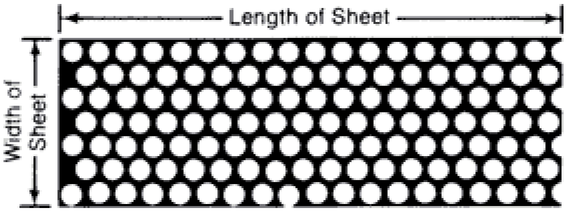
AMICO Perforated Products - Perforated Metals

Strength of Perforated Metals

The use of perforated material is limited by the lack of reliable strength and stiffness properties for use in design. The following information covers the strength of materials perforated with round holes in standard staggered 60° pattern as shown in Figure (1).



Standard 60° Staggered Pattern
Showing Length and Width Orientations

Round holes arranged in a standard 60° triangular pattern ranging from .020″ to 3/4″ account for more than half of the perforating industries production. They produce the strongest pattern and are the most versatile in their application. The standard 60° staggered formation is the most popular hole arrangement because of its inherent strength and the wide range of open areas it provides. In perforating this pattern, the direction of the stagger is the short dimension or width of the sheet as illustrated. The straight row of closely spaced holes is parallel to the long dimension or length of the sheet. This is the so-called “closed pattern.” Under special order, the holes may be punched in the “open pattern.” The directional properties are then reversed from those described herein. Refer to Figure (1) for the length and width directions corresponding to the directional results given in the Tables.

Equivalent Solid Material Concept

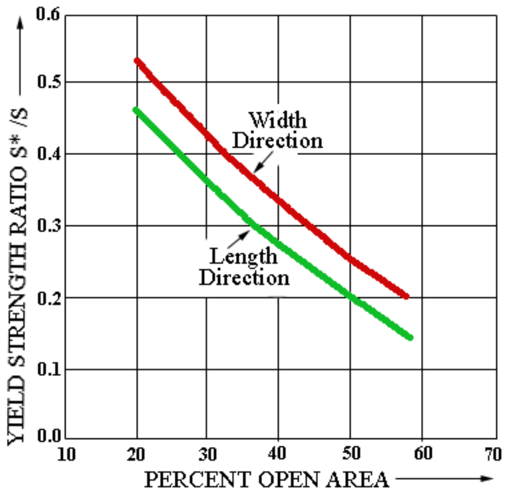
The concept of equivalent solid material is widely used for design analyses of perforated materials. As applied herein, the equivalent strength of the perforated material is used in place of the strength of the solid material. By evaluating the effect of the perforations on the yield strength of the material, S*can be obtained as a function of the yield strength of the solid or unperforated material, S.Thus, the designer is able to determine safety margins for the perforated material for any geometry of application and any loading conditions. The S*/S ratios are the same for bending and stretching of the material. Having the S*/S ratio for the particular penetration pattern of interest, it is therefore easy for the designer to determine what thickness of the perforated material will provide strength equal to that of unperforated material.

Perforated material has different strengths depending on the direction of loading. Values of S*/S are given for the width (strongest) and the length (weakest) directions. The values for the length direction have been calculated conservatively.

Strength of Materials Perforated with Round Holes in a Standard Staggered Pattern

IPA Numbers	Perforations	Centers	Holes / Sq. In.	Open Area	Width Direction	Length Direction
100	.020"	-	625	20%	.530	.465
106	1/16"	1/8"	-	23%	.500	.435
107	5/64"	7/64"	-	46%	.286	.225
108	5/64"	1/8"	-	36%	.375	.310
109	3/32"	5/32"	-	32%	.400	.334
110	3/32"	3/16"	-	23%	.500	.435
112	1/10"	5/32"	-	36%	.360	.296
113	1/8"	3/16"	-	40%	.333	.270
114	1/8"	7/32"	-	29%	.428	.363
115	1/8"	1/4"	-	23%	.500	.435
116	5/32"	7/32"	-	46%	.288	.225
117	5/32"	1/4"	-	36%	.375	.310
118	3/16"	1/4"	-	51%	.250	.192
119	3/16"	5/16"		33%	.400	.334
120	1/4"	5/16"	-	58%	.200	.147
121	1/4"	3/8"	-	40%	.333	.270
122	1/4"	7/16"		30%	.428	.363
123	1/4"	1/2"	-	23%	.500	.435
124	3/8"	1/2"	-	51%	.250	.192
125	3/8"	9/16"	-	40%	.333	.270
126	3/8"	5/8"	-	33%	.400	.334
127	7/16"	5/8"	-	45%	.300	.239
128	1/2"	11/16"	-	47%	.273	.214
129	9/16"	3/4"	-	51%	.250	.192
130	5/8"	13/16"	-	53%	.231	.175
131	3/4"	1"	-	51%	.250	.192

