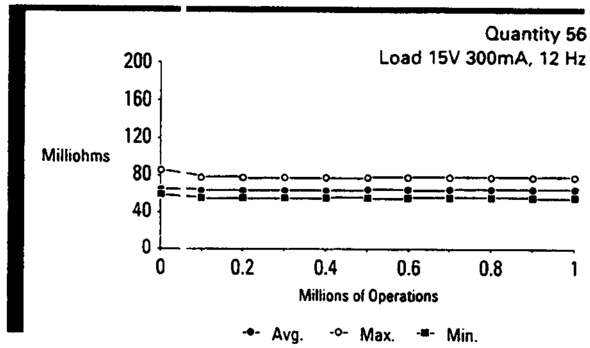
Contact Resistance Stability



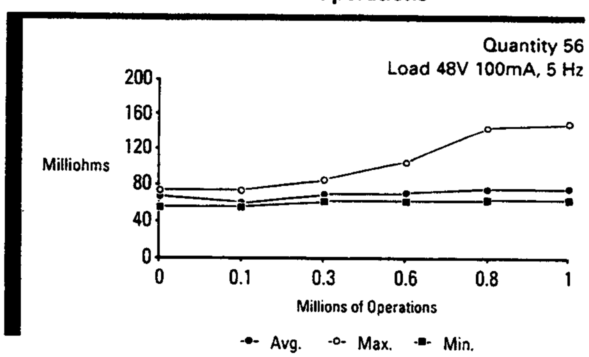
Contact Resistance vs. No. of Operations



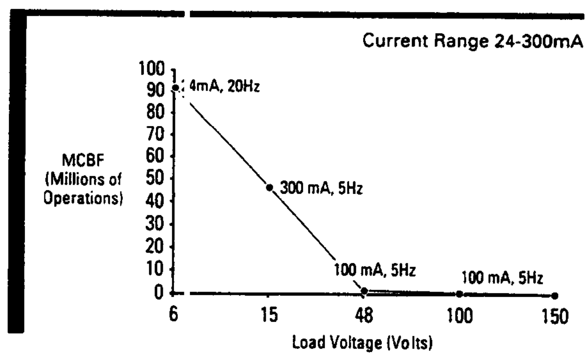
Contact Resistance vs. No. of Operations



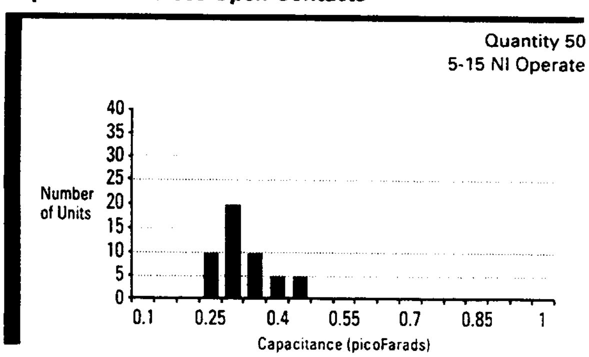
Contact Resistance vs. No. of Operations



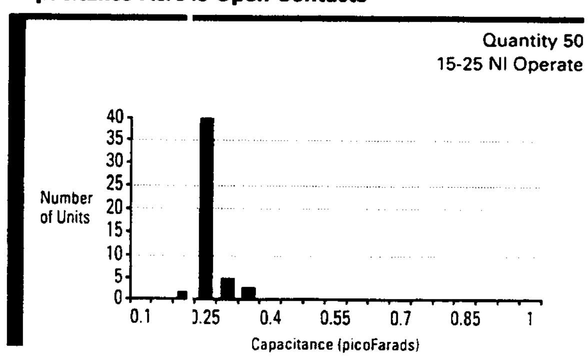
Load Life



Capacitance Across Open Contacts



Capacitance Across Open Contacts



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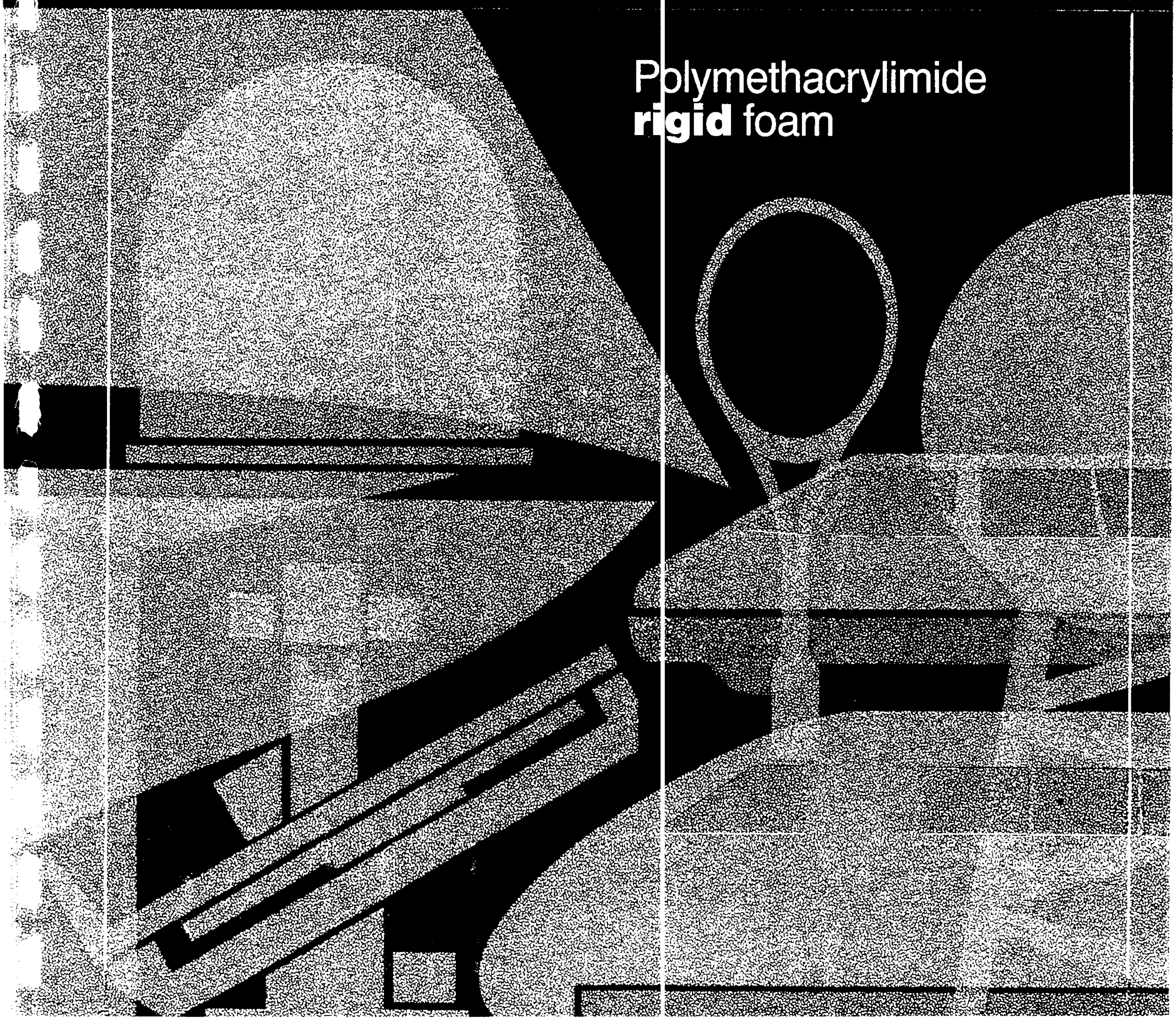
Cat. No. CAPS11

Printed in the U.S.A 9-88

TECHNICAL PRODUCTS

rohacell

Polymethacrylimide **rigid** foam



®rohacell

Technical Information

Contents

Page

The product profile of ROHACELL

What is ROHACELL?

ROHACELL is a closed-cell rigid expanded plastic material or, more accurately, polymethacrylimide rigid foam (PMI) for lightweight sandwich construction. The natural color of ROHACELL is white.

ROHACELL has excellent mechanical properties, high dimensional stability under heat, solvent resistance and, particularly at low temperatures, a low coefficient of heat conductivity. The strength values and the moduli of elasticity and shear are presently not exceeded by any other foamed plastic having the same density.

ROHACELL is manufactured by hot foaming of methacrylic acid/methacrylonitrile copolymer sheets. During foaming this copolymer is converted to polymethacrylimide.

The manufacture of ROHACELL

The foaming temperature is above 338 °F (170 °C), depending on the density and grade. After foaming, the block is cooled to room temperature. Due to the low heat conductivity of the foamed plastic, a temperature gradient develops which results in internal stresses. Therefore, when the block is cut into sheets some bowing may occur. However, the stresses are so slight that even thin sandwich skins yield flat sandwich panels.

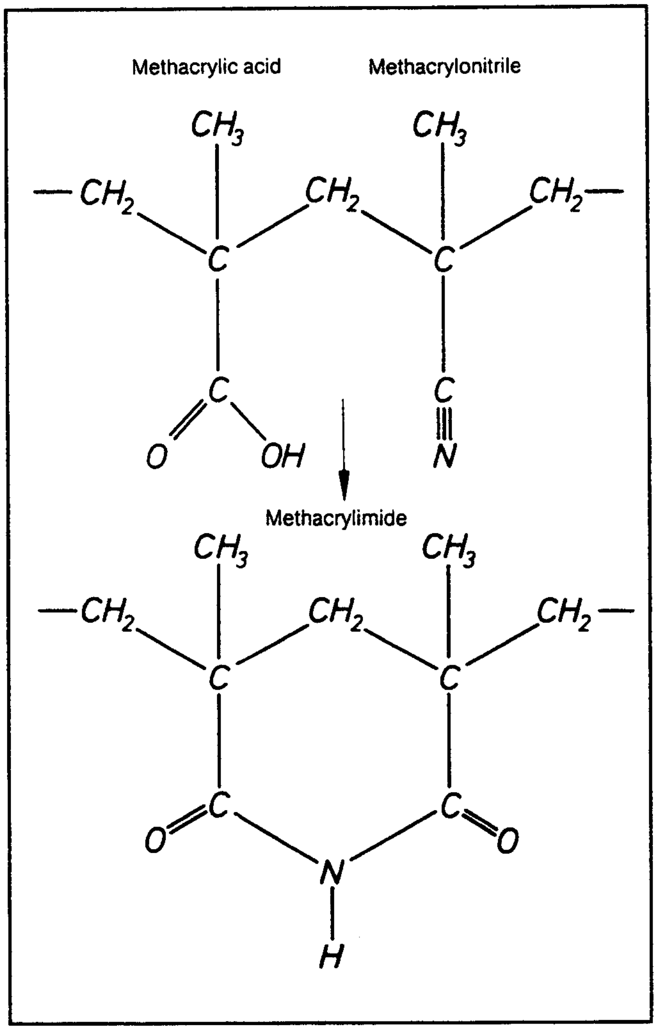


Fig. 1: Formation of polymethacrylimide (PMI)

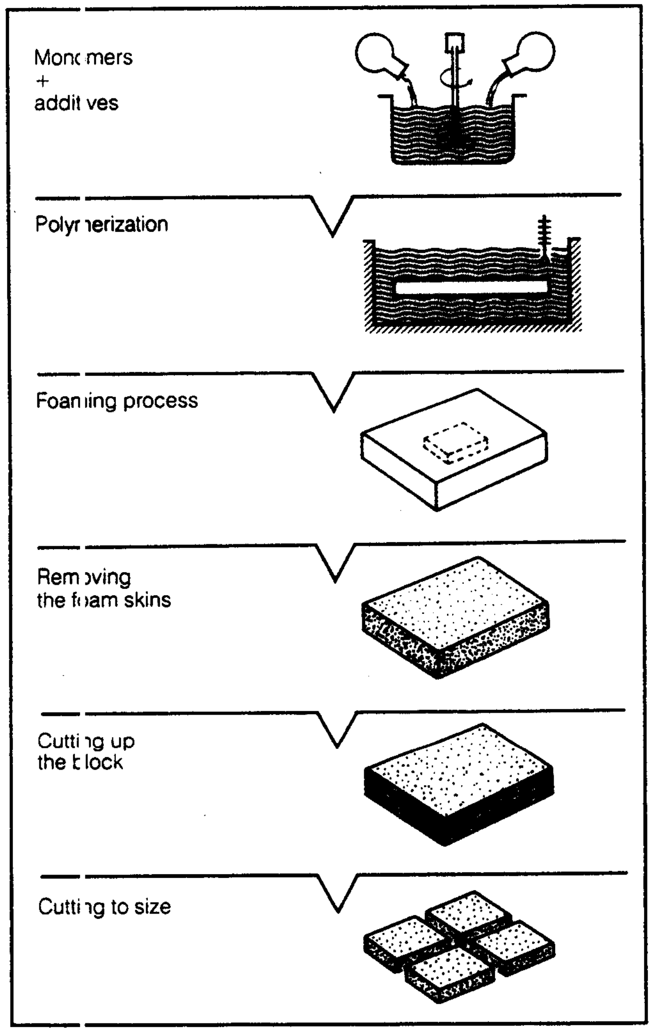


Fig. 2: Production scheme of ROHACELL

ROHACELL supply

Grades that can be supplied

ROHACELL is supplied in different densities

Grade	Density lbs/ft³	kg/m³	Description
ROHACELL 31	**2.0**	32	Grades which, for foam plastics, have the best ratio between specific gravity and strength and therefore a very wide useful technical range.
ROHACELL 51	**3.2**	52	
ROHACELL 71	**4.7**	75	
ROHACELL 110	**6.9**	110	Special grade which closes the property gap between lower-density ROHACELL and the compacted, higher-density grades.
ROHACELL P 170	**10.6**	170	Compacted grades with oriented cell structure which have the highest strength and rigidity in the plane of the sheet
ROHACELL P 190	**11.9**	190	

Availability

ROHACELL is only supplied in the form of sheets.

ROHACELL 31, 51, 71

Thicknesses and sizes according to the standard sales range; other thicknesses than those quoted in the sales range can be produced on request.

ROHACELL 110

Thickness and size in accordance with the standard sales range.

