Designers, Specifiers And Buyers Handbook For Perforated Metals

A publication of the Industrial Perforators Association

IPA
INDUSTRIAL PERFORATORS ASSOCIATION

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A Specialized Production Resource

The member companies of the IPA constitute a highly specialized production resource for punching very large numbers of holes in a wide variety of materials with extraordinary efficiency. If you are a designer or buyer you have an interest in this capability because holes provide solutions to a great many design problems. Round holes, square holes, rectangles, triangles, slots, decorative patterns—the variety of possible shapes is limited only by the designer's imagination. Hole sizes range from a few thousandths of an inch in diameter up to more than three inches while the materials that can be perforated can be as thin as foil or as thick as 1 1/2" steel plate.

To make holes with great accuracy and efficiency and in such enormous variety, takes a very special process. It requires a heavy investment in machinery and tools for one thing, and must be backed up by specialized technology and experience.

The members of the IPA put at your disposal nearly 200 perforating presses and a bank of dies capable of perforating thousands of different hole patterns.

The probability that IPA members will have in their die banks a punch that will exactly match your requirements is better than 9 to 1. Member die banks represent an enormous resource to you as a designer. Literally thousands of patterns are available to choose from. In addition to the patterns listed and illustrated there are hundreds of special patterns available to satisfy your unusual functional or decorative requirements.

Along with all this, IPA members carry extensive stocks of standard sheet sizes and hole patterns available to you for immediate delivery. Modern high speed and electrically controlled presses can make holes as fast as 300,000 per minute and can punch with extreme accuracy, hole patterns that include pre-determined blank areas and special margins. It is this capability that permits designers to lay out patterns of perforations that can be perfectly accommodated by subsequent manufacturing steps such as bending and joining operations. Sheet sizes as wide as 60" are readily accommodated and coils up to 20,000 Ibs. efficiently perforated and rewound.

IPA manufacturing facilities also include many follow-up operations. They are equipped to shear to size, roll for specified flatness conditions, slit for stripping, perform welding and other joining operations, form, paint and apply coatings after perforating.

The Wonderful Things That Holes Can Do

As consumers, we are not given to wonder much about the work that holes do for us. But, for the product designer or architect, holes in sheet metal can provide the perfect solution to a multi-faceted design problem.

Starting on page 6 of this handbook is a special color section illustrating in handsome photography the beauty and versatility, in both form and function, of perforated metal. Each application illustrates the material' s problem-solving capabilities for industrial designers and architects usually performing several important functions simultaneously. In your microwave oven door, for example, a piece of perforated metal holds in the harmful microwaves but lets you look inside to see what' s cooking.

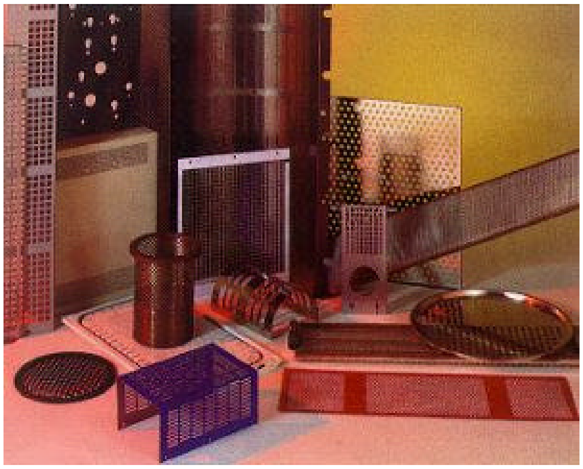
Many of perforated metals uses are relatively new. Examples include applications for sound suppression, microwave and EMI/RFI radiation containment, filtration and purification of air, water and gases. But the rapid growth in the use of perforated materials strongly suggests that just the surface has been scratched on their potential application.

In the chart on the next page, we have attempted to summarize the uses for perforated materials in terms of where and how they are used, what they do and the special conditions they are called upon to meet. We grant, at the outset, that the chart is severely limited. It is presented to be suggestive and to stimulate your creative imagination.

The Uses of Perforated Materials

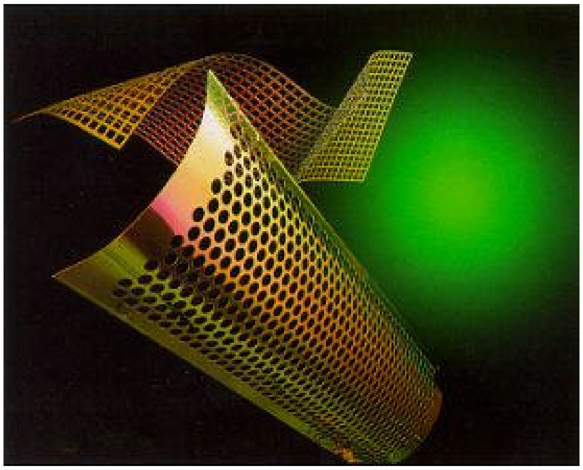
Function	**Basic Application**
Cover	Architectural
Enclose	Components:
Divide	Ceilings
Decorate	Walls
Ventilate	Floors
	Conduits
Control passage of:	Stairways
Air	Grills
Gases	Dividers
Liquids	Acoustical surfaces
Light	
Sound	Product Components:
	Machines, all types
Separate and size solids	Appliances
Filter liquids	Vehicles
Provide display surface	Aircraft
Guard	Ships and boats
Hide	Electrical apparatus
Create lighting effects	Furniture
Contain (Microwaves)	Lighting fixtures
Minimize weight	Shelving
Absorb sound	Dryers
	Agricultural equipment
Special Conditions	Petro-Chemical
	Processing
Sanitary	Mining
Corrosive	Pollution controls
Abrasive	Food processing
High temperature	Papermaking
Low temperature	
Light weight	
Low cost	

