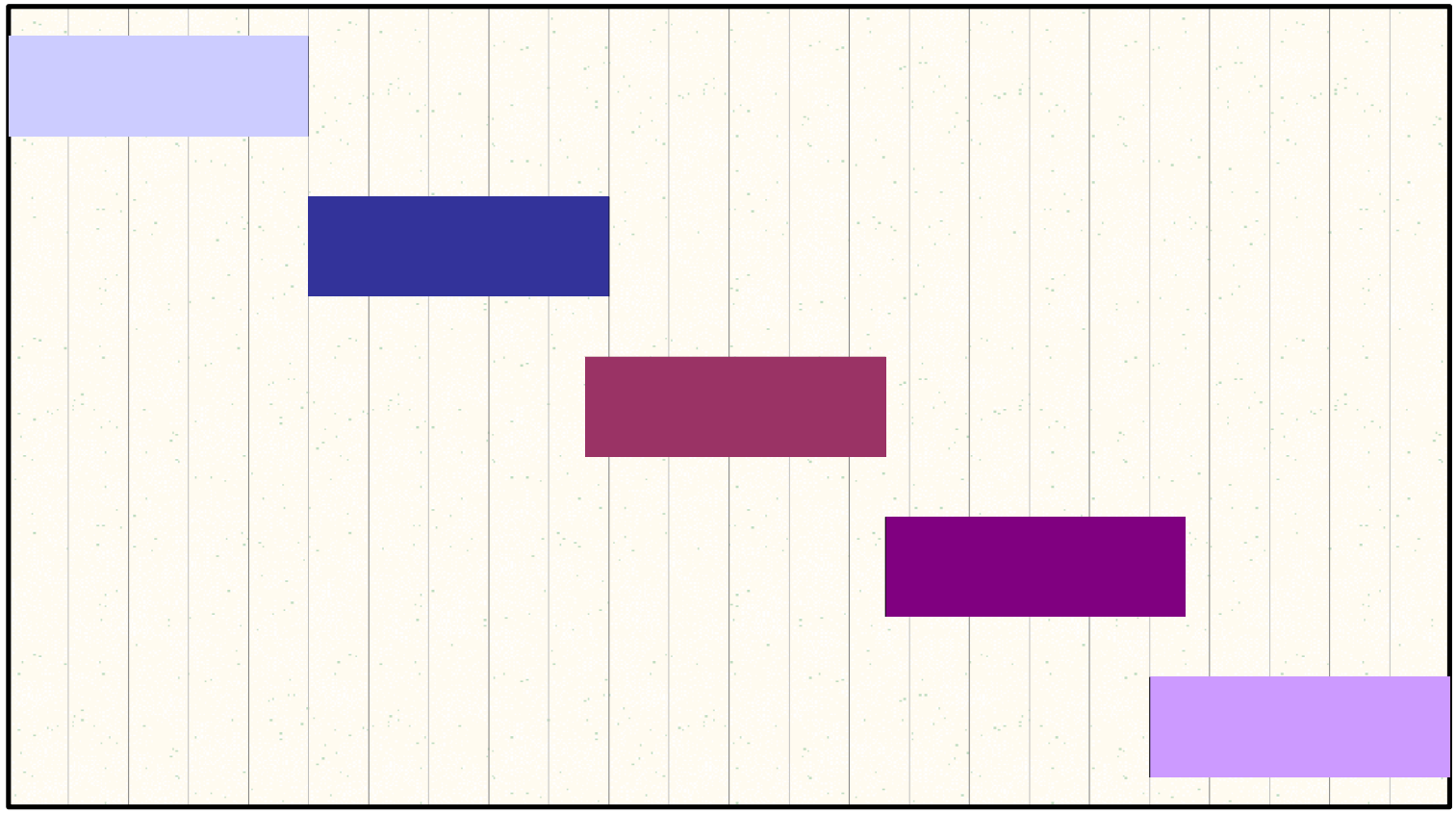
ALUMINUM CASTING PROCESS COMPARISON CHARTS



Austin GROUP, LLC

A Qualitative Comparison of Several Competing Processes for the Production of Aluminum Castings

The following charts are intended to provide a relative guide to compare various aluminum casting methods. It is important to note that, the actual costs and casting results will vary significantly for any given project. The complexity of the part, the number of cores or pulls, the engineering and design time and customer requirements will all have a significant impact on the cost to produce a part with any of the compared methods. An attempt to provide specific comparison data for a given part would be highly sensitive to that particular part. Therefore, a composite of existing source data including foundry results, professional society literature, equipment manufacturer comments and personal experience was used to generate the comparison charts. Foundries, foam molders and tool builders contributed to the collection of the data.