ROHACELL P 170, P 190

Thickness and size in accordance with the standard sales range.

Sales range

Sheet thickness inch / mm	**.25** 6.35	**.5** 12.7	**.75** 19.5	**1** 25.4	**1.5** 38.1	**2** 50.8	**2.559** 65
ROHACELL 31	+	+	+	+	+	+	+
ROHACELL 51	+	+	+	+	+	+	
ROHACELL 71	+	+	+	+	+	+	

Size: + = **98.4 × 49.2** inch 2500 × 1250 mm

Custom type sheet thicknesses are available

Sheet thickness inch / mm	1.9 / 48
ROHACELL 110	+

Size: **85 × 21.6** inch 2160 × 550 mm

Sheet thickness inch / mm	**.9** 23	**1.1** 28
ROHACELL P 170		+
ROHACELL P 190	+	

Size: **98.4 × 23.6** inch 2500 × 600 mm

The properties of ROHACELL

The mechanical properties

Mechanical properties of ROHACELL 31, 51, 71, 110, P 170, P 190

Properties[1]	Units	31	51	71	110	P 170	P 190	Standard
Density	lbs/ft³ (kg/m³)	**2.0** (32)	**3.2** (52)	**4.7** (75)	**6.9** (110)	**10.6** (170)	**11.9** (190)	ASTM D 1622-63
Tensile strength	psi (N/mm²)	**142** (1.0)	**270** (1.9)	**398** (2.8)	**498** (3.5)	**1070** (7.5)	**1210** (8.5)	ASTM D 638-68
Compressive strength	psi (N/mm²)	**57** (0.4)	**128** (0.9)	**213** (1.5)	**427** (3.0)	**924 (398)**[2] (6.5) (2.8)[2]	**1110 (455)**[2] (7.8) (3.2)[2]	ASTM D 1621-64
Flexural strength	psi (N/mm²)	**114** (0.8)	**228** (1.6)	**356** (2.5)	**640** (4.5)	**1490 (1420)**[2] (10.5) (10.0)[2]	**1780 (1710)**[2] (12.5) (12.0)[2]	ASTM D 790-66
Shear strength	psi (N/mm²)	**57** (0.4)	**114** (0.8)	**185** (1.3)	**34[illegible]** (2.4)	**640 (427)**[2] (4.5) (3.0)[2]	**782 (427)**[2] (5.5) (3.0)[2]	ASTM C 273-61
Modulus of elasticity	psi (N/mm²)	**5120** (36)	**9950** (70)	**13100** (92)	**22700** (160)	**45500** (320)	**54000** (380)	ASTM D 638-68
Shear modulus	psi (N/mm²)	**1990** (14)	**2990** (21)	**4270** (30)	**8250** (58)	**17000** (120)	**26300** (185)	ASTM D 2236-69
Shear modulus	psi (N/mm²)	**1850** (13)	**2700** (19)	**4120** (29)	**71[illegible]0** (50)	**12500** (88)	**14200** (100)	ASTM C 273-61
Elongation at break	%	3.5	4	4.5	4.5	5	6	ASTM D 638-68
Dimensional stability under heat	°F °C	**356** (180)	**356** (180)	**356** (180)	**356** (180)	**266**[3] (130)[3]	**266**[3] (130)[3]	DIN 53424

[1]) Test conditions 73.4 °F (23 °C) and 50 % relative humidity
[2]) Measured at right angles to the plane of the sheet
[3]) Beyond this temperature the oriented cell structure starts to decrease

ROHACELL P 170 and P 190 have very high specific strengths. The cell structure has been oriented by a special method which produces a difference in strength between the plane of the sheet and at right angles to it. In this way, and depending on the situation in which the ROHACELL sheets are installed, excellent sandwich constructions can be obtained.
For a number of uses in sandwich construction it is therefore reasonable to allow the direction of the principal stress to coincide with the direction of the highest material strength, i.e. to use the core with an upright cell structure.

Here is an example of this technique (Fig. 3):
The compacted ROHACELL rigid foams are supplied as sheets. Normally they are bonded with adhesives to a height corresponding to the width of the required sandwich core. Out of the resultant block the cores are sawn at right angles to the joints so that their cell structure is vertical when the core is in a horizontal position.
It is not necessary for this technique to be used in every case. If the strength values measured in the molding direction satisfy a given purpose, the ROHACELL sheets may be used flat.

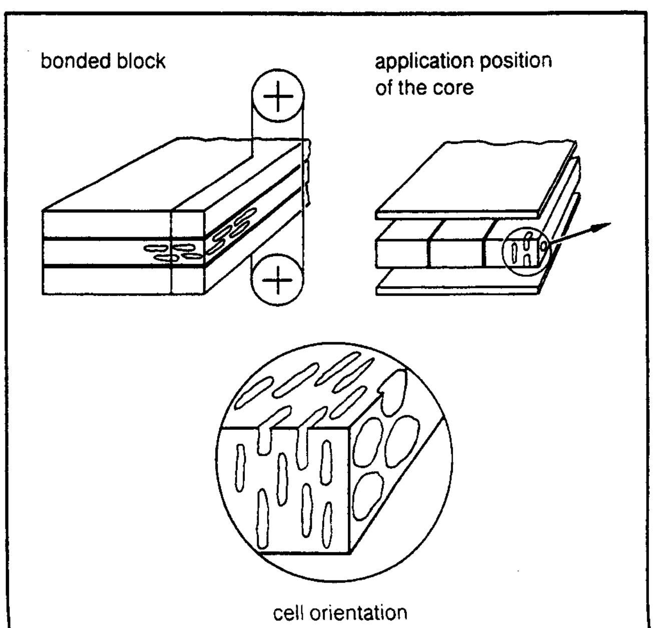


Fig. 3

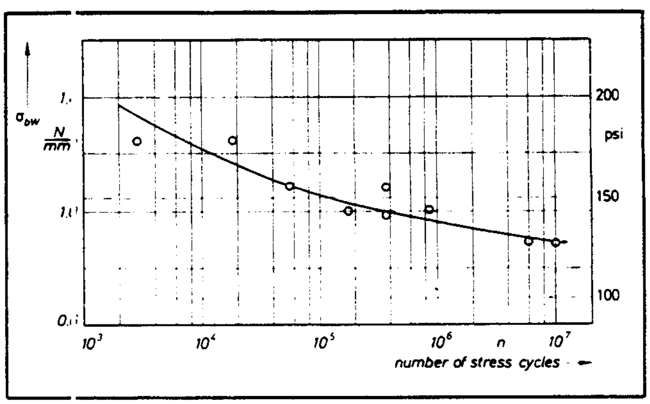


Fig. 4: Fatigue strength in alternating bending test of ROHACELL 51 at a stress frequency of 10 Hz.

The long-term behavior of ROHACELL under dynamic stress is excellent. There was no measurable, time-dependent decrease in the stress up to an exposure time of 10^7 load cycles.

The thermal properties

Thermal properties of ROHACELL 31, 51, 71

Properties	Units	ROHACELL 31	51	71	Standard
Dimensional stability under heat	**°F**	**356**	**356**	**356**	DIN 53424
	°C	(180)	(180)	(180)	
Coefficient of linear thermal expansion[1]	K^{-1}	3.7 $\times 10^{-5}$	3.3 $\times 10^{-5}$	3.5 $\times 10^{-5}$	ASTM D 696-70
	in./in./°F	**2.3**	**2.1**	**2.2**	
Thermal conductivity[1]	**BTU in./ft²h °F**	**0.215**	**0.201**	**0.208**	ASTM C 177-63
	(W/mK)[2]	(0.031)	(0.029)	(0.030)	

[1] Tested at 68 °F (20 °C)
[2] 1 W/mK = 0.86 kcal/m h deg.

Dimensional stability under heat
Normally the 'dimensional stability under heat' of a product is adequately described by the practical requirements made on its strength, weight stability and dimensional stability.

The following tables therefore show the changes in weight, volume and linear dimensions of ROHACELL specimens kept in air at different temperatures for 30 days. The measurements were taken immediately after the specimens had cooled down from the air temperature at which they had been kept.

Changes in weight and dimensions of ROHACELL 31, 51 and 71 after being kept at different temperatures for 30 days.

ROHACELL		31			51			71		
Storage temp.	**°F**	**212**	**248**	**320**	**212**	**248**	**320**	**212**	**248**	**320**
	(°C)	(100)	(120)	(160)	(100)	(120)	(160)	(100)	(120)	(160)
Change in weight	%	-3.3	-4.4	-5.2	-4.0	-5.1	-6.1	-3.7	-4.2	-6.0
Change in length	%	-0.8	-1.0	-1.6	-1.0	-1.4	-1.8	-0.8	-1.0	-1.9
Change in volume	%	-1.7	-3.2	-4.2	-2.3	-3.9	-4.8	-2.3	-3.0	-3.3

Changes in weight and dimensions of ROHACELL 31, 51, 71 after storage as above, followed by keeping under standard conditions (73.4 °F, 23 °C, 50 % r.h.) until the weight was approximately constant.

ROHACELL		31			51			71		
Storage temp.	**°F**	**212**	**248**	**320**	**212**	**248**	**320**	**212**	**248**	**320**
	(°C)	(100)	(120)	(160)	(100)	(120)	(160)	(100)	(120)	(160)
Change in weight	%	0	-0.2	-1.6	-0.2	-0.6	-2.5	-0.3	-0.9	-2.9
Change in length	%	0	-0.2	-1.2	0	-0.4	-1.3	-0.2	-0.4	-1.5
Change in volume	%	-0.1	-0.2	-2.7	-0.1	-1.1	-3.7	-0.5	-1.3	-2.0

Linear thermal expansion
The linear thermal expansion of ROHACELL is unusually low for a plastic material.
Coefficient of linear thermal expansion of ROHACELL 31, 51, 71 at various temperatures:

Temperature **°F** (°C)	ROHACELL 31 in./in. °F ($K^{-1} \cdot 10^{-5}$)	ROHACELL 51 in./in. °F ($K^{-1} \cdot 10^{-5}$)	ROHACELL 71 in./in. °F ($K^{-1} \cdot 10^{-5}$)
−238 (−150)	**1.38** (2.5)	**1.33** (2.4)	**1.66** (3.0)
−148 (−100)	**1.38** (2.5)	**1.33** (2.4)	**1.66** (3.0)
−58 (−50)	**1.55** (2.8)	**1.49** (2.7)	**1.66** (3.0)
+32 (0)	**1.66** (3.0)	**1.66** (3.0)	**1.77** (3.2)
+68 (+20)	**2.05** (3.7)	**1.83** (3.3)	**1.94** (3.5)

The expansion coefficients are distinctly lower than those of other rigid foams, and the values at very low temperatures in particular are similar to those of metals and fibre-reinforced laminates, thus making the stress-deformation behavior of sandwich systems very useful.

Thermal conductivity
The thermal conductivity values of ROHACELL grades differ only slightly; they are within the ranges given in the table below for different temperatures. These values were determined for aged specimens whose cells contained essentially only air rather than propellant gas. They are therefore stable, ultimate values which no longer rise under normal conditions.

Thermal conductivity of ROHACELL 31, 51, 71 at different temperatures

Temperature **°F**	(°C)	ROHACELL 31, 51, 71 BTU in./ft²h°F)	(W/mK*)
−256	(−160)	**0.104−0.132**	(0.015−0.019)
−148	(−100)	**0.132−0.146**	(0.019−0.021)
− 40	(− 40)	**0.159−0.194**	(0.023−0.028)
+ 68	(+ 20)	**0.194−0.234**	(0.028−0.034)
+176	(+ 80)	**0.243−0.284**	(0.035−0.041)
+284	(+140)	**0.291−0.333**	(0.042−0.048)

*) 1 W/mK ≅ 0.86 kcal/m h deg.

Material behavior at elevated temperatures

The illustrations show the tensile, compressive and flexural strengths, the moduli of elasticity and shear of ROHACELL as functions of temperature as well as the creep behavior as a function of the compressive stress at 266 °F (130 °C).

For special techniques, like the manufacture of sandwich panels in the autoclave, the creep behavior of ROHACELL may not be adequate. In this case we recommend the use of ROHACELL WF.