Design With Endless Choices

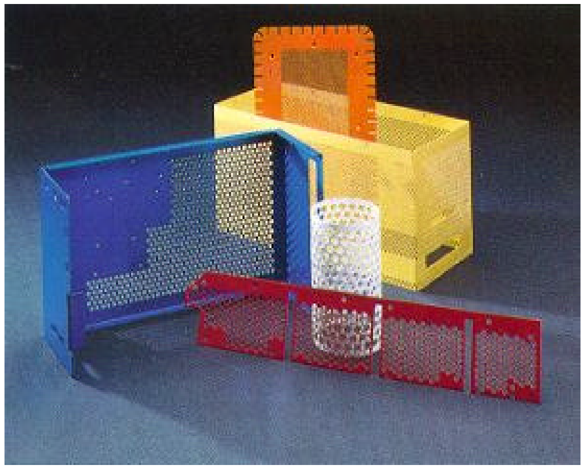


Perforated Metal can take many shapes with uncountable choices of perforations

Whenever holes are needed, you can put them where you want in a wide choice of material specifications and finish with a part that is all one piece



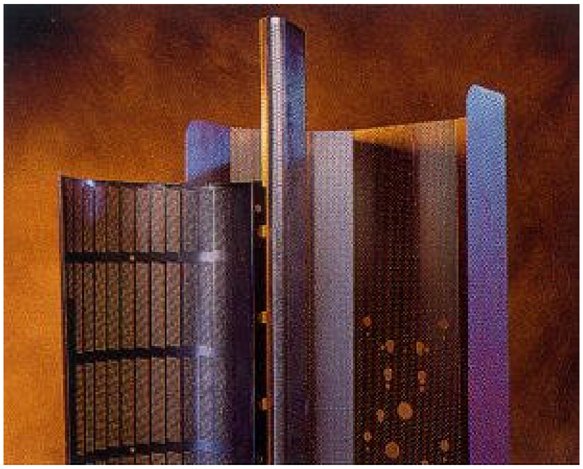
Perfectly Adaptable



The Perforating process is perfectly adaptable to provide surprisingly satisfying design solutions

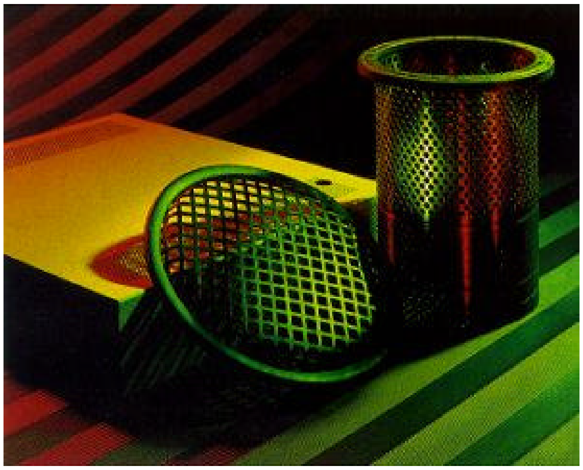
…enhancing the look as well as the performance

Structurally Sound and Efficiently Made

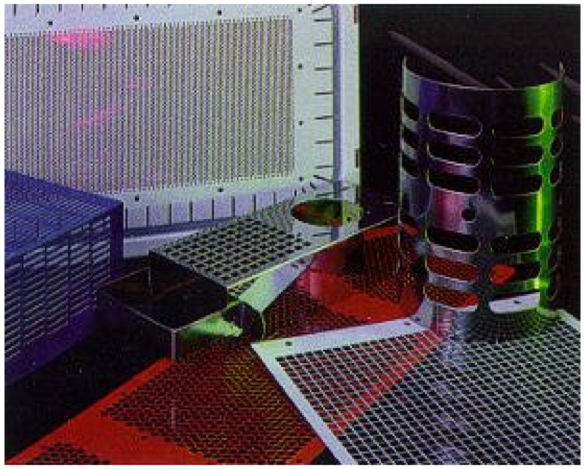


Perforated components make products work better with holes that function several ways. Holes that ventilate while they hold in radiation…

…holes that make your microwave oven safe but let you see what's cooking…holes that filter or select…holes that freely allow the passage of sound waves, gas or liquid for whatever good reasons you may have.