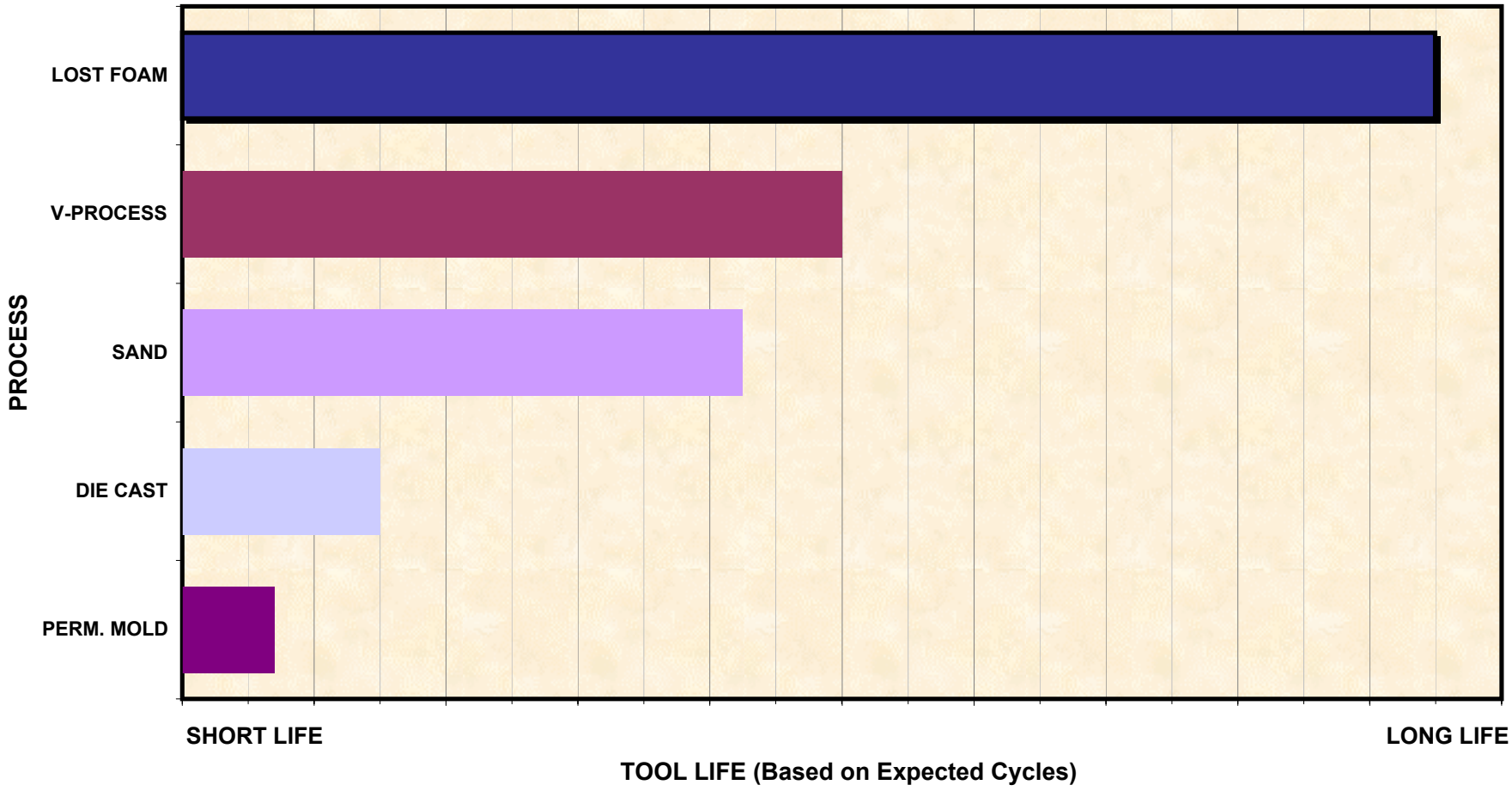
ALUMINUM CASTING PROCESSES - COMPARISON MATRIX