Notes: S* = Yield Strength of Perforated Material
S = Yield Strength of Unperforated Material
Length Direction = Parallel to Straight Row of Closely Spaced Holes
Width Direction = Direction of Stagger



Elastic Properties of Perforated Metals

There are many potential new applications where perforated materials could be used. In many of these uses, however, the strength and stiffness properties of the perforated sheet are very important. The following information covers the stiffness properties for the standard 60° degree triangular penetration patterns. Since perforated materials can potentially be used in so many applications involving different geometries, materials, and loading conditions, design data are given in a very general form. The ratio of the effective elastic modulus of the perforated material, E*, to the elastic modulus of the unperforated material, E, and the effective Poisson's Ratio, v*, are given. These values are given for all the Standard IPA numbered perforations which cover round holes arranged in the standard 60° degree triangular pattern ranging from .020″ to 3/4″, and account for more than half of the perforating industry's production.

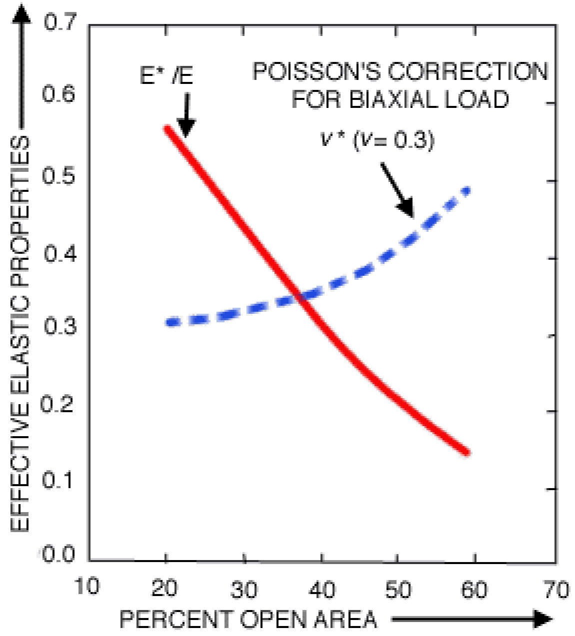
Equivalent Solid Material Concept

The concept of equivalent solid material is widely used for design analyses of perforated materials. As applied herein, the equivalent stiffness of the perforated material is used in place of the stiffness of the solid material. By evaluating the effect of the perforations, the equivalent effective elastic modulus of the perforated material, E*, is obtained as a function of the elastic modulus of the solid or unperforated material, E. In addition, the effective Poisson's Ratio, v*, of the perforated material is obtained. This Poisson's Ratio may be used in cases where correction for load biaxiality is important.

The effective elastic constants presented herein are for plane stress conditions and apply to the in-plane loading of the thin perforated sheets of interest. The bending stiffness of such perforated sheets is somewhat greater. However, most loading conditions involve a combination of bending and stretching, and it is more convenient to use the same effective elastic constants for the combined loading conditions. The plane stress effective elastic constants given herein can be conservatively used for all loading conditions. Using these effective elastic properties, the designer is able to determine the deflections of the perforated sheet for any geometry of application and any loading conditions using available elastic solutions. It is therefore easy for the designer to determine what additional thickness of the perforated material will provide stiffness equal to that of unperforated material.

Effective Elastic Properties for IPA Standard Perforations

IPA Numbers	Perforations	Centers	Holes per sq. in.	Open Area	E*/E
100	.020"	-	625	20%	.565
106	1/16"	1/8"	-	23%	.529
107	5/64"	7/64"	-	46%	.246
108	5/64"	1/8"	-	36%	.362
109	3/32"	5/32"	-	32%	.495
110	3/32"	3/16"	-	23%	.529
112	1/10"	5/32"	-	36%	.342
113	1/8"	3/16"	-	40%	.310
114	1/8"	7/32"	-	29%	.436
115	1/8"	1/4"	-	23%	.529
116	5/32"	7/32"	-	46%	.249
117	5/32"	1/4"	-	36%	.362
118	3/16"	1/4"	-	51%	.205
119	3/16"	5/16"		33%	.395
120	1/4"	5/16"	-	58%	.146
121	1/4"	3/8"	-	40%	.310
122	1/4"	7/16"		30%	.436
123	1/4"	1/2"	-	23%	.529
124	3/8"	1/2"	-	51%	.205
125	3/8"	9/16"	-	40%	.310
126	3/8"	5/8"	-	33%	.395
127	7/16"	5/8"	-	45%	.265
128	1/2"	11/16"	-	47%	.230
129	9/16"	3/4"	-	51%	.205
130	5/8"	13/16"	-	53%	.178
131	3/4"	1"	-	51%	.205