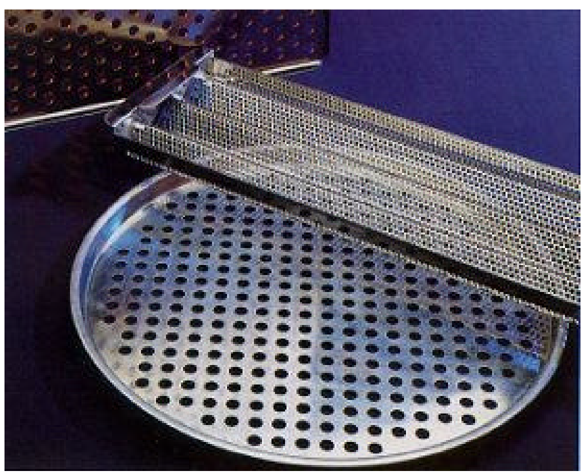


Beautiful, Functional and Versatile

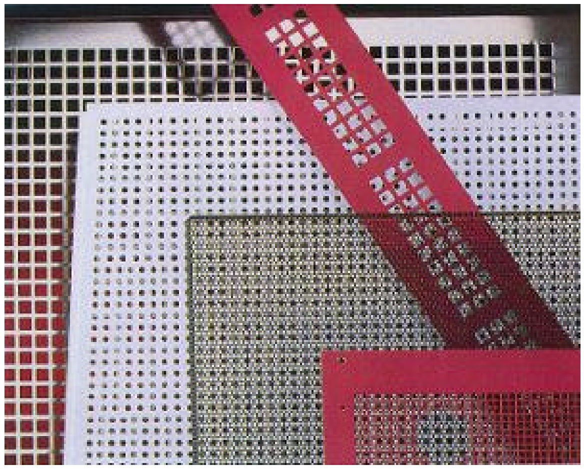


There are so many ways to do it better with perforated metal.

Bakers and pizza makers swear that these are the best bread trays and pizza pans around because the holes let the heat get to everywhere it's needed.



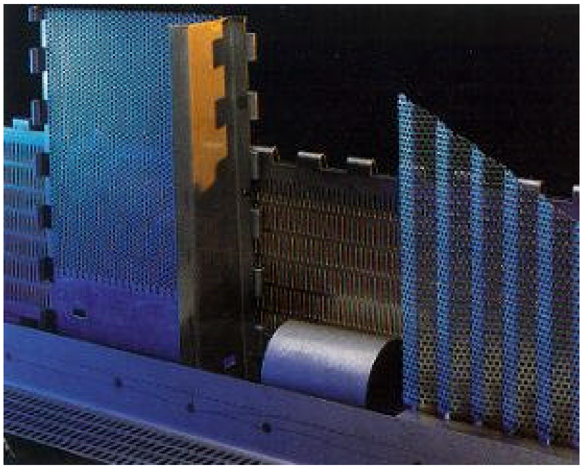
Keeping it Safe, Cool and Beautiful



Architects have found a thousand ways to improve your life with perforated metals.

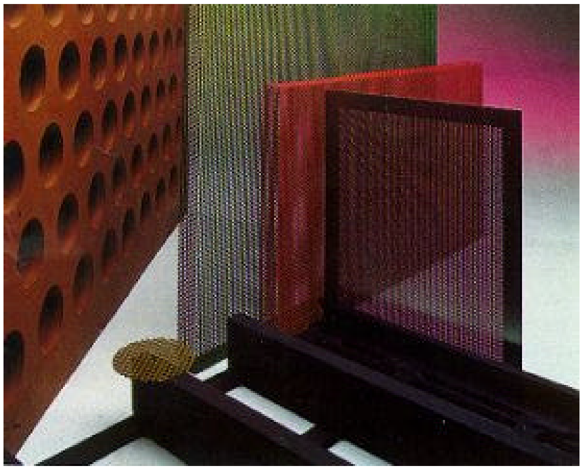
Here, they have provided protection from UV radiation, removed noise and kept small children safe from falling.

Improving Productivity



Production line components like these conveyor and dryer elements work better because they are perforated. But, that's just part of the story.

Perforated metal parts work more efficiently because the perforating process is so adaptable to designer's requirements for perforations and their placement, material specifications and the shape of the finished part.



Strength of Perforated Metal

This material was developed for the IPA
by O' Donnell & Associates, Inc.

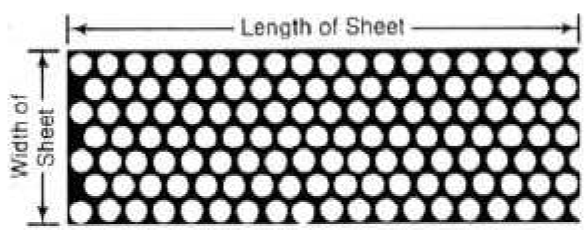
The use of perforated materials is limited by the lack of reliable strength and stiffness properties for use in design. The following information covers the strength of materials perforated with round holes in a standard staggered 60" pattern as shown in Figure (1).

Round holes arranged in a standard 60" triangular pattern ranging from .020" to 3/4" account for more than half of the perforating industry' s 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, the equivalent yield strength of the perforated 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 ratios for the particular penetration pattern of interest, it is therefore easy for the designer to determine what thickness of perforated material will provide strength equal to that of the 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.