PROCESS	DESCRIPTION	TYPICAL SIZE RANGE	TOLERANCES	SURFACE FINISH	MINIMUM DRAFT REQUIRED	MINIMUM SECTION THICKNESS	TYPICAL ORDER QUANTITIES	TYPICAL TOOLING COSTS	NOMINAL LEAD TIMES
LOST FOAM	A metal mold is used to produce foam patterns. Foam patterns are invested in sand. Molten metal is poured on to the foam patterns throug gating. The foam evaporates and is replaced b metal.	Ounces up to 300 lbs.	± .007" to 1" ± .010 1-3" then add ±.003"/inch	63-250 RMS	1/4 to zero degrees	.150"	All	$8000 to $120000	Samples: 3 to 8 weeks Production: 6 to 18 weeks
LOST WAX	A metal mold is used to produce wax replicas. Wax replicas are placed in an investment material. Wax is melted out and molten metal i poured into cavity. The mold is broken and the casting is removed.	Ounces up to 20 lbs.	± .004" to ½" ±.005" to 3" then add ±.003"/inch	63-250 RMS	None	.060"	Under 1000	$4000 to $40000	Samples: 6 to 10 weeks Production: 8 to 12 weeks
SAND CASTING	Treated sand is molded around a wood or meta pattern. The mold halves are opened and the pattern is removed. Metal is poured into the cavity. The mold is broken and the casting is removed	Ounces up to tons	± .03" to 6" then add ±.003"/inch Add ±.020" to .090" across parting line	200-550 RMS	1 to 5 degrees	.25"	All	$1000 to $10000	Samples: 2 to 6 weeks Production: 2 to 6 weeks
V-PROCESS CASTING	Sand is "Vacuum-packed" around pattern halves. The pattern is removed and metal is poured into the cavity. The vacuum is released and the casting is removed	Ounces up to 150 lbs.	±.010" to 1" then add ±.002"/inch. Add ±.020" across parting line	125-150 RMS	1/2 to zero degrees	.125"	All	$3000 to $30000	Samples: 3 to 6 weeks Production: 3 to 6 weeks
DIE CASTING	Steel dies, sometimes water cooled, are injecte with molten aluminum. The material solidifies, the die is opened and the casting ejected.	Ounces up to 20 lbs.	± .002"/inch Add ±.015" across parting line	32-63 RMS	1 to 3 degrees	.030" to .060"	2500+	$10000 to $300000	Samples: 8 to 12 weeks Production: 10 to 18 weeks
PLASTER MOLD	A plaster slurry is poured into the pattern halves. After setting, the mold is removed from pattern, baked and assembled. Metal is poure into the cavity. The mold is broken and the casting removed	Ounces up to 50 lbs.	± .005 to 2" then add ±.002"/inch Add ±.010" across parting line	63-125 RMS	1/2 to 2 degrees	.070"	Prototypes up to 250 pcs.	$3000 to $15000	Samples: 2 to 10 weeks Production: 4 to 8 weeks
PERMANENT MOLD	Molten metal is poured into a steel or iron mold The mold is opened and the casting removed.	1 lb. up to 100 lbs.	± .015" to 1" then add ±.002"/inch Add ±.010" to .030" across parting line	150-300 RMS	2 to 5 degrees	.188"	500+	$12000 to $100000	Samples: 6 to 8 weeks Production: 8 to 20 weeks

ALUMINUM CASTING PROCESS COMPARISON

TOOL LIFE

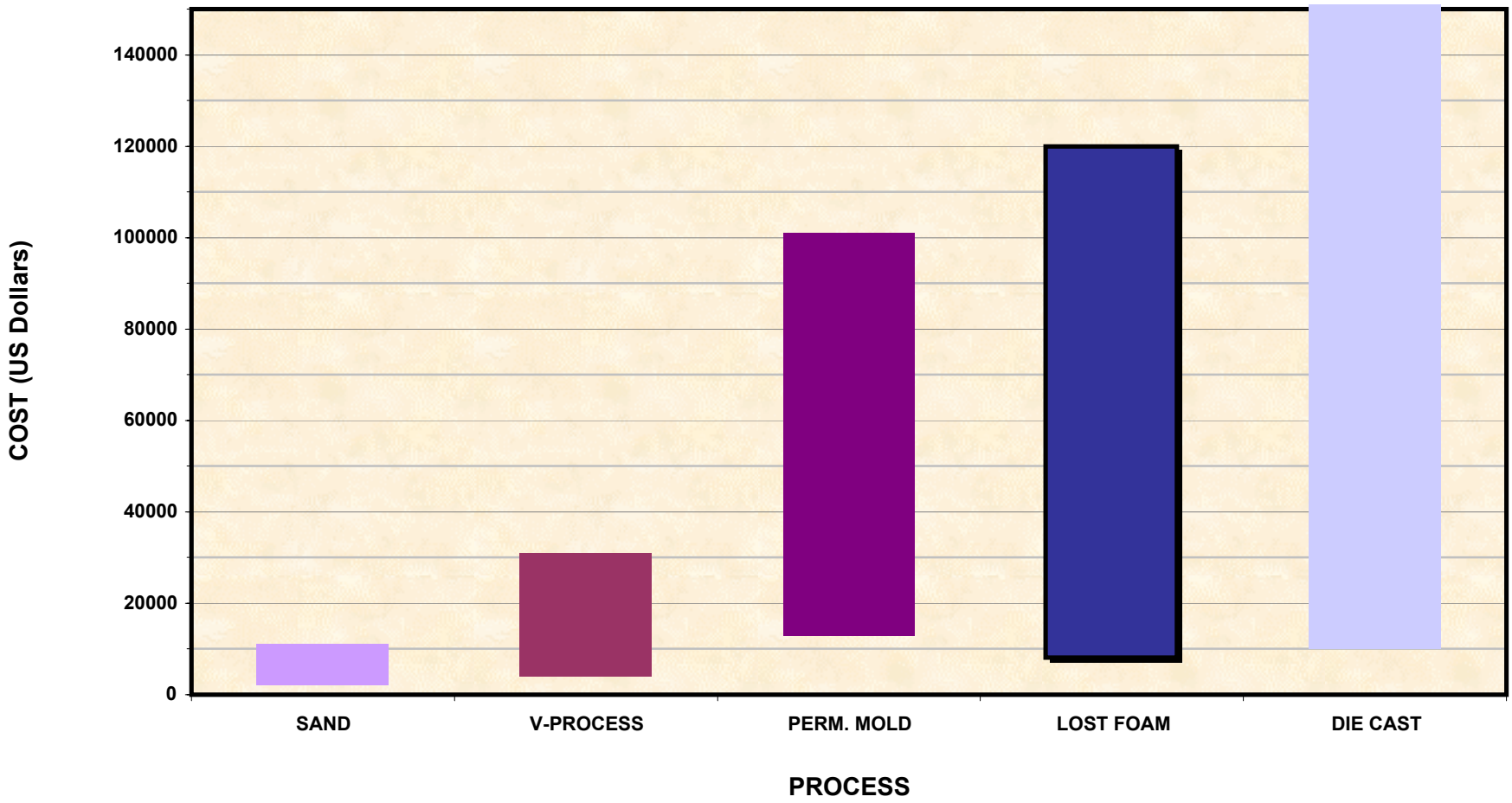
Length of tool life is one of the strongest aspects of the Lost Foam process. Life expectancy of Lost Foam tooling is in the hundreds of thousands cycles range with only low-level maintenance requirements. V-process and sand casting methods offer intermediate tool life but also require increased dimensional tolerances due to pattern wear. Permanent mold casting and die casting typically have the shortest tool life.