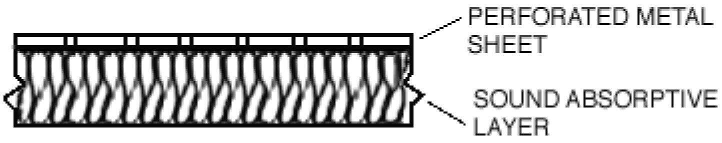
How Perforated Metals are Used in Acoustics

There are two principal acoustical applications for perforated metals:

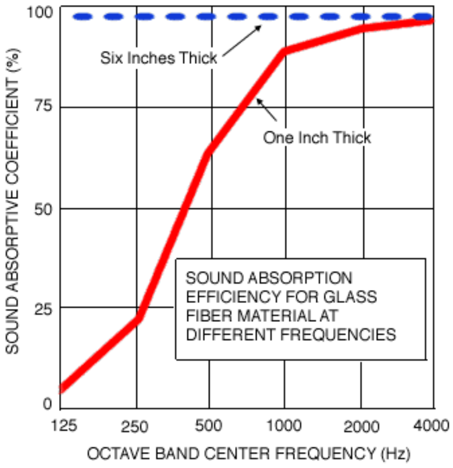
- As a facing for something else
- In a Tuned Resonant Absorber

As a Facing for Something Else

Here the perforated metal is used as a protective or decorative covering for some special acoustical material; that material may be designed either to absorb sound or to reflect or scatter sound in a special way. So, the purpose of the perforated metal in such applications is to be so "transparent" that the sound waves pass right through it, without being diminished or reflected, to encounter the acoustical treatment that lies behind it.

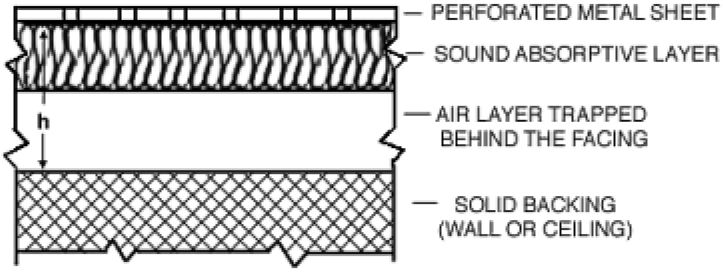


The chart below shows typical sound-absorbing efficiencies for glass fiber materials at different frequencies. Notice that only one inch of glass fiber is quite effective in absorbing sound at high frequencies above 2,000 Hz but very inefficient at absorbing low frequencies. On the other hand, six inches of glass fiber is very efficient at all frequencies (about 99% of the incident noise energy is absorbed). The design problem, here, is that the absorbing material takes up space and is expensive.



The Tuned Resonant Absorber

In many noise control applications, the objective is to remove or reduce sounds that occur only in a narrow range of frequencies. For such situations, it is possible to design a sound-absorption system that is “tuned” to those targeted frequencies in which perforated metal plays a critically active role. This kind of system is called a Tuned Resonant Absorber. By employing such a system, the designer can reduce the thickness of the absorbing layer and save space and cost. This is illustrated in the chart above. It clearly shows that if the target frequency range centered on 2,000 Hz, an absorbing layer of just 1″ would remove nearly all of that sound.



In a resonant sound absorber (refer to diagram), the air motion in and out of the holes in the perforated metal sheet oscillates in response to an incident sound wave. The preferred frequency of oscillation is determined by the mass of the air in the perforations and the springiness of the trapped air layer. At that frequency, the air moves violently in and out of the holes and, also, back and forth in the sound absorptive layer where the acoustic energy is converted by friction into heat and is thereby removed from the acoustical scene. It is the interaction between the thickness of the perforated sheet and the size and number of the holes in it with the depth of the trapped air layer, that determines the target frequency and thereby the thickness of the absorbing layer required to remove the sound.