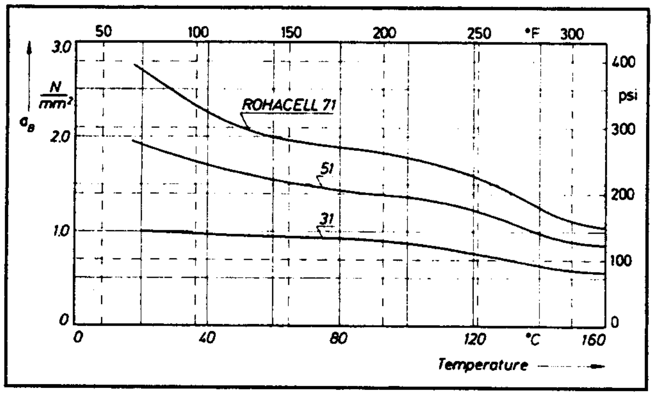


Fig. 5: Tensile strength (ASTM D 638-68) as a function of temperature

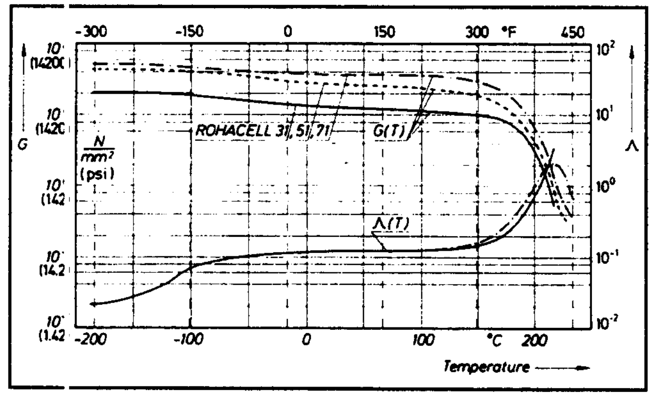


Fig. 8: Shear modulus G and mechanical damping Λ (ASTM D 2236-69) as a function of temperature

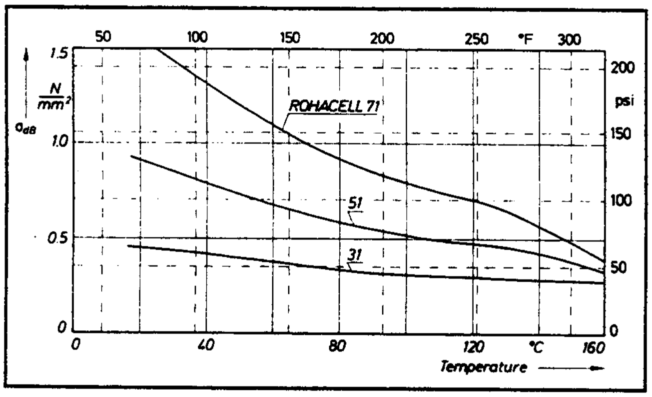


Fig. 6: Compressive strength (ASTM D 1621-64) as a function of temperature

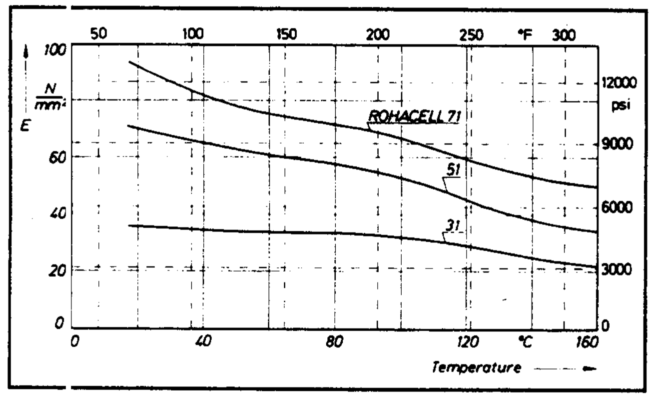


Fig. 9: Modulus of elasticity (ASTM D 638-68) as a function of temperature

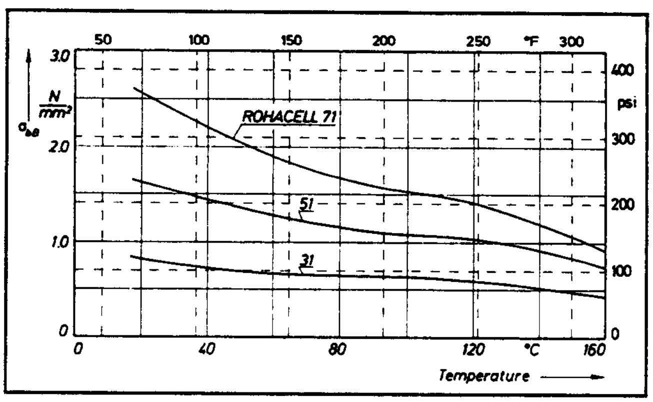


Fig. 7: Flexural strength (ASTM D 790-66) as a function of temperature

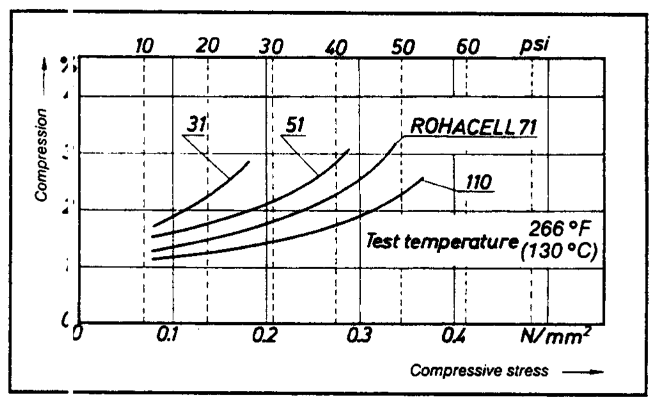


Fig. 10: Creep behavior of ROHACELL; test period 2 hrs., specimen inserted cold, initial compression c. 0.6 mm

Material behavior at low temperatures

The following table presents a few properties of ROHACELL 31, 51 and 71 which permit an assessment of these materials for use at low temperatures. It is of particular interest that the elongation at break at −320.0 °F (−196 °C) is still above 1 %. For further data look under "The thermal properties" (page 6). The moderate heat expansion and cold contraction of ROHACELL is emphasized by the following example: for a temperature change between room temperature of +73.4 °F (+23 °C) and −320.8 °F (−196 °C) the expansion or contraction is only .005 in./in. to .006 in./in. (5 to 6 mm/m). These low values are normally only reached by fiber-reinforced materials and metals. As a result, sandwich systems with a ROHACELL core show a very faborable stress-deformation behavior.

Tensile strength, compressive strength and elongation at break of ROHACELL 31, 51, 71 at low temperatures

Properties	Units	Test temperatures	ROHACELL 31	ROHACELL 51	ROHACELL 71	Standard
Tensile strength	**psi**	**73.4 °F**	**142**	**270**	**398**	ASTM D 638-68
	N/mm²	(23 °C)	(1.0)	(1.9)	(2.8)	
		−94 °F	**156**	**284**	**427**	
		(−70 °C)	(1.1)	(2.0)	(3.0)	
		−320.8 °F	**156**	**313**	**455**	
		(−196 °C)	(1.1)	(2.2)	(3.2)	
Compressive strength	**psi**	**73.4 °F**	**56.9**	**128**	**213**	ASTM D 1621-64
	N/mm²	(23 °C)	(0.40)	(0.9)	(1.5)	
		−94 °F	**58.3**	**142**	**256**	
		(−70 °C)	(0.41)	(1.0)	(1.8)	
		−320.8 °F	**62.6**	**156**	**284**	
		(−196 °C)	(0.44)	(1.1)	(2.0)	
Elongation at break	%	**73.4 °F**				ASTM D 638-68
		(23 °C)	**3.5**	**4.0**	**4.5**	
		−94 °F				
		(−70 °C)	**2.5**	**2.7**	**3.0**	
		−320.8 °F				
		(−196 °C)	**1.4**	**1.4**	**1.5**	

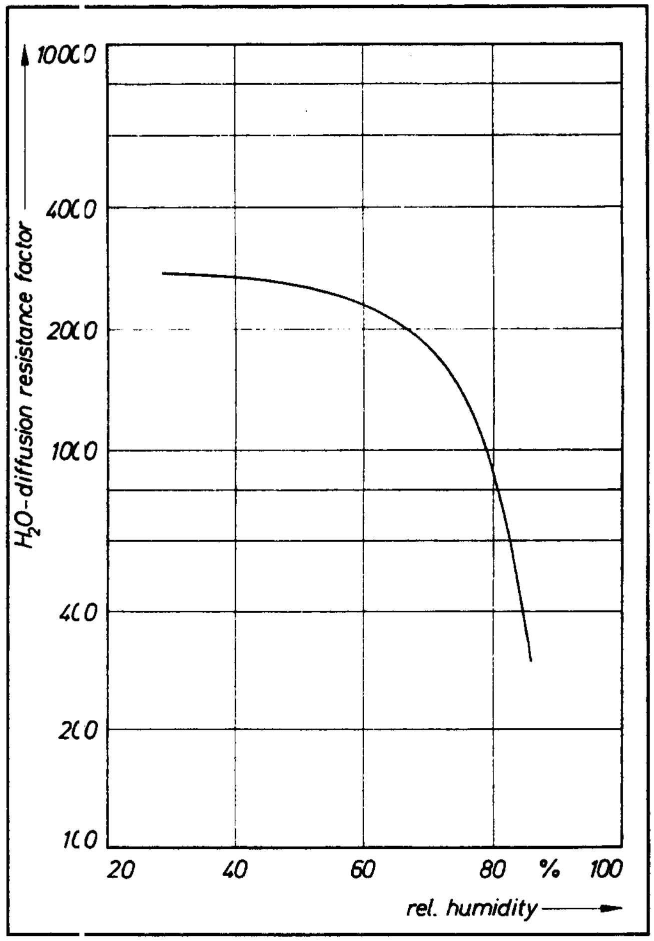
Water vapor diffusion

Water vapor diffusion resistance factor of ROHACELL 31, 51, 71

Property[1)]	Unit	ROHACELL 31	ROHACELL 51	ROHACELL 71	Standard
H_2O diffusion resistance factor	1	400	650	900	ASTM E 96

1) Test conditions 68 °F (20 °C) and 85 % relative humidity.

The values given in the table are surprisingly high. Measurements have shown that the water vapor diffusion of ROHACELL above 65 % relative humidity increases with the humidity reading.



Water absorption

Polymethacrylimide (PMI) absorbs water in a manner similar to polyamide. The following table shows the sorption equilibria (equilibrium water content with respect to dried samples) of ROHACELL in damp air. Size of samples 2 x 2 x 0.08 inches (50 x 50 x 20 mm).

Atm. humidity % r.h.	ROHACELL 31 Equilibrium water content in vol. %	weight %	ROHACELL 51 vol. %	weight %	ROHACELL 71 vol. %	weight %
15	0.05	1.5	0.07	1.3	0.08	1.2
30	0.09	2.9	0.13	2.6	0.17	2.4
50	0.14	4.7	0.21	4.2	0.25	3.6
65	0.18	6.0	0.25	5.0	0.30	4.3
98	0.59	19.5	0.88	17.4	1.1	15.5

The following table illustrates the water absorption and change in volume of test specimens after 50 days of total immersion in water. These values show that despite the relatively high water absorption, the dimensional stability is satisfactory. Shrinkage of the samples is only observed after prolonged immersion at water temperatures above 122 °F (50 °C).

Property	Unit	ROHACELL 31	51	71
H_2O absorption at 68 °F (20 °C)	vol. %	13	15	16
122 °F (50 °C)	vol. %	18	23	26
Vol. increase on water immersion 68 °F (20 °C)	vol. %	<1	<2	<3
122 °F (50 °C)	vol. %	<2	<2	<3

The diagram below shows that, irrespective of the period of water immersion, the compressive strength of ROHACELL settles at a constant value.

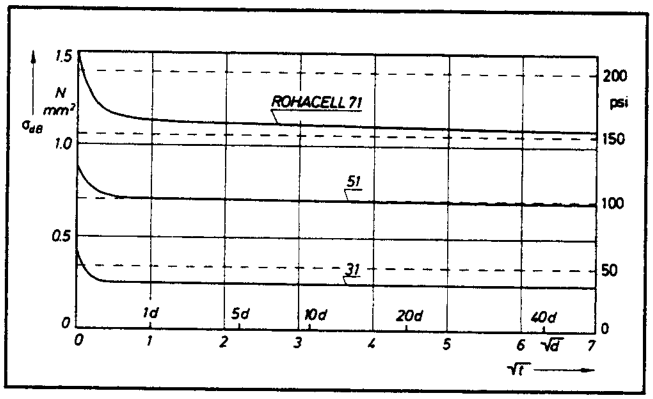


Fig. 12: Compressive strength (ASTM D 1621-64) of ROHACELL immersed in water as a function of time

40-month water permeation tests with ROHACELL P 170 in a sandwich structure

For boat building and similar uses, the water penetration into FRP structural sandwich parts with damaged skins is of particular interest. Corresponding tests were conducted.

ROHACELL P 170 with the dimensions 15.7 x 15.7 x 1.1 in. (400 x 400 x 28 mm) was laminated on all sides with glass-reinforced polyester resin. The skins consisted of: mat (.09 lbs/ft² 450 g/m²), roving (.1 lbs/ft²/500 g/m²), mat (.09 lbs/ft² 450 g/m²), roving (.1 lbs/ft²/500 g/m²) and mat (.09 lbs/ft² 450 g/m²). The laminating resin was a polyester (PALATAL P 51). The skins were applied manually and cold-cured with a thickness of about .2 in. (5 mm).

In the middle of one of the surfaces a part of the skin with a diameter of 2.8 in. (70 mm) was removed. A tube was placed into this opening and sealed with silicone against the remaining skin. The tube was then filled with water to a height of 11.8 in. (300 mm). Since ROHACELL is a foam with closed cells, the penetration of water is purely due to diffusion, a fact which was confirmed by preliminary tests.

After 40 months, the skins were removed and the ROHACELL core examined for water absorption. The places from which the samples were taken are shown in the illustration. The specimens were dried in a vacuum cabinet at 158 °F (70 °C) and the water content thus determined in per cent by weight. The size of each sample was 2 x 2 x 1.1 in. (50 x 50 x 28 mm). The water content reduces very quickly from the center outwards, i.e. even after being in water for 40 months the specimen was not soaked. At a distance of about 5.9 in. (150 mm) from the water tube the material was practically dry.

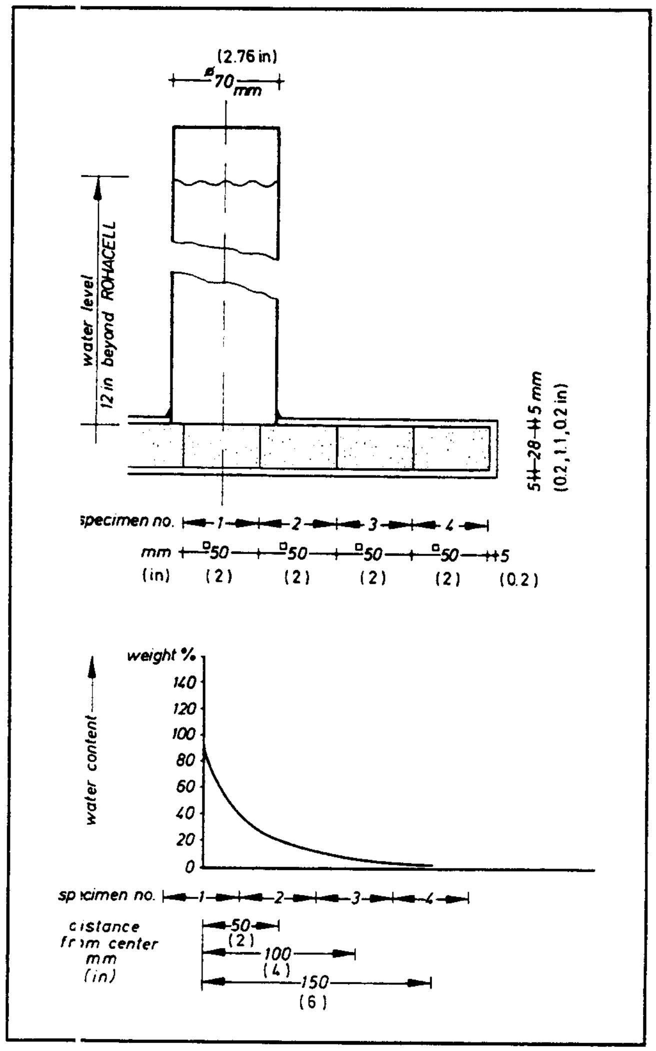


Fig. 13: Sandwich with ROHACELL P 170 kept in water for 40 months

Material behavior upon simultaneous exposure to moisture and heat

Even when ROHACELL is kept for a prolonged period at 100% rel. humidity and 158 °F (70 °C) the compressive strength, for example, is only slightly affected. When the specimen is subsequently kept under normal conditions (73.4 °F, 23 °C, 50% r.h.), the original values are recovered. The table also gives the changes in weight and volume under these conditions with respect to the original weight and volume.