ALUMINUM CASTING PROCESS COMPARISON

TOOL COST

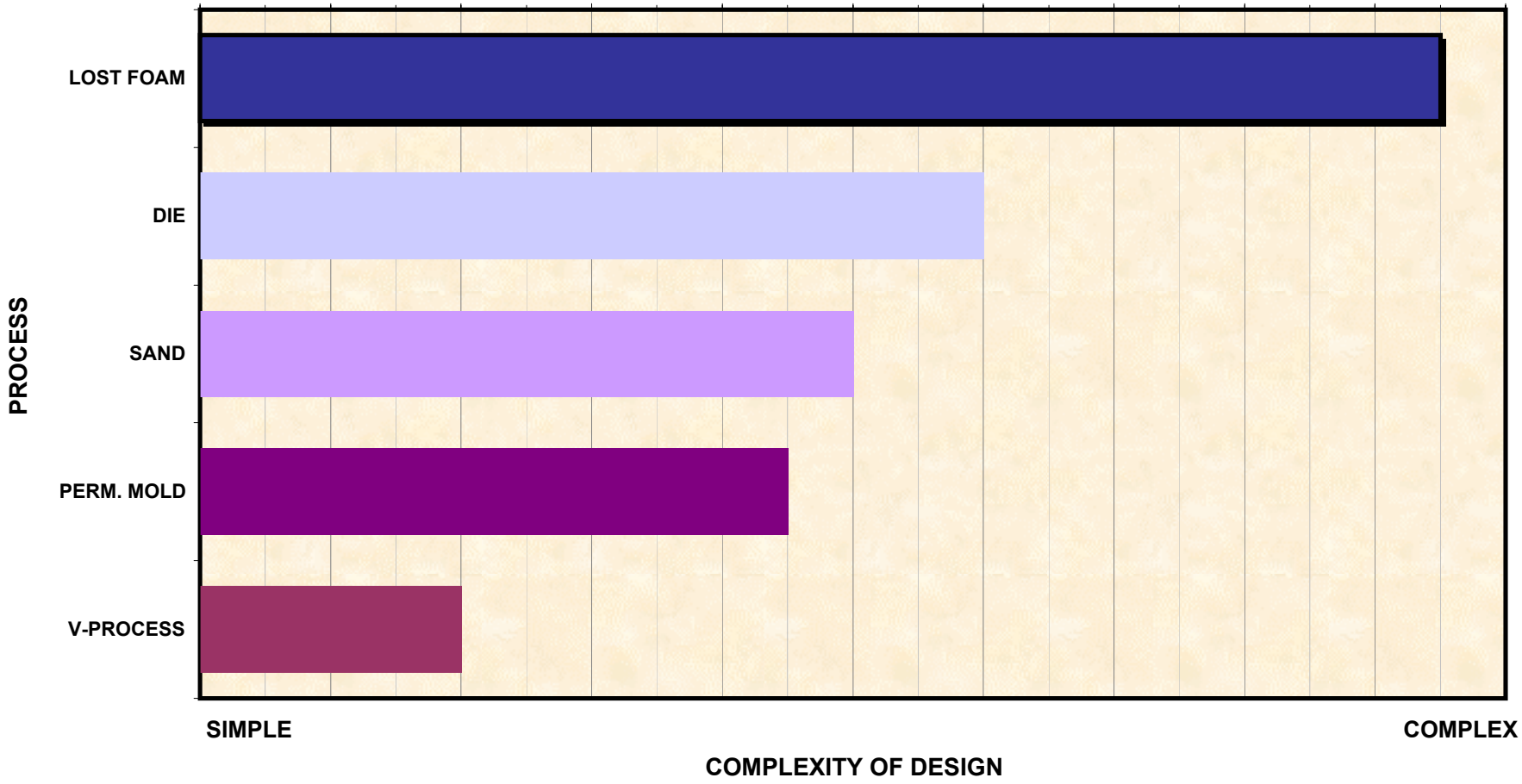
Conventional sand casting offers the lowest cost tool with the V-process having comparable costs for simple tools but varying with complexity. The Lost Foam process allows a wide range of simple to very complex parts resulting in the wide tool cost range. Permanent mold and die cast tools are comparable on simple tooling. Cast iron and steel are more expensive to work with than aluminum, which accounts for the higher starting costs for permanent mold and die casting tools. Die cast tools increase sharply in cost with complexity.