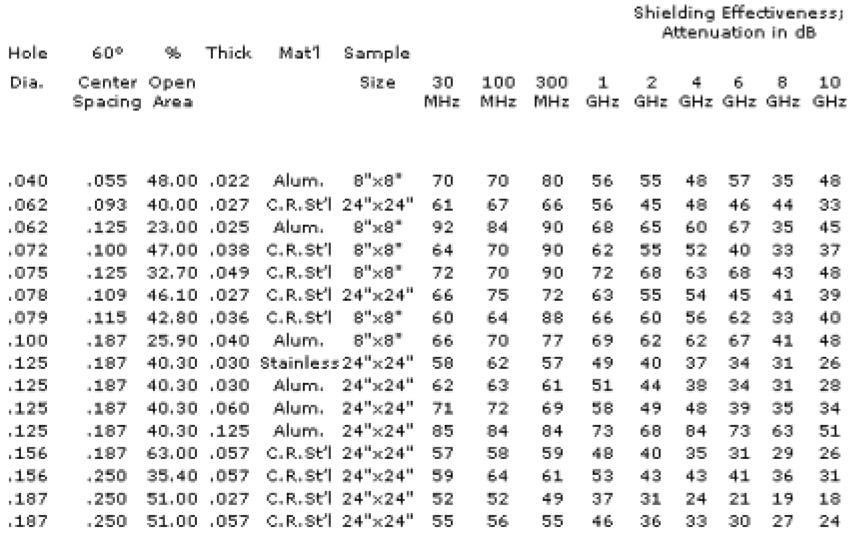
As a component of a resonant sound-absorbing system, perforated metals provide unique capabilities. A comprehensive guide to the theory and calculations for determining perforated metal specifications for both transparent covers and resonant sound-absorbing systems is offered by the IPA in a book authored by Theodore J. Schultz, Ph.D., ACOUSTICAL USES FOR PERFORATED METALS available from the Industrial Perforators Association.

EMI Shielding Effectiveness

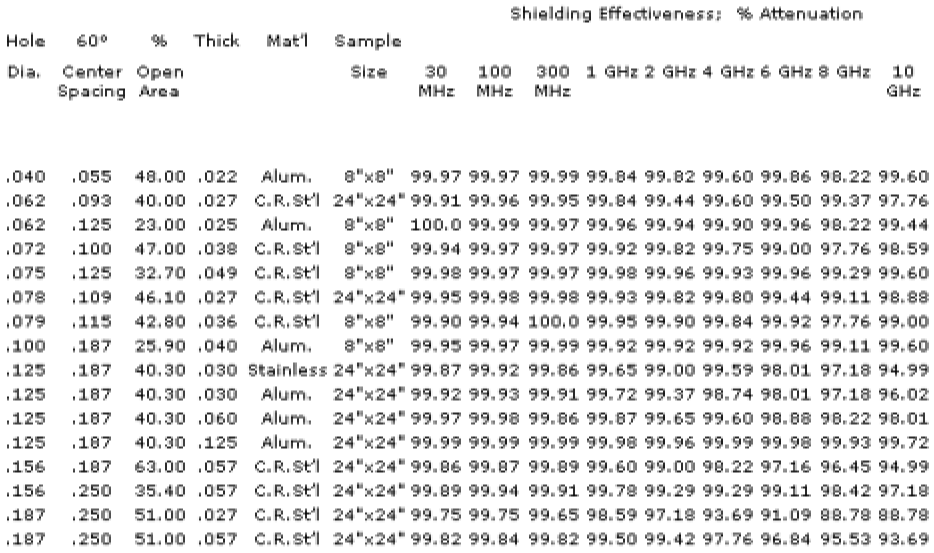
Perforated metal is being used to enclose electrical devices to attenuate the EMI/RFI radiation they emit and to ventilate them at the same time. Many questions have been asked about which perforated pattern should be used to satisfy both of these design requirements and the shielding effectiveness of various perforated patterns and materials. To answer these questions, the I.P.A. contracted with Dash, Straus & Goodhue, Inc., testing laboratories in Boxborough, MA to evaluate the shielding effectiveness of 16 perforation and material combinations at 9 frequency levels. The results of these tests with descriptions of the test samples and the frequencies tested are shown in the charts that follow. Results have been expressed in dB of Shielding Attenuation and in % of Attenuation. Details of the tests are available from the I.P.A.

The test results show that a Shielding Effectiveness of 40 dB provides 99.000% attenuation of the electromagnetic (EMI/RFI) radiation while a Shielding Effectiveness of 40 dB is the targeted minimum in most applications. Very effective shielding was provided by most samples up to frequencies of 7 GHz. Above that frequency, some of the samples dropped below 99.000% effective, but most samples stayed comfortably above 95% effective even at the highest frequency level of 10 GHz. The obvious conclusion to be reached is that there are many perforated patterns that designers can choose from to meet their design requirements.

The largest single source of the leakage is along contact surfaces between two parts. If a tightly sealed electrical connection is not made, the leakage through the interface can be greater than through the structure.