Compressive strength of ROHACELL after 500 h at 158 °F (70 °C) and 100% r.h.

ROHACELL	Test conditions	Change in weight*		Volume change*	Compressive strength	
		(weight %)	(vol. %)	(vol. %)	**psi**	(N/mm^2)
31	A	–	–	–	**56.9**	(0.40)
	B	4.4	0.13	–4.1	**55.9**	(0.39)
	C	1.8	0.06	–5.2	**55.5**	(0.39)
	D	0.7	0.03	–5.5	**55.5**	(0.39)
51	A	–	–	–	**127**	(0.89)
	B	4.1	0.20	–2.8	**112**	(0.79)
	C	1.9	0.09	–3.7	**121**	(0.85)
	D	1.0	0.05	–4.3	**127**	(0.89)
71	A	–	–	–	**213**	(1.5)
	B	3.8	0.27	–2.3	**185**	(1.3)
	C	1.7	0.13	–2.9	**199**	(1.4)
	D	1.2	0.10	–3.0	**213**	(1.5)

*) versus initial values

Test conditions
A = material as supplied
B = after 500 h at 158 °F (70 °C) and 100% r.h.
C = as B and another 500 h in a standard climate of 73.4 °F (23 °C) and 50% r.h.
D = as B and exposure to standard climate of 73.4 °F (23 °C) and 50% r.h. until approx. constand weight

The electrical properties

Dielectric constant and loss tangents of ROHACELL

ROHACELL	Frequency, GHz			
Dielectric constant	2.0	5.0	10.0	26.0
31	1.08	1.05	1.05	1.06
51	1.07	1.09	1.06	1.11
71	1.08	1.11	1.13	1.10
Loss angent				
31	.0001	.0004	.0008	.0034
51	.0002	.0004	.0011	.0050
71	.0003	.0007	.0018	.0076

Measured by: Seavey Engineering Associates, Inc.

Surface resistance

ROHACELL	31	51	71
ohm	2×10^{13}	9×10^{12}	5.5×10^{12}

The excellent dielectric values of ROHACELL are a major advantage for its use in radomes and antenna engineering.

The moisture pick-up of ROHACELL without skins does not really influence the remarkable specific properties of ROHACELL in antenna applications since the water molecules are fixed in the imide groups and are unable to oscillate freely. When ROHACELL is covered with skins as usual, the skin material influences the properties of the antenna more than ROHACELL itself. The change of the antenna properties by water absorption of the skins must also be taken into account as the water molecules may oscillate freely here.

X-ray transmission

Aluminium-equivalent measurements were carried out with 100 kV X-rays on various ROHACELL specimens. The graph shows curves measured for ROHACELL grades 31, 51 and 71. Only the given readings for the indicated thicknesses were measured for ROHACELL 110, P 170 and P 190.

ROHACELL	Thickness **in.** (mm)	Al-equivalent **in.** (mm)
110	**1.9** (48)	**0.17** (0.44)
P 170	**1.1** (28)	**0.16** (0.39)
P 190	**0.9** (23)	**0.15** (0.35)

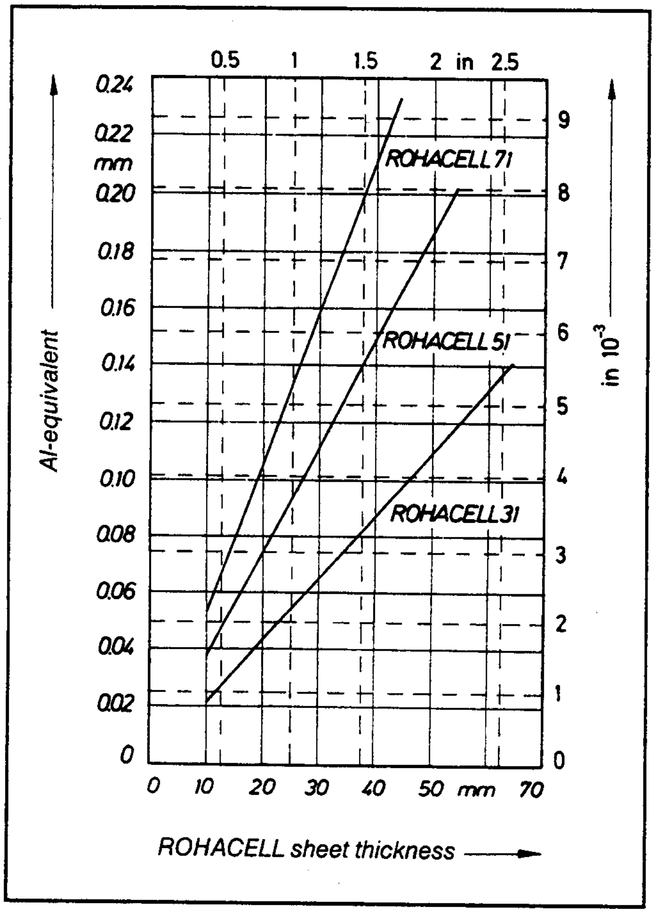


Fig. 14: X-ray transmission of ROHACELL (100 kV)

Chemical resistance

Resistance table for ROHACELL 31, 51, 71, 110

At 68 °F (20 °C)

Acetone	+	Methyl isobutyl ketone	+
Ether	+	Petroleum ether	+
Benzene	+	Sulphuric acid (10%)	+
Dibutyl phthalate	(+)	Soda solution (5%)	–
Diesel fuel	+	Styrene	+
Glacial acetic acid	–	Super petrol	+
Ethyl acetate	+	Carbon tetrachloride	+
Isopropyl alcohol	+	Tetrahydrofuran	–
Paint solvent I	+	Toluene	+
Paint solvent II	+	Trichloroethylene	+
Methyl alcohol	–		

At the boiling point

Carbon tetrachloride	(171 °F) (77 °C)	+
Benzene	(176 °F) (80 °C)	+
Trichloroethylene	(190 °F) (88 °C)	+
Chlorobenzene	(270 °F) (132 °C)	–
Xylene	(282 °F) (130 °C)	+
O-Dichlorobenzene	(356 °F) (180 °C)	–

+ resistant (+) limited resistance – not resistant

Bearing in mind the special behavior under heat, this table also holds for ROHACELL P 170 and P 190.

Among the outstanding characteristics of ROHACELL is its resistance to organic solvents. This is equally true for benzene, xylene and monostyrene as for the usual paint and adhesives solvents fuel constituents and most other industrial solvents. ROHACELL **does not** resist **alkaline** media.

Fire behavior

ROHACELL burns with a slightly smoky flame. The fumes contain no corrosive decomposition products.
The toxicity of the smoke fumes was determined by the mortality of rats after inhaling the thermal decomposition products of ROHACELL for half an hour, decomposition was according to ASTM D 1929. In the temperature range up to 1112 °F (600 °C) the decomposition products of ROHACELL are less toxic than the decomposition products of pinewood.

From .4 in. (10 mm) material thickness upwards, the grades ROHACELL 31, 51 and 71 are "normally flammable" (class B2) within the meaning of DIN 4102 and have a "non-drip" rating. According to ASTM D 1692-59 T, they are classified as "Burning by this Test". The burning rate differs from grade to grade and depends on the material thickness. For ROHACELL 51, .4 in. (10 mm) thick, it amounts to .9 in./min (2.4 cm/min).

When provided with suitable skins, sandwich parts not covered at the edges meet the conditions of FAR, paragraph 25.853 (a) and (b). The specifications of Airbus Industrie for smoke density and toxicity are also met.

According to VDE 0471-3 (incandescent wire method), the ignition temperature of ROHACELL 51 is 1,310 °F (710 °C) when the specimen is .2 in. (5 mm) thick.

According to DIN 51794, the ignition temperature of all ROHACELL grades is about 1,112 °F (600 °C) without flame and about 662 °F (350 °C) with flame.

The calorific value of ROHACELL, measured according to DIN 51708, is about 26000 $\frac{Ws}{g}$ ($2817 \times 10^3 \frac{cal}{pound}$).

The LOI (Limiting Oxygen Index) of ROHACELL 31, 51 and 71 is 19 to 20.

Comparison with other foam plastics

The majority of the values for the following graphs are derived from our own measurements. However, comprehensive literature values were also included so as to be able to form the best possible averages for the different makes of foam plastics. Neither the composition nor the manufacture of the types of foam plastics included in the comparison is uniform. As a result, there may be deviations from the given values, depending on the make. The properties are not rated. It is only intended to show where ROHACELL is to be classified.

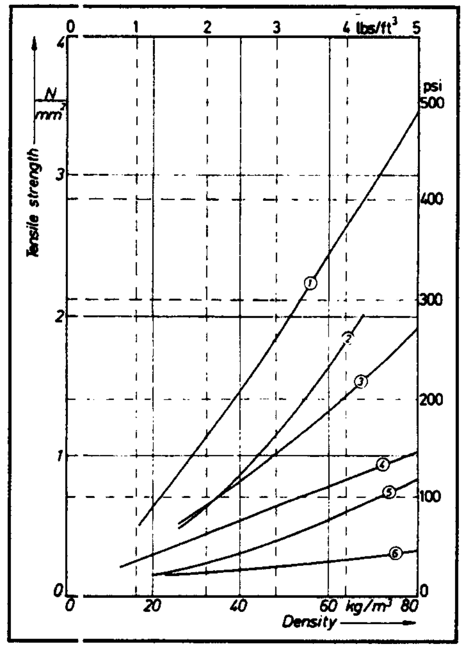


Fig. 15:
Tensile strength according to ASTM D 638-68 of various rigid foams as a function of density at 68 °F (20 °C)

1 = ROHACELL
2 = PS (extruded)
3 = PVC (cross-linked)
4 = PS (foamed in a mold)
5 = PUR
6 = PF

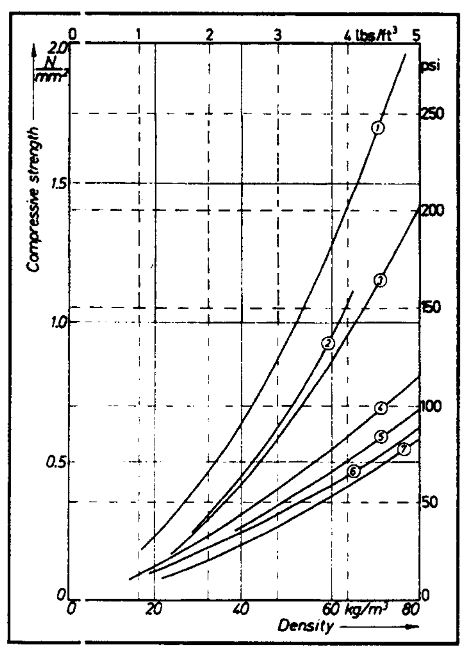


Fig. 16:
Compressive strength according to ASTM D 1621-64 of various rigid foams as a function of density at 68 °F (20 °C).
For PS foamed in a mold the compressive strength at 10% compression was included for comparison's sake

1 = ROHACELL
2 = PS (extruded)
3 = PVC (cross-linked)
4 = PS (foamed in a mold)
5 = PF
6 = PUR

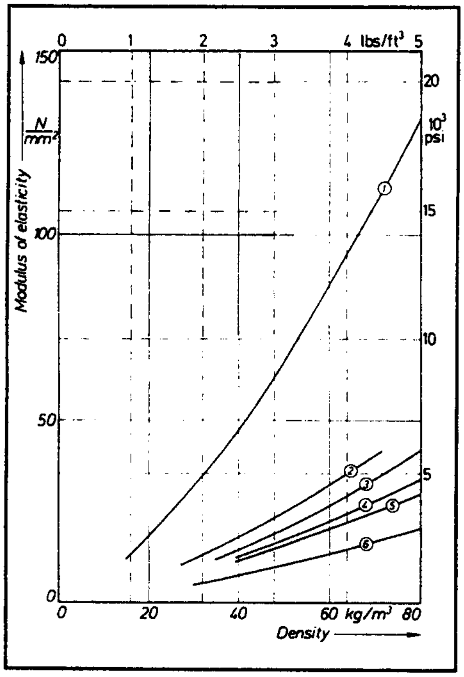


Fig. 17: Modulus of elasticity according to ASTM D 638-68 of various rigid foams as a function of density at 68 °F (20 °C)

1 = ROHACELL
2 = PS (extruded)
3 = PVC (cross-linked)
4 = PVC (not cross-linked)
5 = PF
6 = PUR