ALUMINUM CASTING PROCESS COMPARISON

COMPLEXITY OF DESIGN

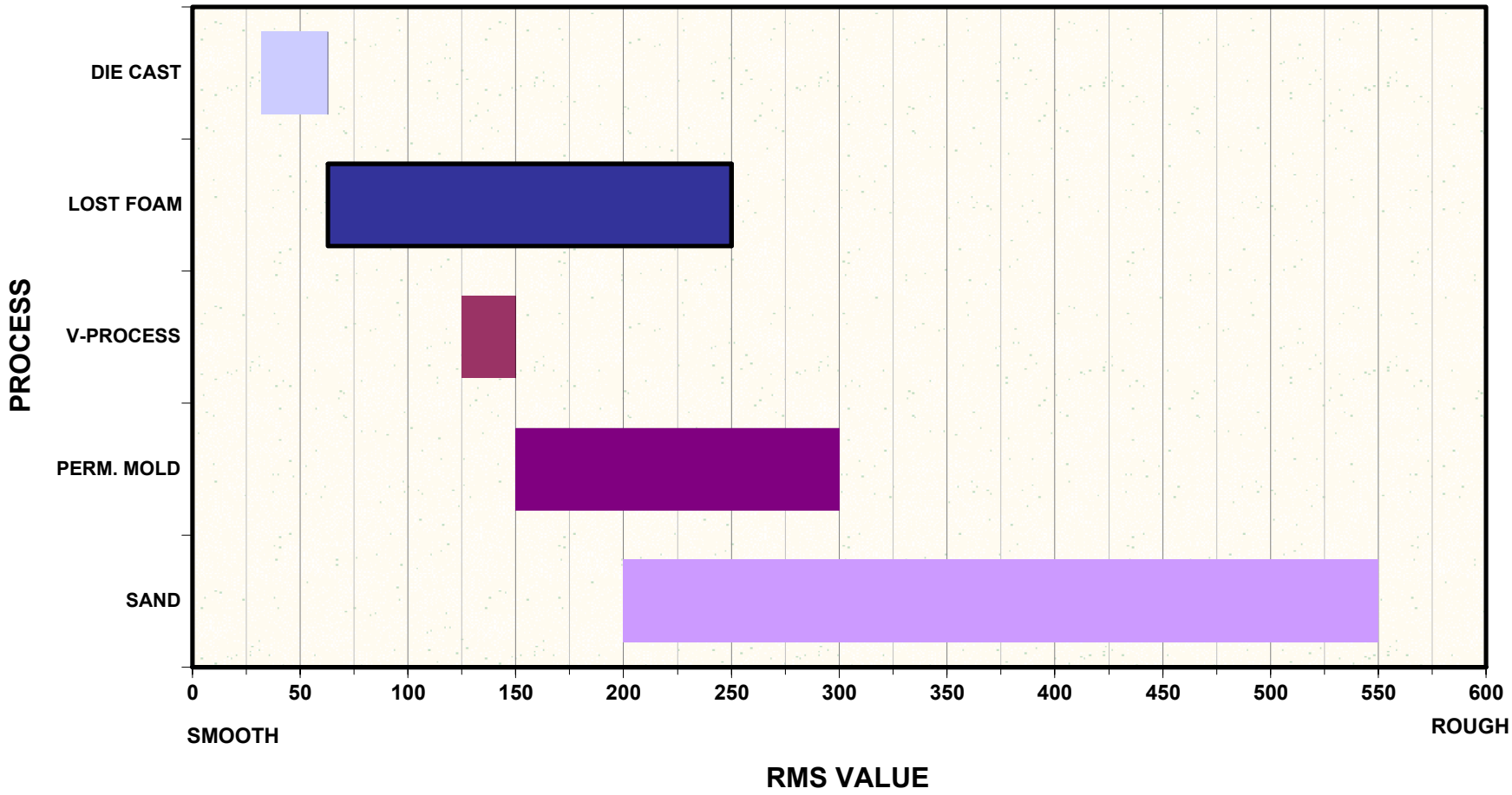
The Lost Foam process will allow the most complex part designs of all the methods. Foams can be assembled and glued together to produce exceptionally complicated castings, often combining two or more castings into one piece. Die casting with the use of core pulls can produce complex one piece parts. V-process castings typically do not use cores and are simpler. Sand casting and permanent mold methods with their use of cores allow the next highest level of complexity.