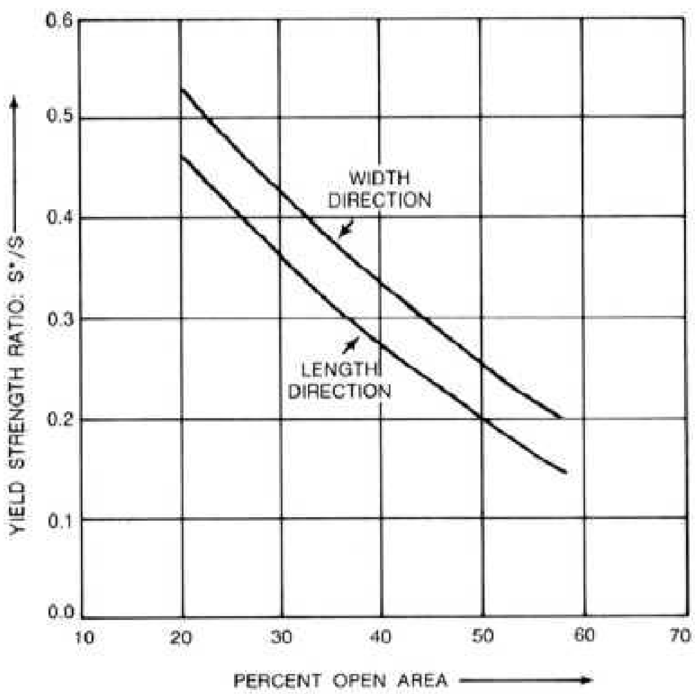
Strength of materials perforated with round holes in a standard staggered pattern:

IPA #	Perforations	Centers	Holes Per sq.in.	Open Area	S*/S= Strength[1] 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

[1]Notes: S* = Yield strength of perforated material
S* = Yield strength of unperforated material

Length Direction = parallel to straight row of closely spaced holes (see Fig. 1)

Width Direction = direction of stagger



Elastic Properties of Perforated Metals (Stiffness)

This material was developed for the I.P.A.
by O' Donnell & Associates, Inc.

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" triangular penetration pattern. 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" triangular pattern ranging from .020" to 1", 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 #	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%	.395
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

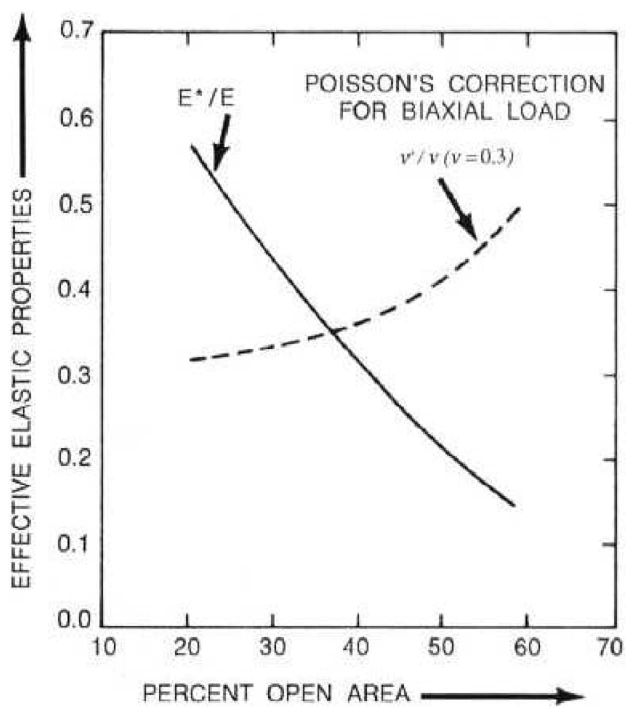


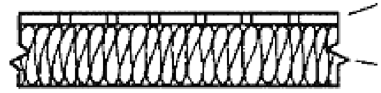
Figure 4: Effective Elastic Modulus, E*, and Poisson’s Ratio, v*, vs. Percent Open Area

How Perforated Metals Are Used in Acoustical Applications

There are two principal acoustical applications for perforated metals:

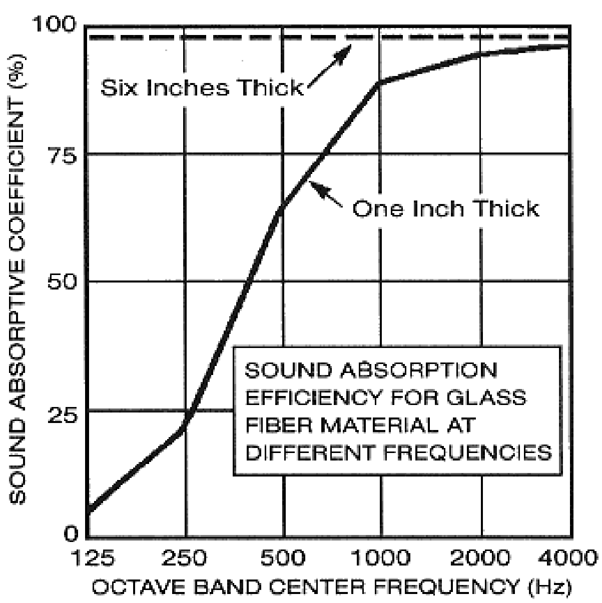
1. As a facing for something else
2. In a Tuned Resonant Absorber

1. As a Facing for Something Else

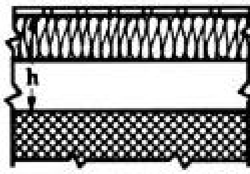


Here the perforated metal is used as a protective or decorative covering for some special acoustical material; that material may be designed either to absorb sound or to reflect or scatter sound in a special way. So, the purpose of the perforated metal in such applications is to be so "transparent" that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

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 absorbing sound at high frequencies above 2,000 Hz but very inefficient 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.



2. 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.