						Shielding Effectiveness; Attenuation in dB								
Hole Dia.	60° Center Spacing	% Open Area	Thick	Mat’l	Sample Size	30 MHz	100 MHz	300 MHz	1 GHz	2 GHz	4 GHz	6 GHz	8 GHz	10 GHz
.040	.055	48.00	.022	Alum.	8"x8"	70	70	80	56	55	48	57	35	48
.062	.093	40.00	.027	C.R.St’l	24"x24"	61	67	66	56	45	48	46	44	33
.062	.125	23.00	.025	Alum.	8"x8"	92	84	90	68	65	60	67	35	45
.072	.100	47.00	.038	C.R.St’l	8"x8"	64	70	90	62	55	52	40	33	37
.075	.125	32.70	.049	C.R.St’l	8"x8"	72	70	90	72	68	63	68	43	48
.078	.109	46.10	.027	C.R.St’l	24"x24"	66	75	72	63	55	54	45	41	39
.079	.115	42.80	.036	C.R.St’l	8"x8"	60	64	88	66	60	56	62	33	40
.100	.187	25.90	.040	Alum.	8"x8"	66	70	77	69	62	62	67	41	48
.125	.187	40.30	.030	Stainless	24"x24"	58	62	57	49	40	37	34	31	26
.125	.187	40.30	.030	Alum.	24"x24"	62	63	61	51	44	38	34	31	28
.125	.187	40.30	.060	Alum.	24"x24"	71	72	69	58	49	48	39	35	34
.125	.187	40.30	.125	Alum.	24"x24"	85	84	84	73	68	84	73	63	51
.156	.187	63.00	.057	C.R.St’l	24"x24"	57	58	59	48	40	35	31	29	26
.156	.250	35.40	.057	C.R.St’l	24"x24"	59	64	61	53	43	43	41	36	31
.187	.250	51.00	.027	C.R.St’l	24"x24"	52	52	49	37	31	24	21	19	18
.187	.250	51.00	.057	C.R.St’l	24"x24"	55	56	55	46	36	33	30	27	24



						Shielding Effectiveness; % Attenuation								
Hole Dia.	60° Center Spacing	% Open Area	Thick	Mat’l	Sample Size	30 MHz	100 MHz	300 MHz	1 GHz	2 GHz	4 GHz	6 GHz	8 GHz	10 GHz
.040	.055	48.00	.022	Alum.	8"x8"	99.97	99.97	99.99	99.84	99.82	99.60	99.86	98.22	99.60
.062	.093	40.00	.027	C.R.St’l	24"x24"	99.91	99.96	99.95	99.84	99.44	99.60	99.50	99.37	97.76
.062	.125	23.00	.025	Alum.	8"x8"	100.0	99.99	99.97	99.96	99.94	99.90	99.96	98.22	99.44
.072	.100	47.00	.038	C.R.St’l	8"x8"	99.94	99.97	99.97	99.92	99.82	99.75	99.00	97.76	98.59
.075	.125	32.70	.049	C.R.St’l	8"x8"	99.98	99.97	99.97	99.98	99.96	99.93	99.96	99.29	99.60
.078	.109	46.10	.027	C.R.St’l	24"x24"	99.95	99.98	99.98	99.93	99.82	99.80	99.44	99.11	98.88
.079	.115	42.80	.036	C.R.St’l	8"x8"	99.90	99.94	100.0	99.95	99.90	99.84	99.92	97.76	99.00
.100	.187	25.90	.040	Alum.	8"x8"	99.95	99.97	99.99	99.92	99.92	99.92	99.96	99.11	99.60
.125	.187	40.30	.030	Stainless	24"x24"	99.87	99.92	99.86	99.65	99.00	99.59	98.01	97.18	94.99
.125	.187	40.30	.030	Alum.	24"x24"	99.92	99.93	99.91	99.72	99.37	98.74	98.01	97.18	96.02
.125	.187	40.30	.060	Alum.	24"x24"	99.97	99.98	99.86	99.87	99.65	99.60	98.88	98.22	98.01
.125	.187	40.30	.125	Alum.	24"x24"	99.99	99.99	99.99	99.98	99.96	99.99	99.98	99.93	99.72
.156	.187	63.00	.057	C.R.St’l	24"x24"	99.86	99.87	99.89	99.60	99.00	98.22	97.16	96.45	94.99
.156	.250	35.40	.057	C.R.St’l	24"x24"	99.89	99.94	99.91	99.78	99.29	99.29	99.11	98.42	97.18
.187	.250	51.00	.027	C.R.St’l	24"x24"	99.75	99.75	99.65	98.59	97.18	93.69	91.09	88.78	88.78
.187	.250	51.00	.057	C.R.St’l	24"x24"	99.82	99.84	99.82	99.50	99.42	97.76	96.84	95.53	93.69