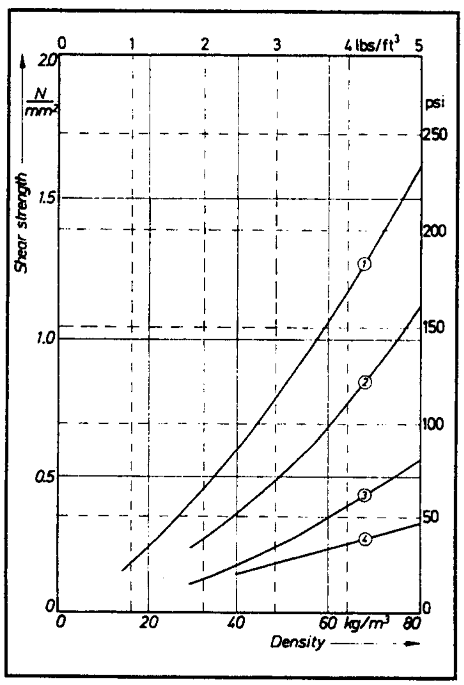
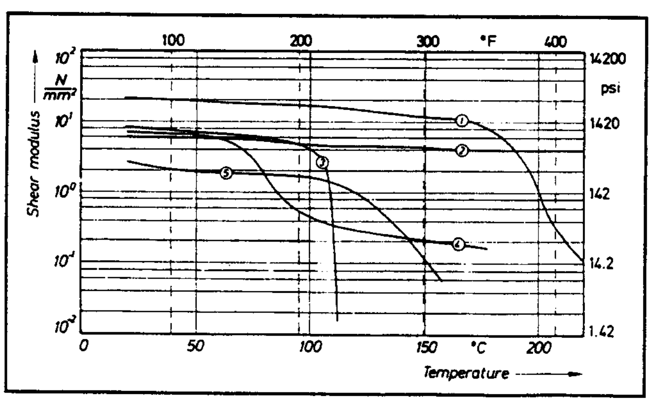


Fig. 18: Shear strength according to ASTM C 273-61 of various rigid foams as a function of density at 68 °F (20 °C)

1 = ROHACELL
2 = PVC (cross-linked)
3 = PUR
4 = PVC (not cross-linked)



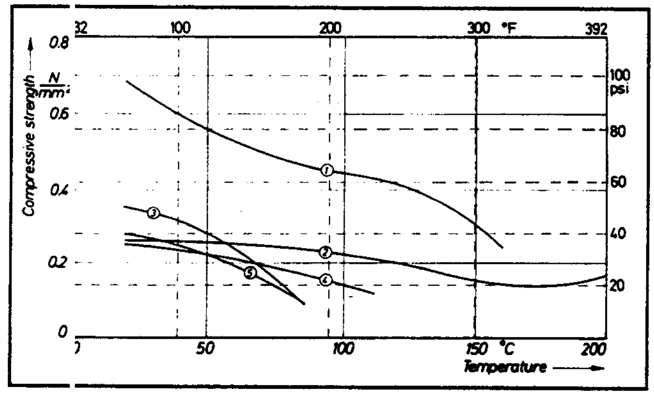


Fig. 20: Compressive strength according to ASTM D 1621-64 of various rigid foams with a density of 2.5 lbs/ft³ (40 kg/m³) as a function of temperature. For PS foamed in a mold the compressive strength at 10% compression was included for the sake of comparison.

1 = ROHACELL
2 = PF
3 = PVC (cross-linked)
4 = PUR
5 = PS (foamed in a mold)

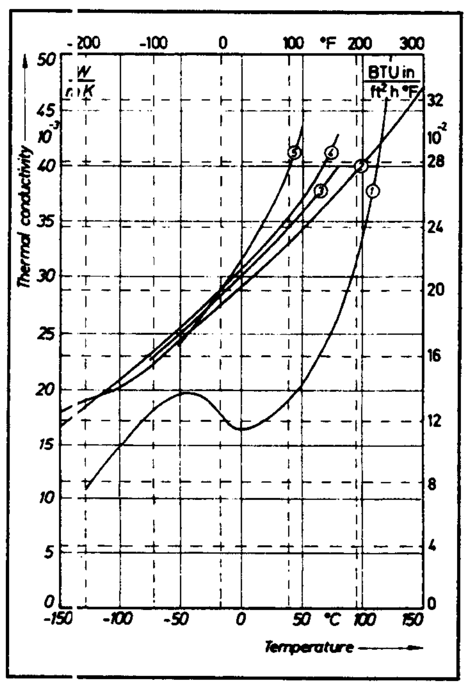


Fig. 21: Thermal conductivity according to ASTM C 177-63 of various rigid foams as a function of temperature

1 = PUR (density 2.5 lbs/ft³/ 40 kg/m³, foamed with fluorotrichloromethane)
2 = ROHACELL (density 2.2 lbs/ft³/ 35 kg/m³)
3 = PS (density 2.5 lbs/ft³/ 40 kg/m³, foamed in a mold)
4 = PF (density 2.5 lbs/ft³/ 40 kg/m³)
5 = PVC (density 3.1 lbs/ft³/ 50 kg/m³, cross-linked)

Fig. 19: Shear modulus according to ASTM D 2236-69 of various rigid foams with a density of 2.5 lbs/ft³ (40 kg/m³) as a function of temperature

1 = ROHACELL
2 = PF
3 = PS (foamed in a mold)
4 = PVC (cross-linked)
5 = PUR

Comparison with other foam plastics

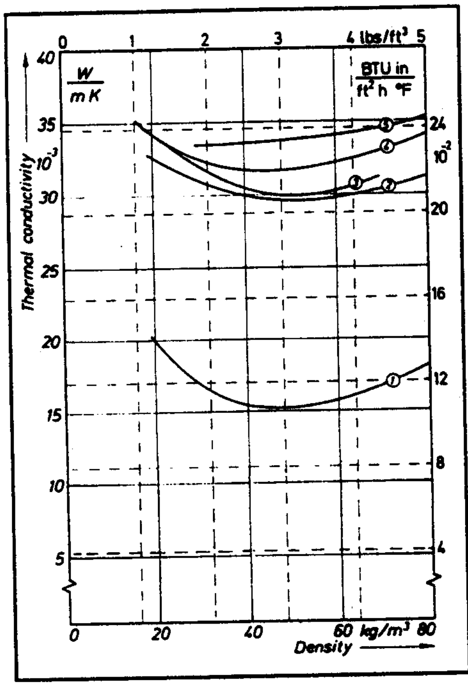


Fig. 22: Thermal conductivity according to ASTM C 177-63 of various rigid foams as a function of density

1 = PUR foamed with fluorotrichloromethane)
2 = PF
3 = ROHACELL
4 = PS (foamed in a mold)
5 = PUR (foamed with CO_2)

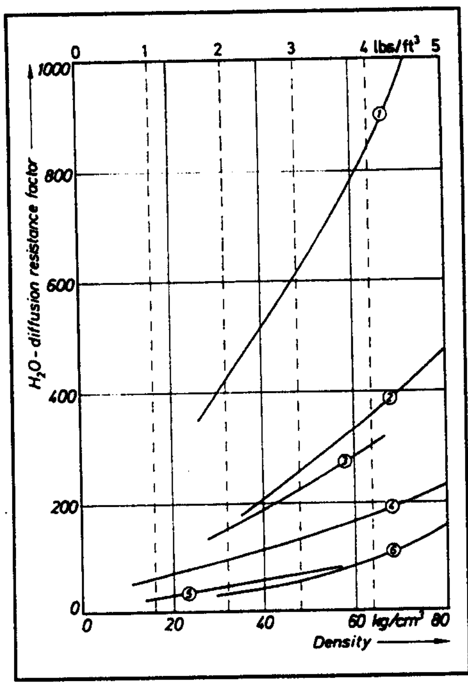


Fig. 23: H_2O diffusion resistance factor of various rigid foams as a function of density, measured in a 0 – 85 % r.h. gradient

1 = ROHACELL
2 = PVC (cross-linked)
3 = PS (extruded)
4 = PS (foamed in a mold)
5 = PUR
6 = PF

Explanation of the abbreviations

The foam plastics consist of:

PS = polystyrene
PVC = polyvinyl chloride
PUR = polyurethane
PF = phenol formaldehyde

Test methods for ROHACELL

The gross density of ROHACELL in lbs/ft³ (kg/m³) is determined according to ASTM D 1622. The specimens are taken from a ROHACELL sheet 4 in. x 4 in. x 1 in.

The compressive strength of ROHACELL in psi (N/mm²) is determined according to ASTM D 1621. The dimensions of the test specimens are given in the table below.

ROHACELL	Specimen size in.	(mm)
31	2x2x2	(50 x 50 x 50)
51	2x2x2	(50 x 50 x 50)
71	2x2x1.77	(50 x 50 x 45)
110	2x2x1.9	(50 x 50 x 48)
P 170	2x2x1.1	(50 x 50 x 28)
P 190	2x2x.9	(50 x 50 x 23)

The elastic modulus from the tensile test in psi (N/mm²) is determined according to ASTM D 638. The specimens have a cross-section of 10 x 10 mm according to specimen type M.

The shear strength and the shear modulus are determined as per ASTM C 273 and stated in psi (N/mm²). Specimen size is 7.87 x 1.97 x .78 in. (200 x 50 x 19.8 mm).

Fabricating ROHACELL

Cutting and stamping

Cutting

Thin sheets are cut with a knife. Thicker sheets can be scored half-way through and then broken. A particularly clean fracture is obtained by breaking the sheet at the edge of a table.

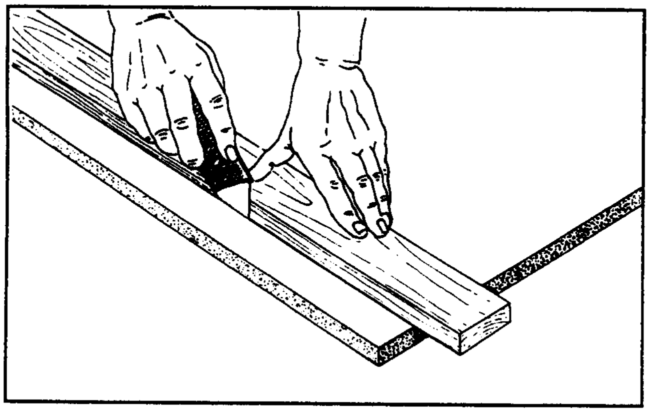
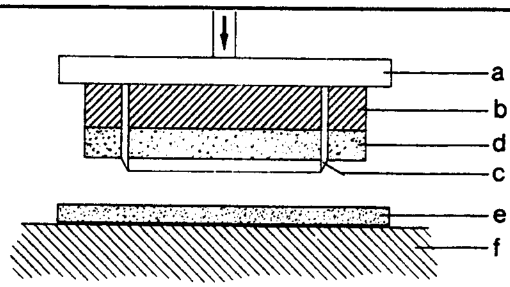


Fig. 24: Cutting



a) force plate
b) mounting
c) steel rule die
d) rubber pad
e) ROHACELL
f) support

Fig. 25: Steel rule die for ROHACELL

Stamping

Parts can be stamped out of thin sheets (max. .4 in. [10 mm] thick) in this way. The maximum sheet thickness depends on the ROHACELL grade used.

Machining

ROHACELL is machined without lubricants on high-speed wood or plastics processing machines employing tools common to this field. Common machining methods include: drilling, planing (including cutting to thickness), milling, sawing and sanding. Make sure that the resultant dust is thoroughly removed by suction.

Sawing

Circular saws are used for cutting sheets to size.
Band and compass saws can be used for cutting shapes.

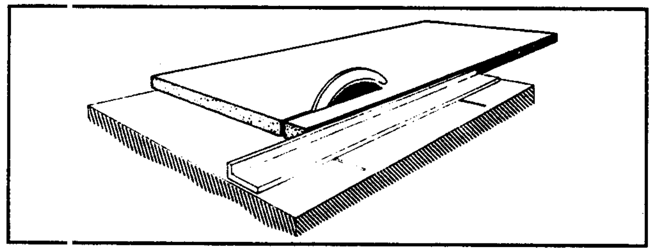


Fig. 26: Cutting-to-size by circular saw

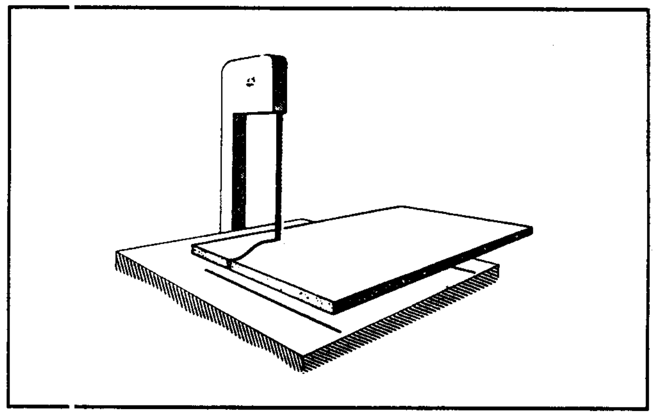


Fig. 27: Cutting shapes by means of a band saw

Sanding

The foam sheet can be shaped by sanding, using a steel template fixed to the sheet. Sanding is either done with an abrasive belt or by hand on a grinding stand. For large parts a board covered with abrasive paper is used, which is drawn across the template by hand. Plane ROHACELL sheets with close thickness tolerances are treated on grinding machines with vacuum table.

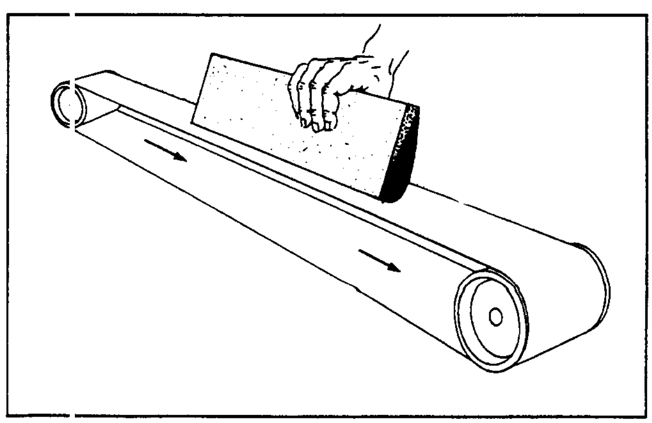


Fig. 28: Shaping by sanding with an abrasive belt

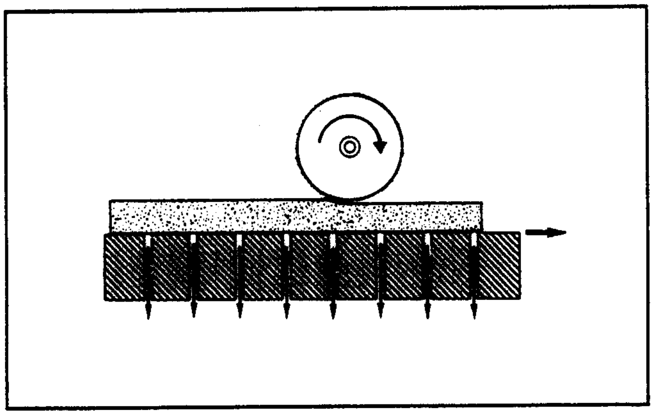


Fig. 29: Plane grinding on a face grinding machine

Planing
The common planing machines used for wood are also used to plane edges and surfaces. It is equally possible to work with a thicknessing machine. Since the foam is more easily crushed than wood, the profile of the feed rollers may be reproduced. Chip removal should therefore be sufficiently deep for the impression to disappear. The contact pressure of the rollers should be matched to the compressive strength of the foam plastic, too. If the roller pressure is too high, the outer parts of the cells are most likely to be destroyed. This is noticeable through the "feltlike feel" of the foam surface. Rubber-covered rollers have also proved useful.