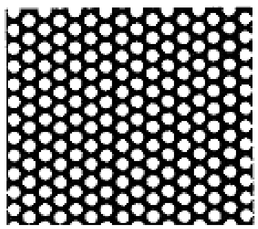
As a component of a resonant sound absorbing system, perforated metals provide unique capabilities. **A comprehensive guide to the theory and calculations for determining perforated metal specifications for both *transparent covers* and *resonant sound absorbing* systems is offered by the IPA in a book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

Summary of Tests Conducted by the Riverbank Acoustical Laboratories

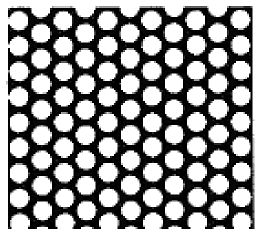
These tests were sponsored by the IPA to validate data developed by Theodore J. Schultz, Ph.D. and presented in his book ACOUSTICAL USES FOR PERFORATED METALS published by the Industrial Perforators Association. The perforation patterns tested are shown below.

The test's objectives were:

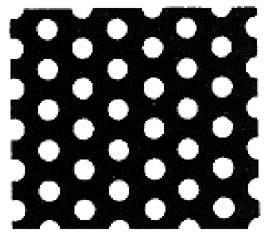
a. Determine which perforated metal specifications would provide a high degree of sound transparency.
b. Demonstrate the theories regarding Tuned Resonant Absorbers set forth by Dr. Schultz.



IPA#107: 48% Open Area



IPA#112: 37% Open Area



IPA#115: 23% Open Area

Wide Range of Perforations Provide High Transparency

Test 1. compared the sound absorption performance of a bare, unprotected 4" blanket of glass fiber with the same material protected by perforated metal sheets of the specifications shown above.

Results showed that there was no diminishment of the glass fiber blanket's absorption performance by the presence of any of the perforated metal sheets. Each of the perforated-protected tests followed very closely the performance of the bare blanket at all frequency levels.

Test 2. focused on the use of IPA pattern #115, the pattern with the least Open Area (23%) in conjunction with 4 different sound-absorbing materials. Again, the results demonstrated a high degree of transparency for the #115 material. The differences between the sound absorbing performances of the various materials were small at their greatest divergences and the presence of the perforated metal had no effect on their performances.

Place Sound Absorbent Material Against the Perforated Metal for Maximum Transparency and Absorbency

Tests 3, 4 and 5 employed #115 test samples mounted over a frame having a rigid back into which glass fiber blankets of varying thicknesses were placed. In some tests the sound-absorbing blanket was placed against the perforated sheet with or without airspace behind it. In others the blanket was placed against the back leaving an airspace between the face of the blanket and the perforated sheet.

The tests clearly demonstrated:

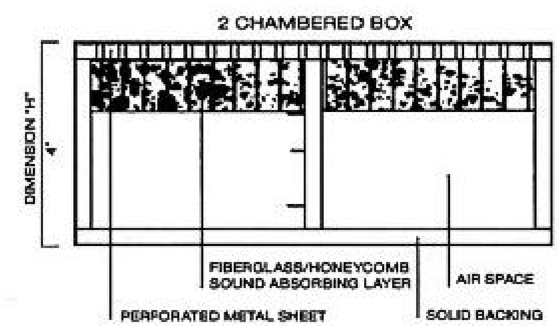
1. As a general rule, the thicker the absorbing blanket, the greater the sound absorbency. But, the thickness of the absorbing blanket showed its greatest effect below 500 Hz with the effect increasing towards the lower frequencies.
2. Placement of the absorbent blanket against the perforated metal with an airspace behind it does not diminish sound absorbency. On the other hand, the airspace behind does not contribute to sound absorbency.
3. Placement of the sound absorbent blanket away from the perforated metal-leaving an airspace between noticeably reduced sound absorbency. To achieve maximum transparency of the perforated metal sheet and the greatest sound absorbing efficiency requires that the absorbent material be placed against the perforated sheet.

Test 6 demonstrated that when a polyethylene film was placed as a protective cover between the absorbent blanket and the perforated sheet, there was a substantial loss in absorbency at frequencies above 500 Hz and the loss increased as frequencies went up. Below 500 Hz, the absorbency loss was negligible. Loss also increased with the thickness of the polyethylene film.

Dr. Schultz's Calculations Relating to Tuned Resonant Absorbers were Clearly Demonstrated

(Refer to explanations of Tuned Resonant Absorber on page 17.)

Riverbank's test device comprised the basic elements of a tuned Resonant Absorber with the notable exception that the perforated metal sheet was backed by a layer of aluminum honeycomb with 1" cells.



For the tests, glass fiber was pressed into the cells to varying thicknesses from 1" to 4". This assembly was placed at the top of a box which was 4" deep from the underside of the perforated sheet to the bottom of the box.

Dr. Schultz explained the need for this design:

"When the airspace is continuous, the behavior of the absorber changes greatly at different angles of incidence of the sound. As the sound direction changes from perpendicular to the surface of the absorber (angle of incidence = 0) to the grazing incidence of 90, the resonance frequency changes drastically, rising away from the intended frequency to as much as three octaves higher."

"By contrast, with the partitioned backstructure, not only does the resonance frequency remain the same as the angle of incidence increases, but the bandwidth of high sound absorption actually becomes broader."

The chart on page 22 illustrates a test which used an aluminumsheet.080" thick perforated with 1/8" (.125") holes on 2 1/4" straight row centers providing an unusually small percentage of open area, .2437%. The target frequency was a low 125 Hz. Clearly the Tuned Resonant Absorber performed as expected with a Sound-Absorbing Coefficient of 1.0, very close to 100% efficiency.