Pressure Loss Through Perforated Plate

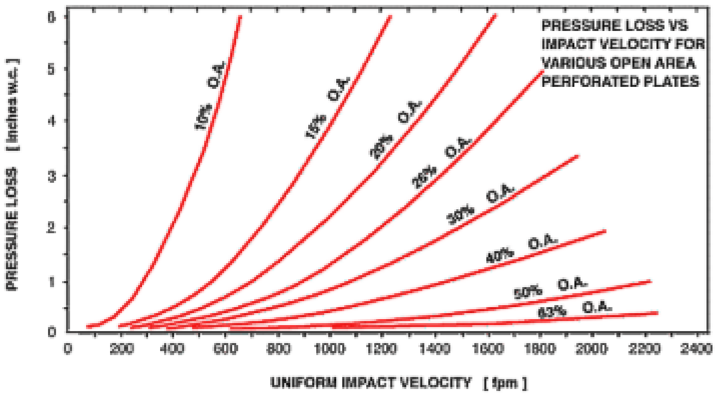
Pressure Loss Through Perforated Plate (Air)

In many applications of perforated plates, the estimated energy loss or pressure loss through perforated plates is one of the design considerations. The following pressure loss information was developed from a laboratory airflow system. The laboratory system maintained a non-swirling flow impacting perpendicularly on the sample.

Various perforated thin gage plates were inserted into a uniform velocity airflow stream. Pressure loss for ambient airflow was then measured at a series of velocities and reported as inches of water column loss for each flow. This data presents the best flow condition value of the loss. Pressure loss can be estimated beyond the range of the data on the basis of the ratio of the anticipated velocity to the highest tabulated velocity. This ratio squared multiplied by the tabulated pressure loss can be used to approximate the higher velocity loss.

Pressure loss can be estimated from the tables for a different gas density by using the ratio of the anticipated gas density to the tabulated density as a multiplier of the noted loss.

In applying this data, consideration must be given to the actually anticipated characteristics of the flow impacting on the perforated plate. Distorted flow patterns with high-velocity zones will increase the loss of the plate, as will directional flow not perpendicular to the plate surface.



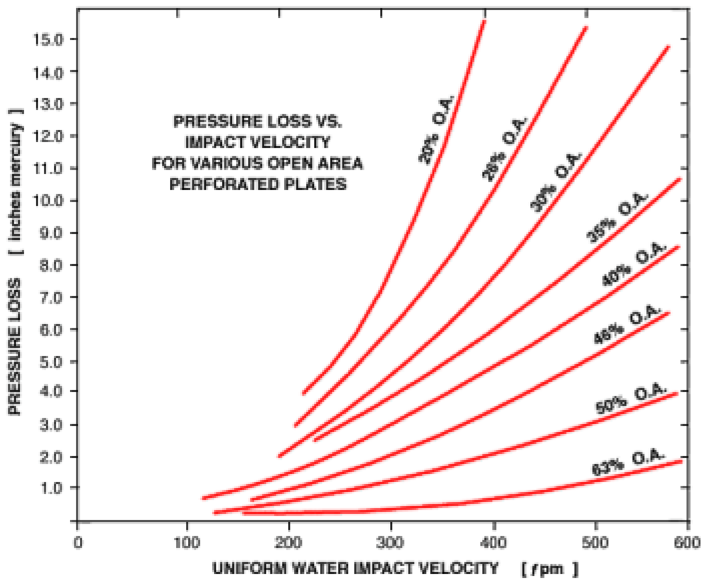
Pressure Loss Through Perforated Plate (Fluid)

In many applications of perforated plates, the estimated energy loss or pressure loss through perforated plates is one of the design considerations. The following pressure loss information was developed from a laboratory liquid flow system. The laboratory system maintained a non-swirling flow impacting perpendicularly on the sample.

Various perforated thin gage plates were inserted into a uniform velocity liquid flow stream. Pressure loss for ambient liquid flow was then measured at a series of velocities and reported as inches of mercury loss for each flow. This data, therefore, presents the best flow condition value of the loss. Pressure loss can be estimated beyond the range of the data on the basis of the ratio of the anticipated velocity to the highest tabulated velocity. This ratio squared multiplied by the tabulated pressure loss can be used to approximate the higher velocity loss.

Pressure loss can be estimated from the tables for a different liquid density by using the ratio of the anticipated liquid density to the tabulated density as a multiplier of the noted loss.

In applying this data, consideration must be given to the actual anticipated characteristics of the flow impacting the perforated plate. Distorted flow patterns with high-velocity zones will increase the loss of the plate, as will directional flow not perpendicular to the plate surface.



BOYLE ENGINEERING LABORATORIES, FEBRUARY 1985

Reasons for Calling Perforated Metal

Apart from the one illustrated calls for punching an array of holes along with several other turret press operations. It’s a temptation to do them all in-house because it seems to make sense. But you are likely to have problems and run up costs, instead.

First, to punch that array of holes requires special cluster tooling that not only is expensive but takes time to make. More than that, the tooling you make will be limited in its use to specific material and a narrow range of thicknesses because of clearance requirements between the male and female tool components. If the type and thickness of the material for the part change, new tooling will be needed.