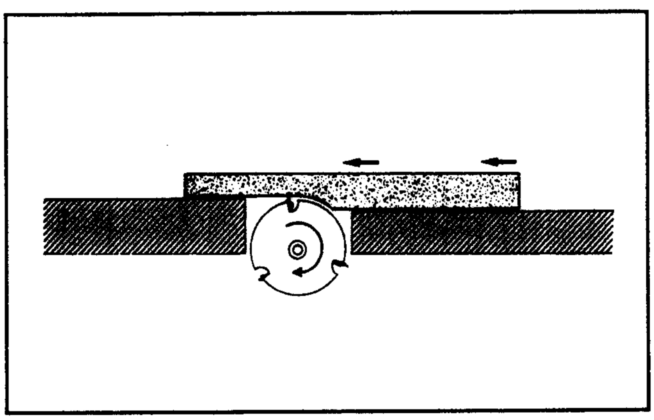


Fig. 30: Trueing on the planing machine

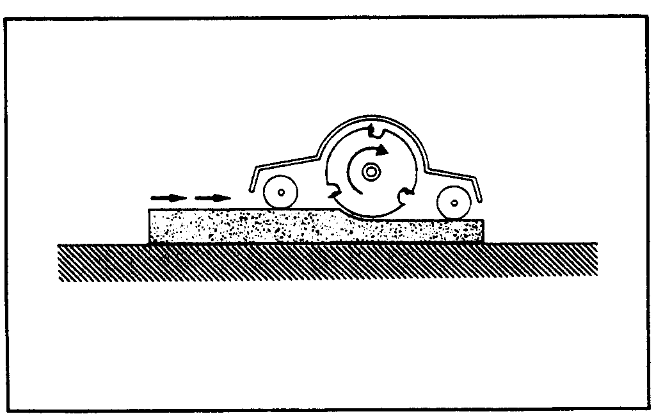


Fig. 31: Cutting to thickness

Milling
Grooves, rabbet and other profiles can be cut with a routing cutter. With due care, the material can be cut to web widths of .08 in. (2 mm).
Parts matching the contours of a template can be produced with a suitable milling cutter.

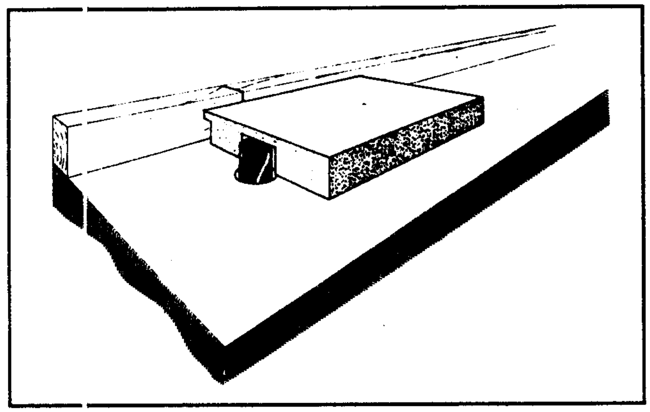


Fig. 32 Cutting grooves and rabbets with a routing cutter

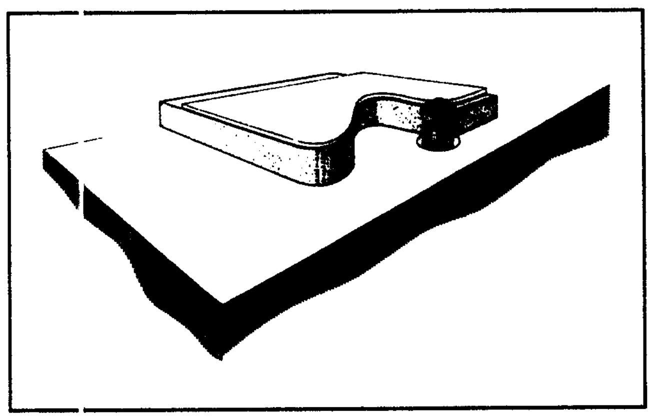


Fig. 33: Contour milling using a template

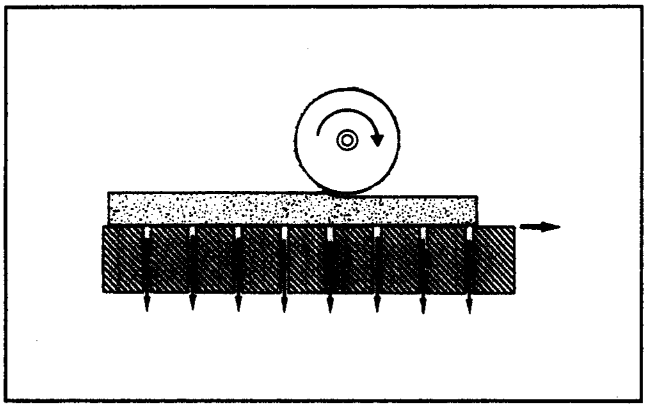


Fig. 29: Plane grinding on a face grinding machine

Planing

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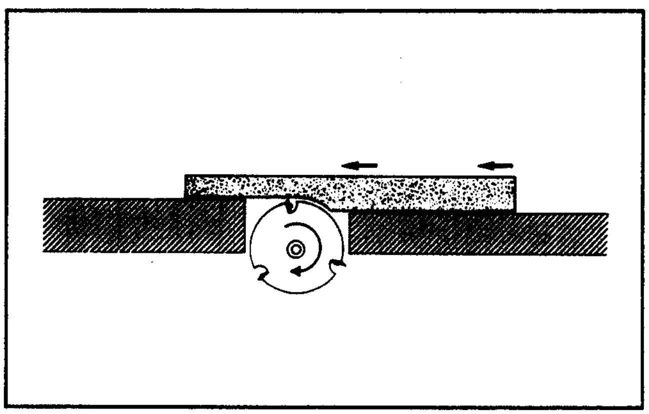


Fig. 30: Trueing on the planing machine

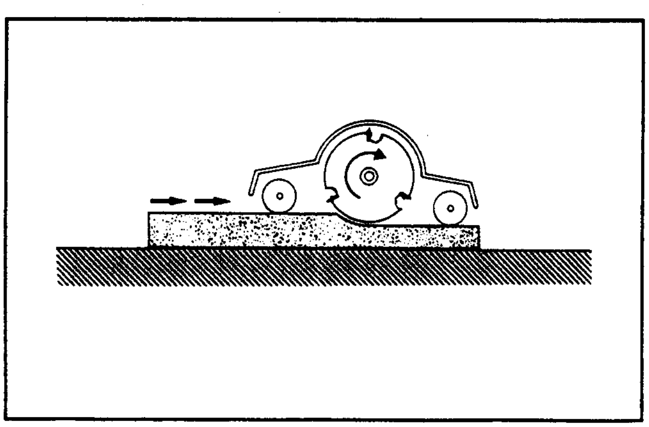


Fig. 31: Cutting to thickness

Milling

Grooves, rabbet and other profiles can be cut with a routing cutter. With due care, the material can be cut to web widths of .08 in. (2 mm).

Parts matching the contours of a template can be produced with a suitable milling cutter.

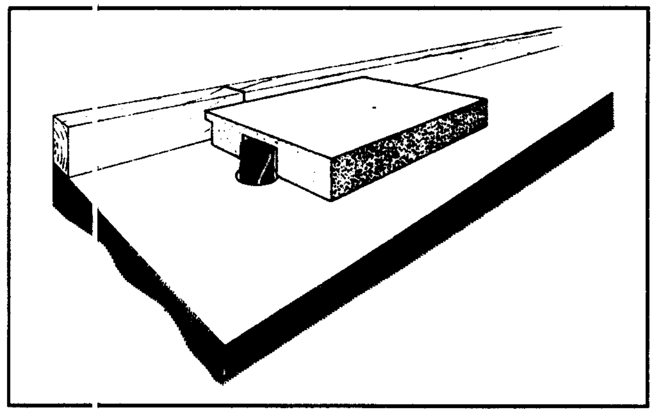


Fig. 32: Cutting grooves and rabbets with a routing cutter

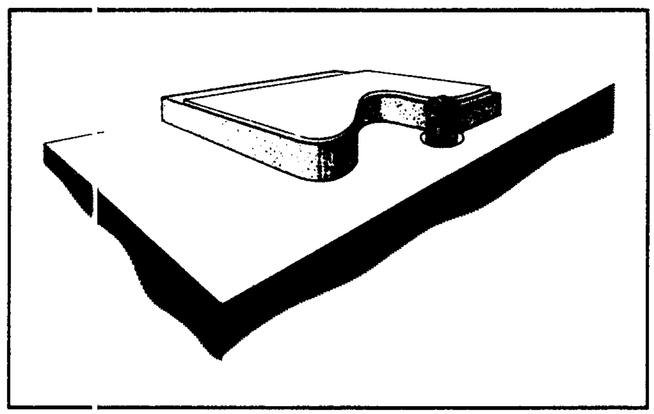
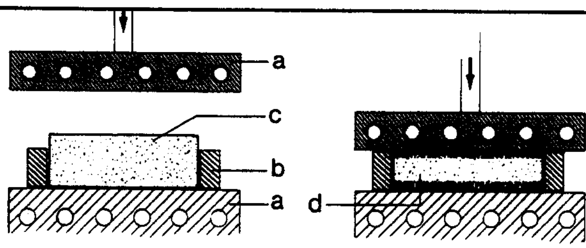


Fig. 33: Contour milling using a template

Compressing ROHACELL

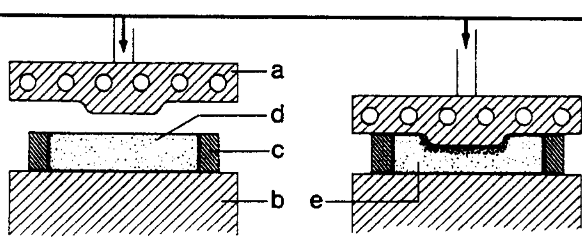
Surface compression
ROHACELL sheets with an integral structure are produced in a press which can be cooled and heated. A cold, suitably oversized ROHACELL sheet is placed between heated platens at 320 – 356 °F (160 – 180 °C) and then the press closed immediately. The specific molding pressure should be about 30 % less than the compressive strength of the particular ROHACELL grade at 68 °F (20 °C). As the heat penetrates into the ROHACELL sheet, the outer cells correspondingly give way and are squeezed flat. The procedure gives a higher density in this layer. The molding time depends on the desired degree of compression until the thickness stop is reached. The sheet must now be cooled to about 176 °F (80 °C) before it can be taken out of the press. This prevents the flattened cells from recovering their original shape (Fig. 34). The method also serves for partial compression ol molded articles (Fig. 35).

In practice, this procedure is also utilized for sandwich parts with thin skins in order to increase the bending stiffness of the sandwich. Another important fact is that the indentation resistance is considerably improved through the higher density of the edge zones. During hot curing of the adhesives or resins, the outer surface is compressed until the desired thickness stop is reached.



a) heatable and coolable press
b) thickness stop
c) uncompressed ROHACELL
d) compressed ROHACELL

Fig. 34: Surface compression

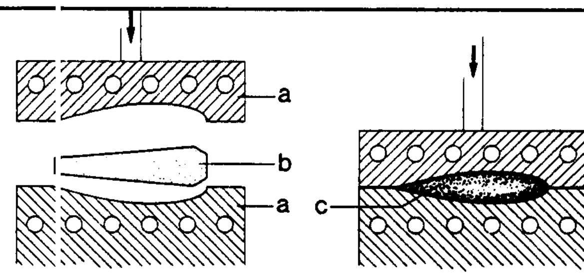


a) heatable and coolable tool
b) support
c) thickness stop
d) uncompressed ROHACELL
e) partially compressed ROHACELL

Fig. 35: Partial compression

Moldings with complex exterior contours
After heating the ROHACELL part to be molded to the forming temperature (338 – 374 °F [170 – 190 °C], depending on material grade), it is placed in a heated mold and brought to the required geometrical form by compression. The molding must be cooled down to about 176 °F (80 °C) before it can be taken out of the mold.

The described method is far more cost-effective than other techniques, because there is no machining to a precise exterior contour.



a) heatable and coolable mold
b) rough-cut ROHACELL part
c) compressed ROHACELL molding

Fig. 36: Manufacture of moldings with complex exterior contours

Forming

Moldings can be relatively simply produced from ROHACELL sheets. The smallest attainable bending radius is about twice the sheet thickness.

Heating the ROHACELL sheets

Before heating the ROHACELL sheets, they should be dried for 2 hrs. at 248 °F (120 °C), using a heating cabinet with air circulation. ROHACELL becomes thermoelastic and can therefore be formed at a temperature of 338 to 374 °F (170 – 190 °C). The required forming temperature depends on the degree of shaping, the pretreatment and the density.
The heating time for ROHACELL sheets in a heating chamber with air circulation that has been brought to forming temperature is about 1 min/0.04 in. (1 min/mm) sheet thickness. Care must always be taken so see that the hot air sweeps uniformly over both sides of the foam plastic sheets and that no heat is allowed to accumulate (Fig. 37). This method is particularly suitable for the manufacture of prototypes. Heating is much simpler and more dependable between heating plates, which you can easily make yourself (Fig. 38). This method can be recommended for series production.
Radiant heaters can be used to warm up thin sheets of ROHACELL up to 0.24 in. for line bending (Fig. 39). A vacuum forming machine may be used to mold these same sheets.