Calculating the Resonance Frequency of a Tuned Resonant Absorber (TRA)

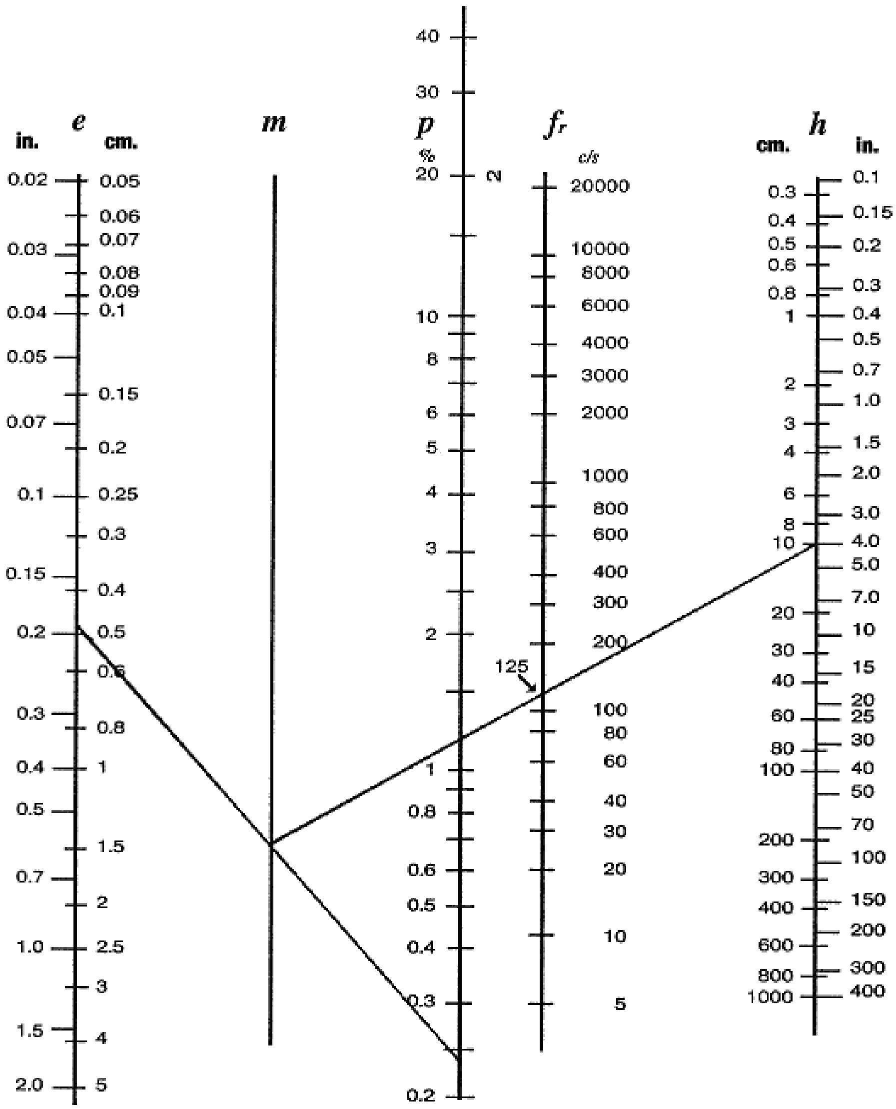
To determine the resonance frequency of the TRA used in the test discussed above, Dr. Schultz's nomogram for doing so is shown on the next page. The elements of the TRA are as follows:

t   thickness of the sheet = **.080"**
e = the effective throat length of the holes in the sheet, (e = t + .8d) = .080 + .125 x .8) = **.l8"**
h = distance from the perforated sheet to the back of TRA = **4"**
P = Percentage of open area = **.2437%**

Using a ruler, connect the point .18 on the "e" scale with the point .2437 on the P scale. Now place your ruler on the point where this line crosses the M line and draw a line to the 4" position on the "h" scale. Where this line crosses the "f" scale, you'll find the target frequency that should be most highly attenuated by this Tuned Resonant Absorber. The target frequency for this TRA has been determined to be 125 Hz.

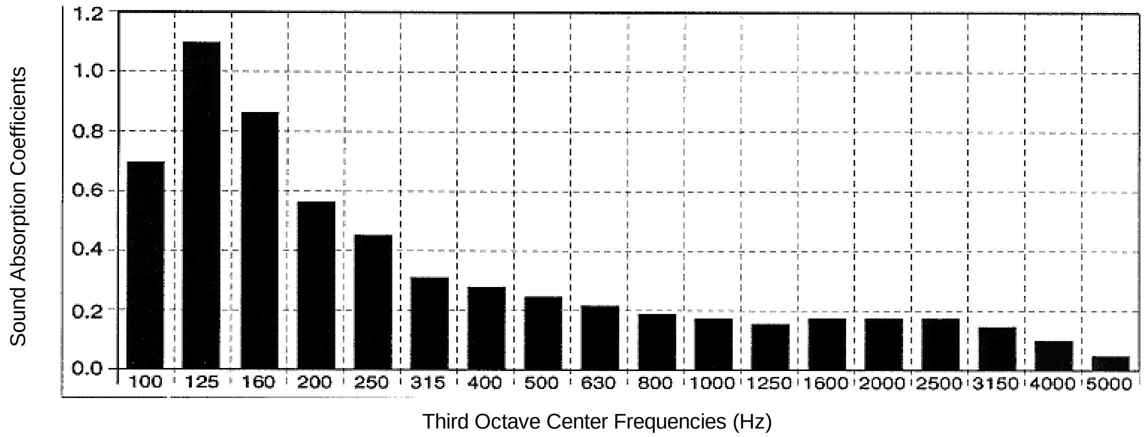
You can use this nomograph to solve for any missing component of a TRA you are designing. Clean copies of this nomogram are found in the Appendix of Dr. Schultz's book, ACOUSTICAL USES FOR PERFORATED METALS, available from the I.P.A. or ask your I.P.A. perforator to secure one for you. It can be reproduced on any copying machine.