ALUMINUM CASTING PROCESS COMPARISON

RELATIVE SURFACE FINISH

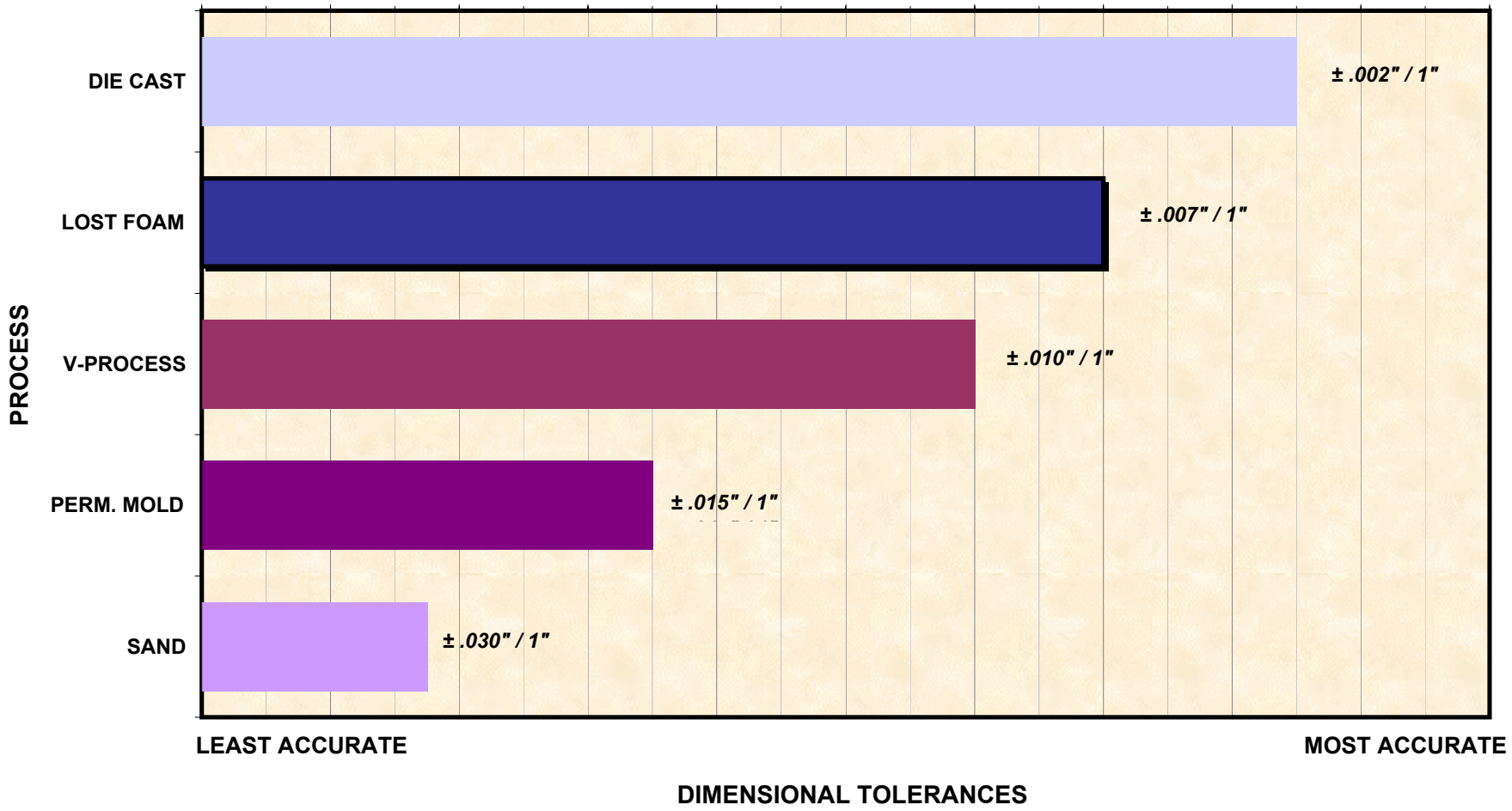
A wide range of surface finishes are produced by the various casting methods. Green sand casting will produce the worst surface finish while die casting typically produces the best results when dies are new. The Lost Foam casting surface is usually better than all of the processes with the exception of die casting. In addition, the surface finish in the Lost Foam process should be consistent throughout the tool life cycle. Die cast and permanent mold surface finish will deteriorate as more cycles are run.