Second, punching all of those holes with a cluster tool, just as the name implies, permits punching just a small “cluster” of holes with each stroke of the press. The machine time required to make those holes is very expensive, indeed.

Third, maintaining accuracy in the placement of the holes and uniformity in their spacing will prove difficult because of the distortion in the workpiece that occurs with every press stroke.

Fourth, when the part comes out of the punching process, it will be distorted and need flattening. Without a roller leveler, you will need to send the part out to be put back in shape. This means even more time and money and, at this point, your Quality Control people may be beginning to hyperventilate along with your cost controller.

Better let your perforating specialist put those holes in for you… or, better yet, make the part completely. Here are some good reasons why.

Your perforating specialist’s entire production process is dedicated to perforating metal and its related operations. His is a highly specialized production resource that requires a heavy capital investment in extremely fast and accurate perforating presses surrounded by state-of-the-art peripheral equipment all controlled by well-trained, experienced people. His modern, high-speed electronically controlled presses can make holes as fast as 300,000 per minute, all with extreme accuracy. It’s no trick for him to produce patterns that include predetermined blank areas and special margins. The tolerances he can hold are extraordinary.

These capabilities permit designers to layout patterns of perforations that can be perfectly matched to subsequent manufacturing operations such as bending and joining. All of this he can do in nearly every type of material in thicknesses from foil to 1 1/2″ plate. Sheet sizes as wide as 60″ are readily accommodated and coils up to 20,000 lbs. efficiently perforated and rewound.

Because he is a specialist, he has accumulated extensive banks of tooling capable of perforating round holes, square holes, rectangles, triangles, slots, and a wide variety of odd-shaped holes in hundreds of patterns. Hole sizes can be as small as 1/64″ to 12″. The probability that he will have the tooling to match your requirements is better than 9 to 1….and all of these tools are yours to choose from.

He has the necessary follow-up operations, too, of which roller leveling is one, that removes the distortions, burrs, and oil that the perforating process leaves behind. And, most perforators can do the secondary operations that will finish your parts such as bending, welding, painting, and plating.

Compare your costs; these are some you need to consider:

- The cost of tooling
- The time it takes to make tools
- The set-up charges on your turret press
- The production cycle of your press
- Machining time
- Roller-leveling, deburring, and degreasing
- Quality considerations

When you consider them all, your decision should be an easy one. You can use your perforating specialist exactly as you would use any other manufacturing department under your own roof. And he’ll produce your work faster, at lower cost, and to tolerances and other standards of quality that you’ll be surprised to discover go well beyond “acceptable.”

Perforated Metal, Expanded Metal or Wire Cloth

When choosing between Perforated Metal, Expanded Metal, or Wire Cloth, there is more than a price to consider…

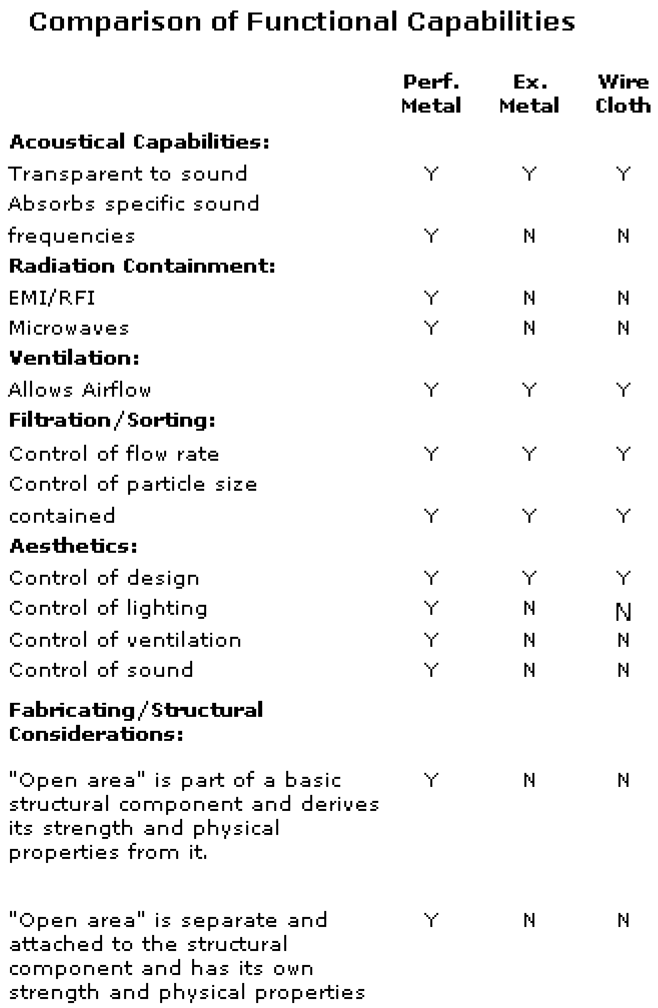
There are many applications where the product designer or architect needs to provide a component that has a perforated or otherwise open area to allow the passage of air or liquids or sound…or perhaps even solids as is the case in some food processing machinery. The choice of material for these situations usually comes down to one of three, perforated metal, expanded metal or wire cloth.