Caution: The forming temperature is close to the foaming temperature, so that it must be accurately controlled in order to prevent post-foaming. This is particularly important when warming up the ROHACELL sheet by means of radiant heaters.

Avoiding unduly fast cooling

Since the heat capacity of the rigid foam is low because of its small mass and the sheet surfaces cool quickly because of the multitude of cut cells which act as "cooling vanes", the blanks must be protected against cooling while they are moved from the heating cabinet or the heating plates to the forming device. Unduly fast cooling is avoided by covering the ROHACELL sheets on all sides with cotton cloth, thin aluminium foil, glass fabric or silicone rubber. The foam plastic is heated and formed together with this cover. The cover is intended to keep the ROHACELL sheet just long enough at the necessary forming temperature until forming is finished.
With simple moldings a cover on one side is often sufficient if the work is done fast. The cover must be applied to that side of the ROHACELL sheet which is subject to tensile stress during forming (Fig. 41).

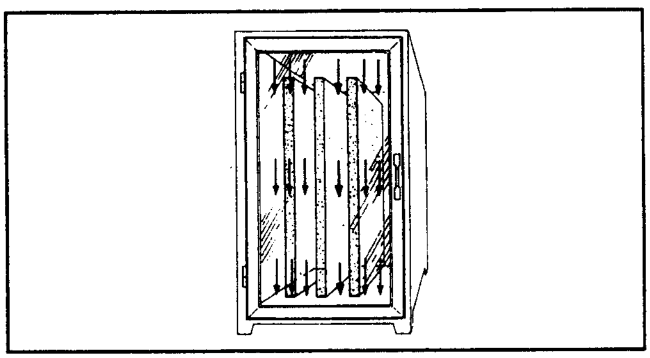


Fig. 37: Heating in a cabinet with air circulation

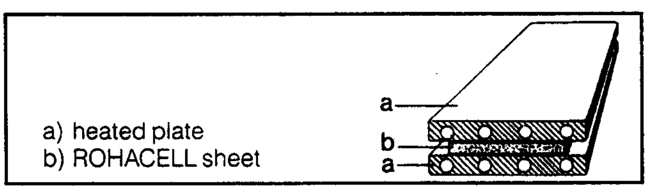


Fig. 38: Heating between plates

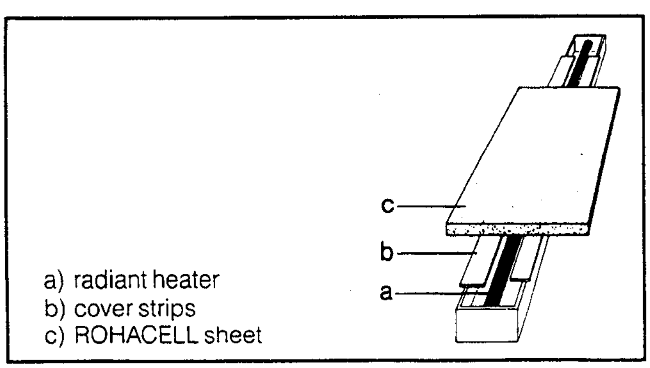


Fig. 39: Line bending of thin ROHACELL sheets

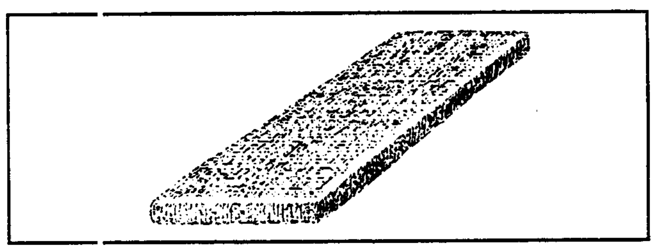


Fig. 40: ROHACELL sheet covered all around

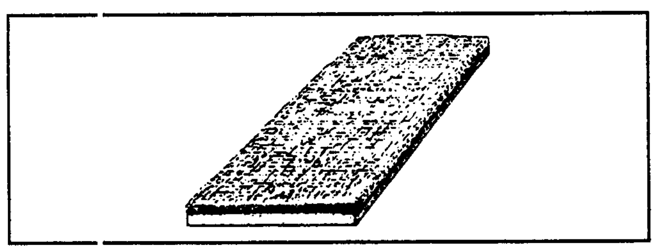


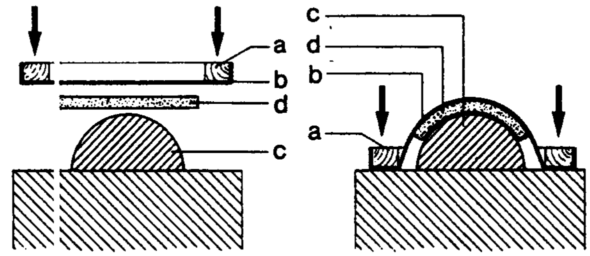
Fig. 41: ROHACELL sheet covered on one side only

For series production, the heating plates and the forming tool can be put in such a position that, when the heated ROHACELL blank is quickly and automatically taken from the heating plates to the forming tool, there is often no need for any cover.

Design of the forming tools
Tools which are not heated can be used for simple parts when the degree of forming is small. Tool temperatures of 176 to 212 °F (80 – 100 °C) may be necessary when more complex parts have to be formed.

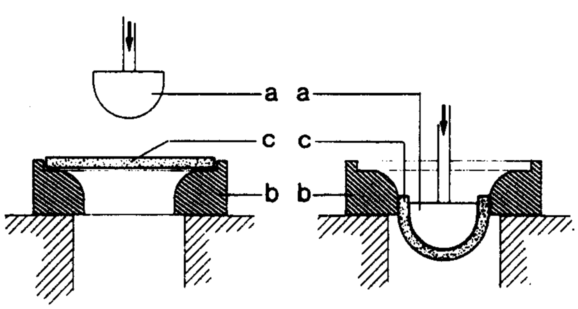
The foam plastic cools quickly because of its low heat capacity, and once the formed part has cooled down to c. 176 °F (80 °C) it may be removed from the tool. With simple parts, the molds are not subjected to a substantial amount of heat, so that hardwood molds are adequate. Polyester and epoxy resin molds are also used. The advantage of these non-metallic molds is that the ROHACELL surfaces do not cool down so quickly during forming because of the relatively poor heat conductivity. Metal molds should be thermostatically controlled.

In order to ensure that the ROHACELL sheet can be drawn into the mold without much resistance, the edges should have large radii. If the radii are too small, the edge is squeezed into the heated foam at the start of forming and impedes further sliding. Cracks at these points will then be unavoidable. Forming itself should be done uniformly and quickly. Abrupt forming must be avoided.



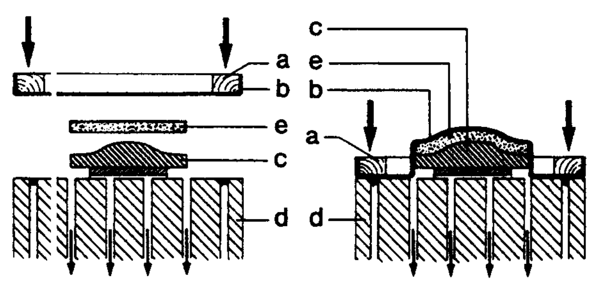
a) frame b) stretch rubber c) mold d) ROHACELL

Fig. 44: Forming ROHACELL with stretch rubber



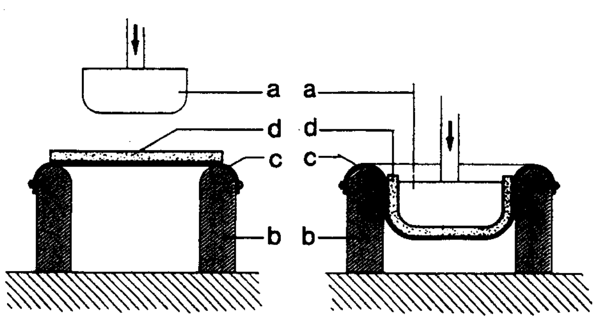
a) force plug b) annular mold c) ROHACELL

Fig. 42: Forming of a hemisphere from ROHACELL



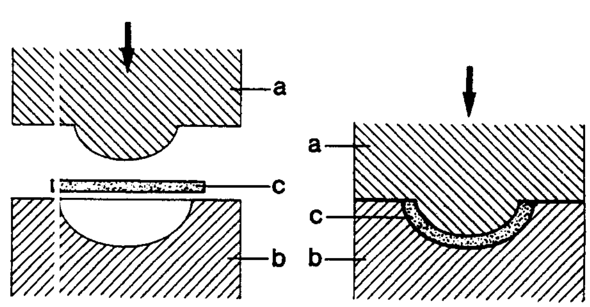
a) frame b) stretch rubber c) mold
d) vacuum table e) ROHACELL

Fig. 45: Forming ROHACELL with stretch rubber



a) force plug b) mold c) stretch rubber d) ROHACELL

Fig. 43: Forming ROHACELL with stretch rubber



a) force plug b) mold c) ROHACELL

Fig. 46: Forming in the tool

Bonding

Owing to the large number of available adhesives and the multitude of materials which may be bonded to ROHACELL, it is difficult to provide complete information on the application methods and amounts of adhesives, as well as on the drying and curing times. However, in case of special problems we will be glad to look for a practical solution together with the adhesive manufacturers. For most bonding problems ROHACELL offers the decisive advantages of solvent resistance and heat distortion resistance for hot curing up to 320 °F (160 °C).

Practically all commercial adhesives can therefore be used.

The bond between the adhesive and ROHACELL is much improved through mechanical anchoring in the cut cells.

It is essential that the ROHACELL surfaces are freed from dust by suction or blowing with oil-free compressed air before bonding.

Since ROHACELL is highly impervious to solvent diffusion, great care must be taken, when large areas of ROHACELL are to be bonded to ROHACELL or other diffusion-tight materials by solvent-based adhesives, that the adherends are well devolatilized after the adhesive has been applied to both sides before they are joined together under pressure.

Joints made with these adhesive systems (generally rubber-based) normally remain somewhat elastic and have good peel strength. When it is possible to hot-cure the joint, the quality of the bond can be greatly improved.

Owing to the good heat transfer which is required, heat-sealing can only reasonably be done where thin material layers are to be bonded to ROHACELL; e.g. for laminating with metal sheets or decorative paper sheeting.

Emulsion adhesives are not recommended.

The solvent-free systems include hot-melt adhesives, reactive adhesives and adhesive films. Reactive adhesives like epoxy and polyester resins should be allowed to cure under sufficient pressure (1.25 – 43.5 psi/0.05 – 0.3 N/mm^2) or be very fluid during application so that the cells of the foam are well filled. The cure can be accelerated by heat (up to 320 °F/160 °C). The joints become very hard and rigid.

Adhesive films and hot-melt adhesives need heat for bonding and can therefore normally be heat-cured. Adhesive films must be sufficiently thick (.02 – .04 lbs/ft^2/100 – 200 g/m^2) in order to anchor them firmly in the cut ROHACELL cells.

Some adhesive films such as phenolics give off volatile constituents while curing. Therefore they should be warmed-through with gentle pressure. Before pressing for bonding, the press should be briefly opened again to allow the volatile constituents to escape.

When hot-melt films are used, it has frequently proved useful to perforate them before bonding in order to avoid air bubbles.

For the purpose of better deaeration in difficult cases, prior grooving of the ROHACELL sheet surfaces will help. Grooves about .04 – .06 in. (1 – 1.5 mm) deep and .08 in. (2 mm) wide have proved useful.

When ROHACELL is to be bonded to other materials, the adhesive may generally be selected according to its suitability for these materials.

To obtain perfectly straight sandwich panels, it is important for both sides of the ROHACELL sheet to be simultaneously bonded to the skin. Both skins must be of the same material and have the same thickness. Equally important are uniform heating and cooling on both sides.

To prevent core compression during hot press bonding we recommend starting ont with a ROHACELL core .02 – .04 in. (0.5 – 1 mm) over thickness and closing the press to stops.

The application of laminates

The usual laminating methods like hand lay-up and molding techniques can be used. In order to obtain good peel strengths, pressures of a least 1.25 psi/0.05 N/mm² are desirable. Hot curing is recommended for the short cycle times. ROHACELL tolerates up to 320 °F (160 °C), but in that case the press should be run to a stop (see also "Bonding"). When polyester resins are used there is no need to seal the foam plastic surface, because it is resistant to styrene.

If the molding pressure is to be applied with a vacuum bag, the ROHACELL sheet may, for the sake of better venting, be perforated with holes about .08 in (2 mm) in diameter at intervals of about 2 in. (5 cm). Before laminating, the ROHACELL surfaces must be completely free from dust in order to ensure good adhesion of the resins. Sandwich parts are also made with the prepregs usual in aircraft construction. Pressing-on and curing is either done in an autoclave or in a mold. The first layer on ROHACELL should be a resin-rich prepreg in order to have sufficient resin for anchoring in the cut cells and thus to achieve good bond strength.

Before applying the prepregs, the ROHACELL surfaces should be freed from dust by suction or by blowing with oilfree compressed air.

When prepregs are used which release volatile constituents during the curing process, e.g. water from phenolic resin prepregs, the removal of the volatiles, e.g. from an autoclave, must be ensured by suction. If curing takes place in a molding tool, the press must be briefly opened again when the prepregs are warmed through, so that the bulk of the volatile constituents can escape. In the case of matrix systems, which are cured at very high temperatures, the ROHACELL core may yield excessively when curing takes place in an autoclave or a press without a stop. Better results are then achieved with ROHACELL WF.

In any case it is recommended whenever possible to run the tool against a stop, particularly when curing takes place in molding tools, in order to avoid exceeding the lower tolerance limit through thermoelastic creep.