Nomogram 1



Nomogram for Calculating the Resonance Frequency of a Tuned Resonant Sound Absorber.

Riverbank Test for Target Frequency of 125 Hz absorption through .080 aluminum with 1/8" Holes .2437 Open Area



E.M.I Shielding Effectiveness of Perforated Metals

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 l.P.A. contracted with Intertek Testing Services, 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 l.P.A.

The test results show that a Shielding Effectiveness of 40 dB provides 99.000% attenuation of the electro-magnetic (EMI/RFI) radiation while a Shielding Effectiveness of 92 dB, the highest Shielding Effectiveness found in the tests, provides 99.997% attenuation. 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 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.

E.M.I Shielding Effectiveness of Perforated Metals (continued)

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

E.M.I Shielding Effectiveness of Perforated Metals (continued)

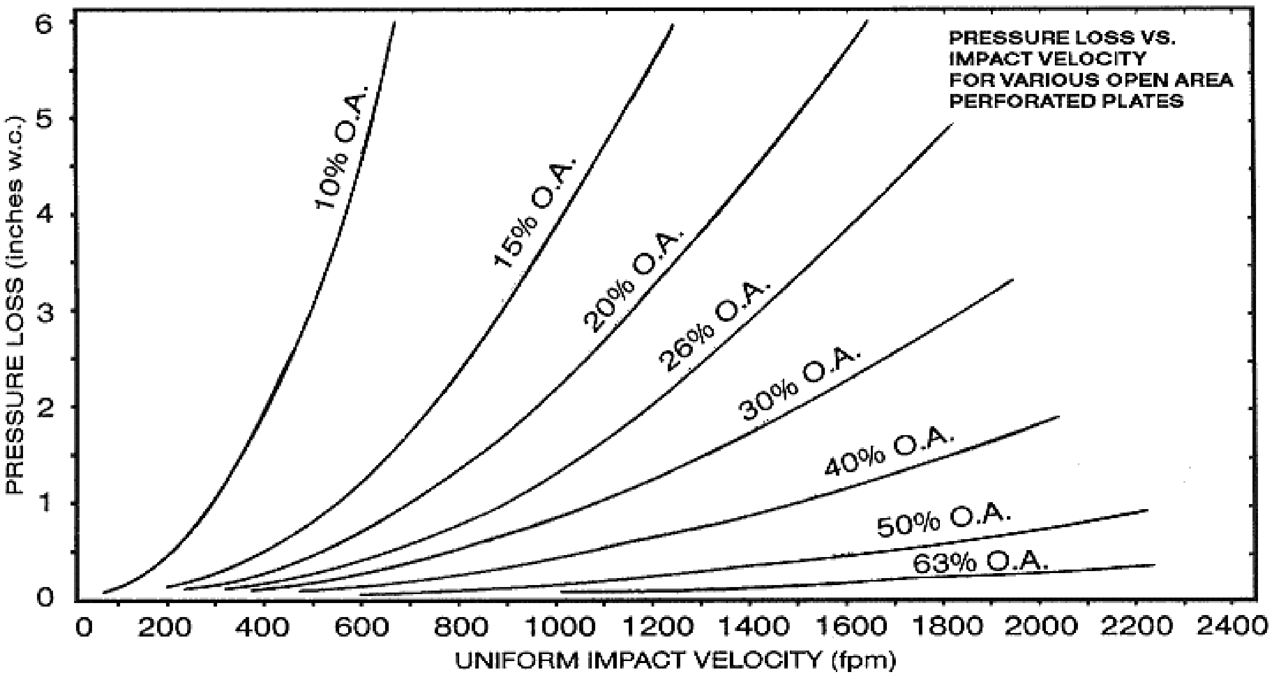
Hole Dia.	60° Center Spacing	% Open Area	Thick	Mat'l	Shielding Effectiveness- % Attenuation									
					Sample Size	30MHz	100MHz	300MHz	1GHz	2GHz	4GHz	6GHz	8GHz	10GHz
.040	.055	48.00	.022	Alum.	8" x 8"	99.97	99.97	99.99	99.84	99.82	99.60	99.86	98.22	99.60
.062	.093	40.00	.027	C.R. Steel	24" x 24"	99.91	99.96	99.95	99.84	99.44	99.60	99.50	99.37	97.76
.062	.125	23.00	.025	Alum.	8" x 8"	100.00	99.99	99.97	99.96	99.94	99.90	99.96	98.22	99.44
.072	.100	47.00	.038	C.R. Steel	8" x 8"	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. Steel	8" x 8"	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. Steel	24" x 24"	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. Steel	8" x 8"	99.90	99.94	100.00	99.95	99.90	99.84	99.92	97.76	99.00
.100	.187	25.90	.040	Alum.	8" x 8"	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" x 24"	99.87	99.92	99.86	99.65	99.00	98.59	98.01	97.18	94.99
.125	.187	40.30	.030	Alum.	24" x 24"	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" x 24"	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" x 24"	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. Steel	24" x 24"	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. Steel	24" x 24"	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. Steel	24" x 24"	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. Steel	24" x 24"	99.82	99.84	99.82	99.50	99.42	97.76	96.84	95.53	93.69