A basic criterion for selection is price, of course, but, there are other more important criteria to consider.

The intended function of the material is most important. There are some functions that only perforated metal can do.

Exhibit 1 compares the functional capabilities of the three materials. Some of the functional capabilities are what you would expect to find in such a list. Ventilation, filtering, sorting and the support for sound-absorbing material used in walls and ceilings to reduce noise are all familiar applications of these materials. You may be surprised at some of the less obvious capabilities of perforated metal, its capabilities in sound managing systems go beyond being “transparent” to sound to allow it to pass through to absorbing materials. Perforated materials also can play an active role in systems that eliminate specific sound frequencies such as those placed in jet engine nacelles and in enclosures that surround large air conditioning or compressor units. Perforated metal is also widely used to contain various kinds of radiation and still provide ventilation or visibility; your microwave oven is a good example.

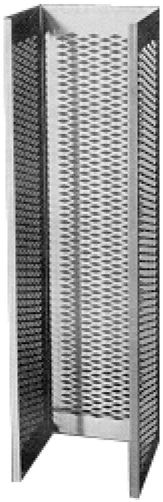
Some of the functions listed in the chart can only be performed, and others might be better performed, by perforated metal. Important among its virtues is its great variability. Many hole shapes, sizes, and patterns are available to offer designers and architects more choices and superior solutions to their design problems. But, there are many situations in which all three materials will perform equally as well. Is it then simply a matter of price?



Comparison of Functional Capabilities

	Perf. Metal	Ex. Metal	Wire Cloth
Acoustical Capabilities:			
Transparent to sound	Y	Y	Y
Absorbs specific sound frequencies	Y	N	N
Radiation Containment:			
EMI/RFI	Y	N	N
Microwaves	Y	N	N
Ventilation:			
Allows Airflow	Y	Y	Y
Filtration/Sorting:			
Control of flow rate	Y	Y	Y
Control of particle size contained	Y	Y	Y
Aesthetics:			
Control of design	Y	Y	Y
Control of lighting	Y	N	N
Control of ventilation	Y	N	N
Control of sound	Y	N	N
Fabricating/Structural Considerations:			
"Open area" is part of a basic structural component and derives its strength and physical properties from it.	Y	N	N
"Open area" is separate and attached to the structural component and has its own strength and physical properties	Y	N	N

Material costs do not tell the whole story



There are fabricating considerations that can be more important to the ultimate costs of the choice. Consider Exhibit 2, for example. This stainless steel part was finished in two operations. Three panels of perforations were made with a single pass through the perforator's press and then the part was formed in a press brake. The part is all in one piece.

Using expanded metal or wire cloth to provide the "open area" would require at least five operations, a punch press operation to open the "windows," a bending operation to form the structure and finally three welding operations to fasten the open material to the structure. Instead of one piece, there are four work pieces involved. And certainly the welding operations will not provide the finished result you see in the perforated piece. The costs of these fabricating operations, both in dollars and in product quality, must be considered to make a valid comparison of the material

Perforating Cost Influences Checklist

1. Material type – Remember the least expensive material may not be the lowest cost, a higher strength alloy may allow reducing thickness. Keep hardness below 80 Rb.

2. Material thickness – Thinner materials perforate easier and faster.

3. Hole shape and pattern – Round holes are the most economical, 60° degree staggered round hole pattern strongest and most versatile.

4. Hole size – Do not go below a 1-to-1 ratio with sheet thickness. Stay at 2-to-1 or larger if possible.

5. Bar size – Do not go thinner than 1-to-1 ratio with sheet thickness.

6. Center distance – It controls feed rate and thereby the production rate. If possible, choose a pattern with a longer center distance.

7. Open areas – Extreme open areas tend to increase distortion; if possible, stay under 70%

8. Margins – Keep side margins to a minimum to reduce distortion. Use standard Unfinished End Margins if you can.

9. Blank areas – Consider the die pattern when locating them. Consult with your IPA supplier.

10. Stick to standards – Specify standard hole patterns, materials, dimensions, and tolerances whenever possible. Before specifying a “Special,” consult with your IPA member supplier; he can work wonders with existing tooling.

11. Normal commercial burrs – Unless otherwise specified.