When relatively brittle skins are used, e.g. phenolic resin prepregs, the bond strength can be considerably increased by applying an elastic primer or hot-melt adhesive film to the ROHACELL core. ROHACELL is a foam plastic with closed cells. During bonding or when a laminating resin is applied, the resins only penetrate the open pores of the cut surface. The bond strength obtained in this way is very good for ordinary purposes.

A peel test is often performed to provide information on the bond strength of a skin on the core, although this test does not really resemble practical conditions. A peel force generally only acts on the sandwich after the skins have failed for reasons of stability (e.g. creasing or wrinkling) or strength (cracking or compression), which is most likely to occur in practice.

Painting

ROHACELL can be painted or sprayed with most commercial paints (including nitrocellulose lacquers). Most emulsion paints of the kind used in the building trade are chemically basic. These paints are unsuitable, because ROHACELL does not resist alkaline media. For smooth and glossy surfaces the foam plastic is first filled and sanded. Spraying fillers, e.g. polyester fillers, are also suitable for this purpose. If a paint with grain effect is to be applied, spray-filled surfaces need not be sanded before painting.

When joints or damaged areas on ROHACELL parts have to be filled and then sanded, the filler should have about the same sanding behavior as the ROHACELL grade in order to get a perfect transition from the filled area to the adjoining foam plastic. You can prepare such a filler yourself according to the following formulations:

Formulation 1:

90 parts by wt. filler
20 parts by wt. thinner
15 parts by wt. microballoons

The amount of added microballoons depends on the ROHACELL grade to be filled. The more microballoons are added the easier is the sanding. The thinner is used to vary the consistency so that the filler can be smoothly applied.

Formulation 2:

100 parts by wt. pore filler
25 parts by wt. microballoons.

The amount of added microballoons again depends on the ROHACELL grade to be sanded.

For the sake of better adhesion, the ROHACELL area to be filled is first brushed once with pore filler before the filling compound is knifed on. Filling greatly raises the compressive strength of the foam plastic surface.

Particularly decorative and resistant surfaces are obtained by metal flame spraying. Aluminium, bronze, copper and iron may be sprayed on.

The production of prepreg (SMC) moldings with ROHACELL 71

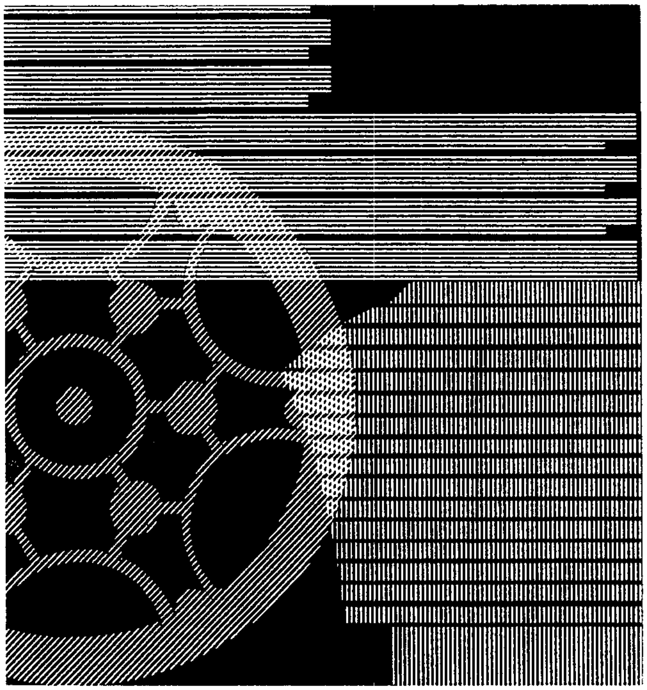
Prepregs are SMC's. Their main constituents are unsaturated polyester resins, textile glassfiber, fillers and auxiliaries. They are applied in steel tools at 248 – 320 °F (120 – 160 °C).

For the manufacture of sandwich parts with SMC skins and ROHACELL 71 as the core material, a molding pressure of about 116 psi/0.8 N/mm² has proved beneficial. This specific molding pressure should only be applied until the mold cavity is filled by the flowing prepreg. Afterwards it is reduced to about 58 psi/0.4 N/mm² and kept constant until the end of the curing cycle. The press temperature should be 248 – 266 °F (120 – 130 °C).

This processing technique has proved useful where normally reactive and free-flowing SMC resins are used.

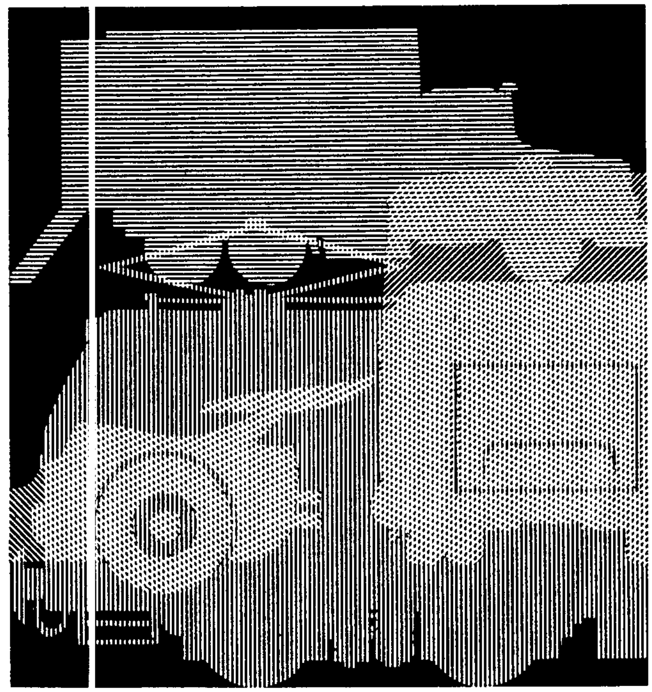
Practical examples of ROHACELL

Model building



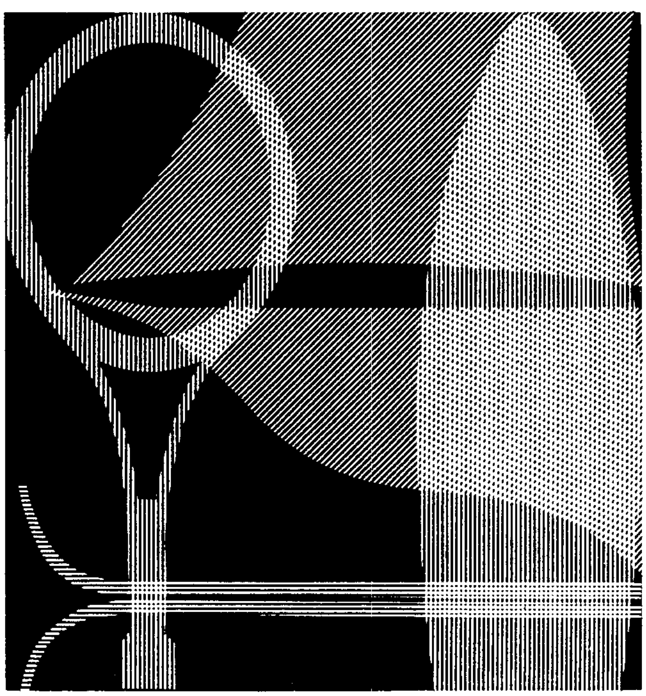
- easy machining
- readily painted
- good dimensional stability
- easy handling

Vehicle construction



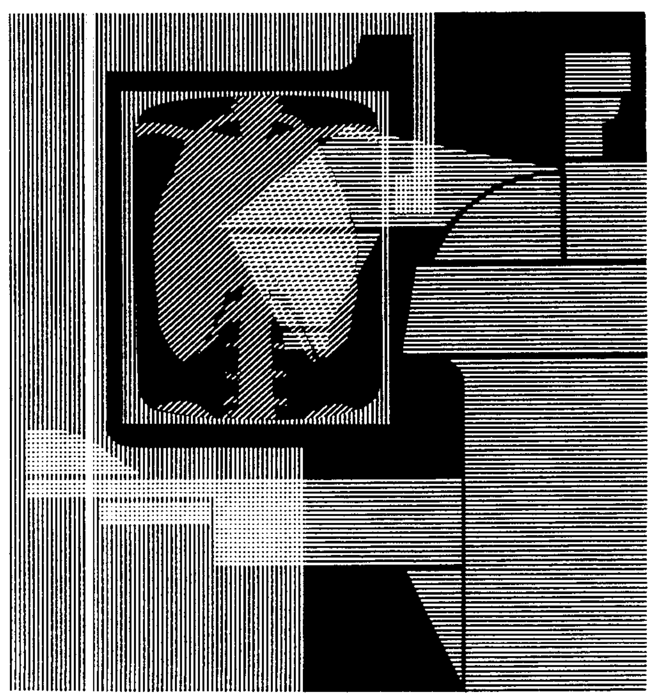
- high rigidity
- low weight
- self-supporting sandwich structures
- extreme stresses are tolerated
- short cycle time for polyester moldings with ROHACELL core
- can be painted with bake on coatings

Sports equipment



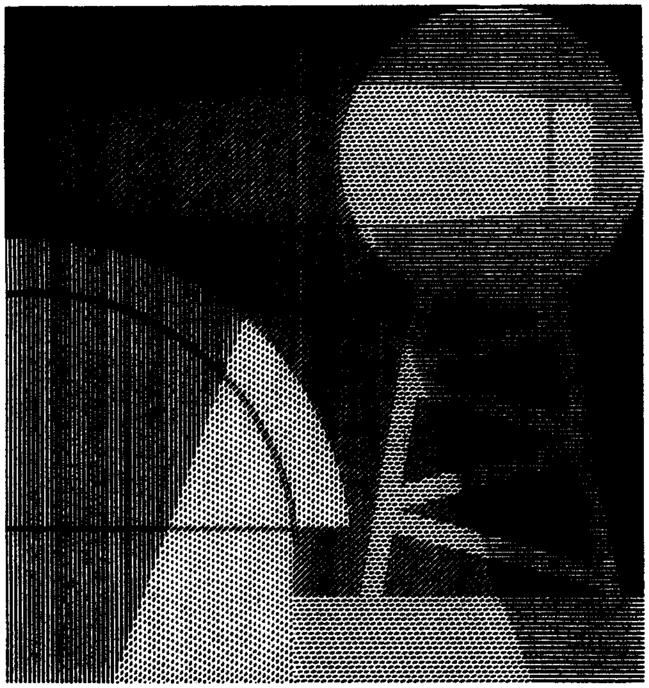
- can be highly stressed dynamically
- good damping
- low weight
- simple manufacture

Medical engineering



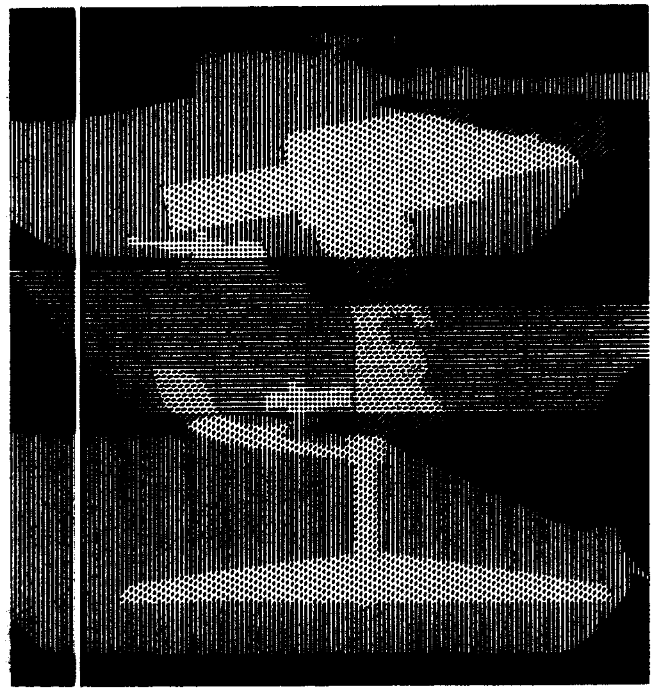
- outstanding radiation transmission
- minimum radiation scatter
- smaller doses are therefore required

Antennae, radomes



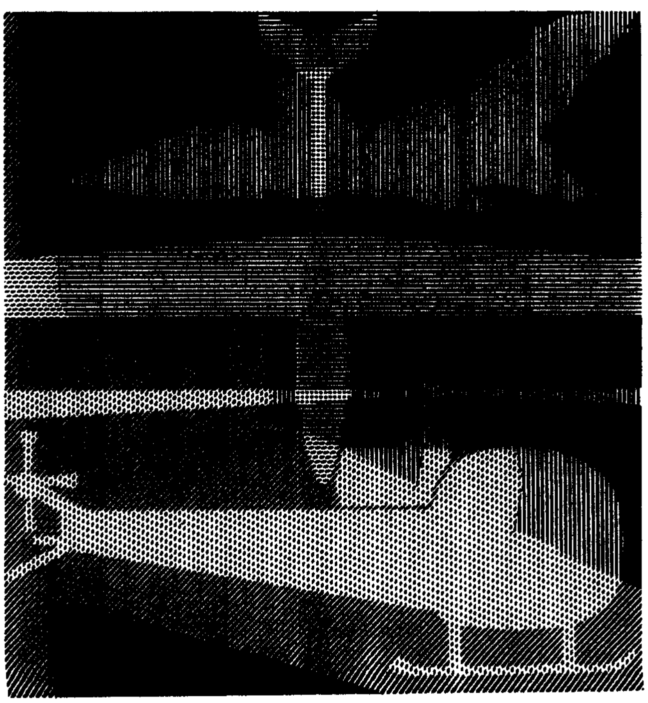
- excellent radiation transmission
- minimum radiation scatter
- good forming properties
- can be highly stressed dynamically
- high heat resistance

Arms technology



- can be extremely highly stressed

Aircraft construction



- can be extremely highly stressed dynamically
- self supporting structures
- high specific strengths
- low weight
- simple forming
- simple machining
- core material with closed cells

Polymethacrylimide
rigid foam

Important notice

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