ALUMINUM CASTING PROCESS COMPARISON

DIMENSIONAL TOLERANCES

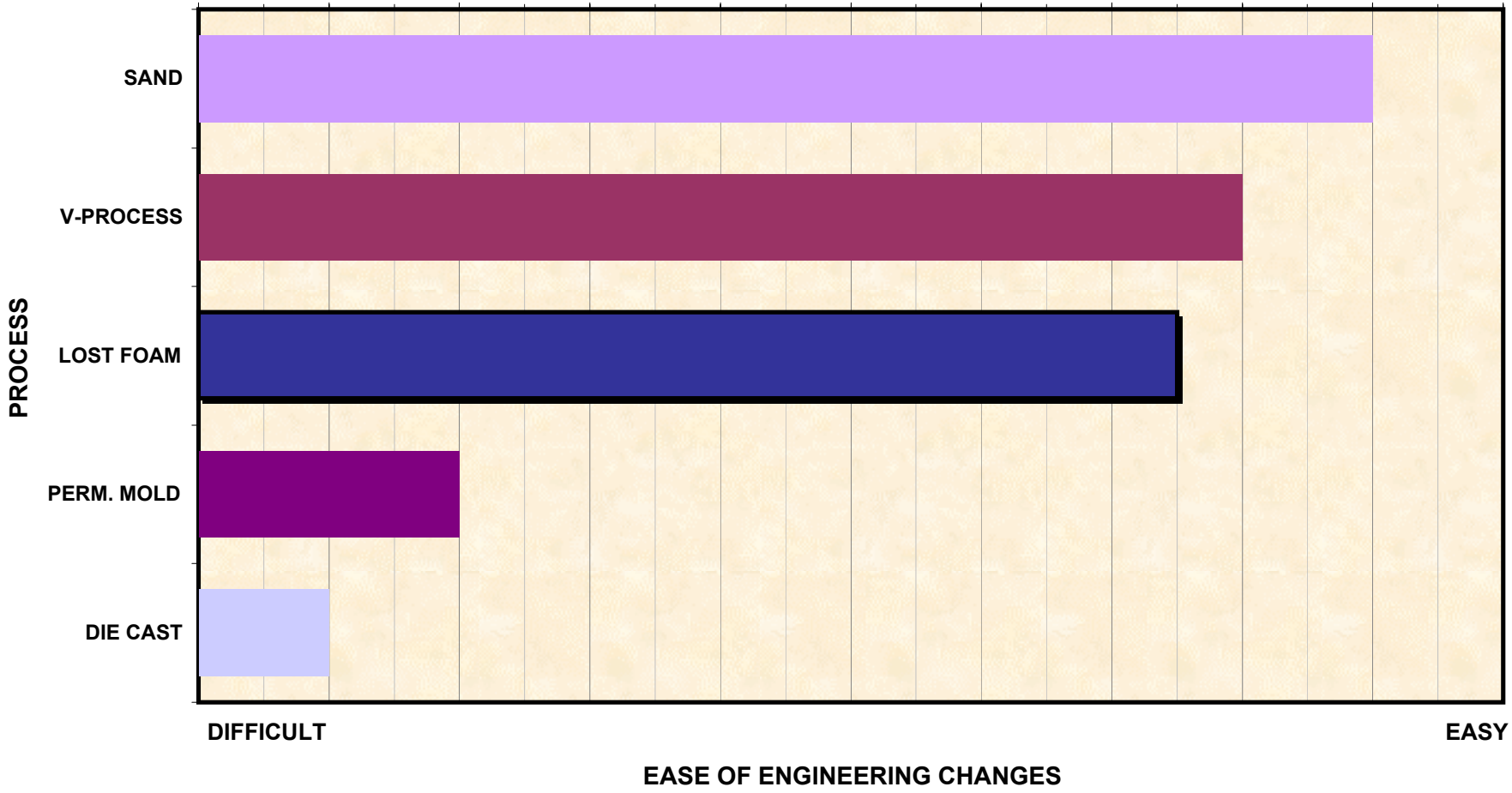
Die casting is expected to result in the highest level of dimensional accuracy. Lost Foam and V-process methods are typically better than permanent mold casting. Green sand casting yields the least accurate results



ALUMINUM CASTING PROCESS COMPARISON

EASE OF ENGINEERING CHANGES

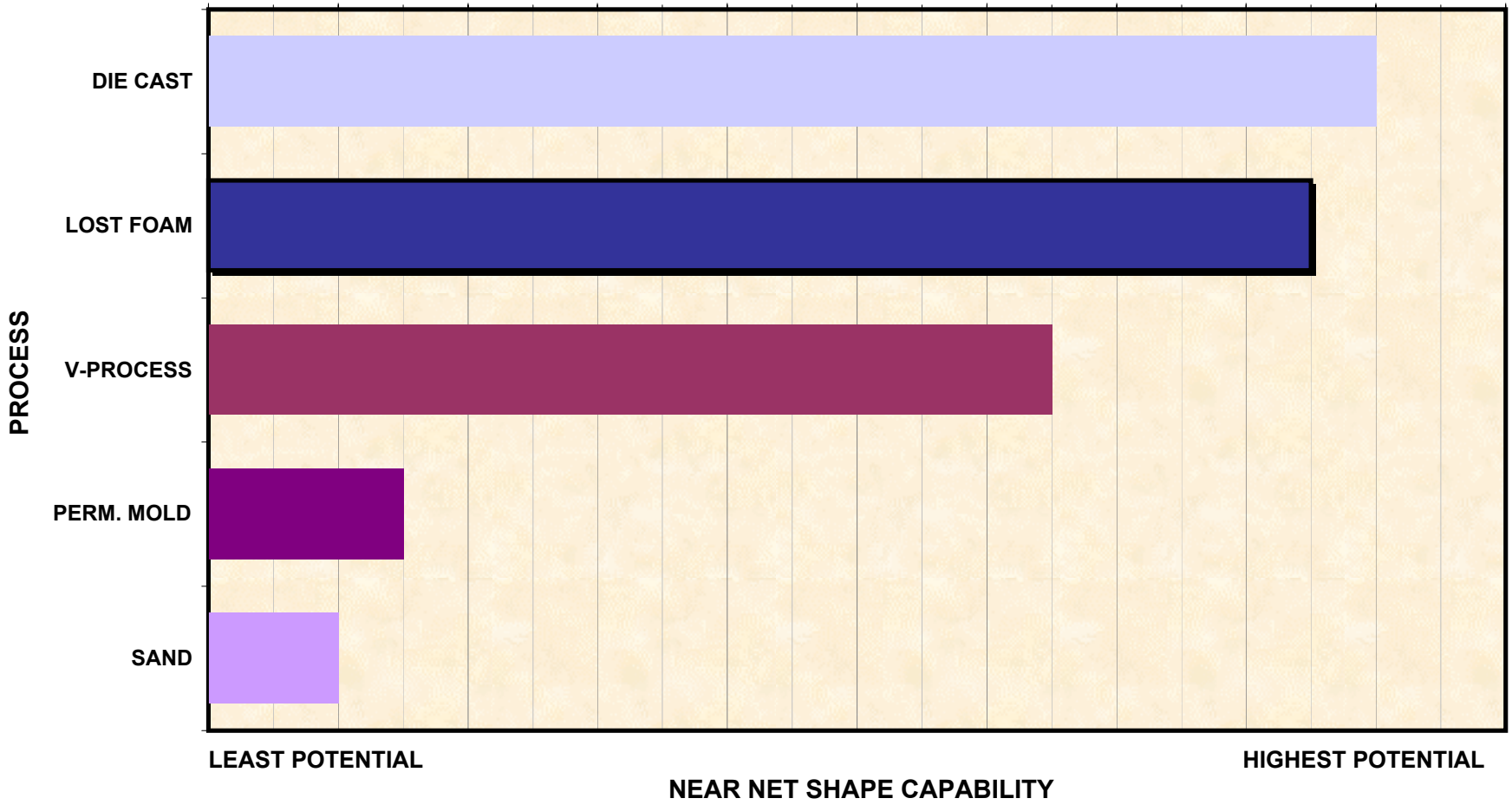
Engineering or tooling changes are expected to be easiest to implement on sand casting equipment, where aluminum or even wood patterns are used. The V-process also allows relatively easy changes due to pattern material. The Lost Foam process use of aluminum tooling makes tool changes the next easiest to change. Cast iron permanent molds and steel dies are the most difficult to change.



ALUMINUM CASTING PROCESS COMPARISON

NEAR NET SHAPE CAPABILITY

Die casting will produce the best near-net-shape casting. The combination of a good surface finish, dimensional accuracy and added features make the Lost Foam process a close second to die casting. V-process patterns are subject to wear but produce good results in low volumes. Permanent mold and green sand methods have the least potential for producing near-net-shape castings.



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INTERNAL METAL SOUNDNESS

Permanent mold has demonstrated the best internal metal soundness. The Lost Foam process has smooth metal flow characteristics resulting in less gas entrapment during pouring and producing results comparable to Permanent Mold. The lack of cores or sand bonding media in the Lost Foam process eliminates gas absorption from the mold during solidification. By contrast, die castings are noted for air and gas entrapment and can be expected to demonstrate the most porous metal characteristics.