Pressure Loss Through Perforated Plate (Air)

In many applications of perforated plate, 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 air 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 air flow stream. Pressure loss for ambient air flow was then measured at a series of velocities and reported as inches of water column loss for each flow. This data, therefore, presents the best flow condition value of 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 actual 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 plate surface.

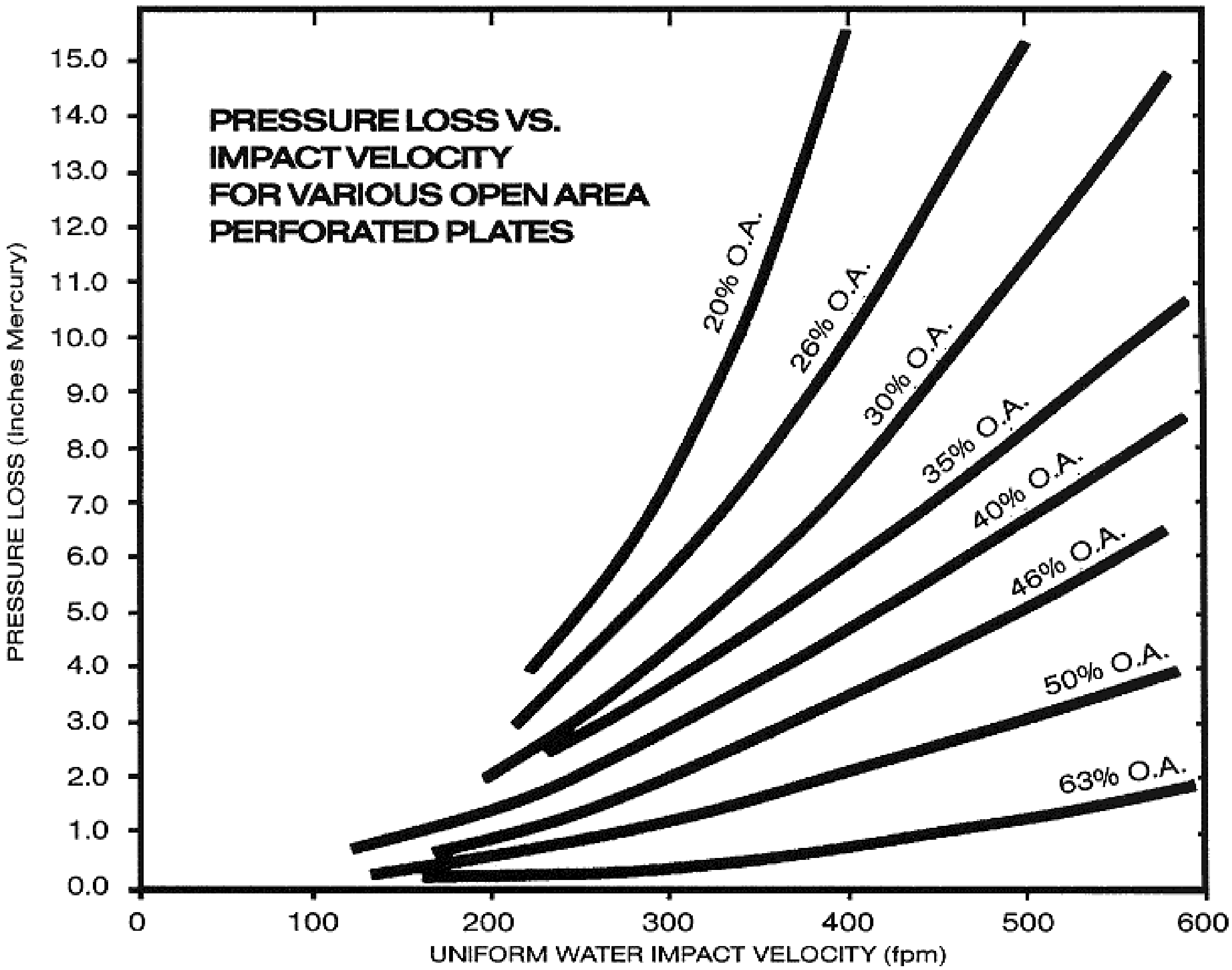

PRESSURE LOSS VS.
IMPACT VELOCITY
FOR VARIOUS OPEN AREA
PERFORATED PLATES
10% O.A.
15% O.A.
20% O.A.
26% O.A.
30% O.A.
40% O.A.
50% O.A.
63% O.A.
PRESSURE LOSS (inches w.c.)
0
1
2
3
4
5
6
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400
UNIFORM IMPACT VELOCITY (fpm)

Pressure Loss Through Perforated Plate (Fluid)

In many applications of perforated plate, 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 loss.

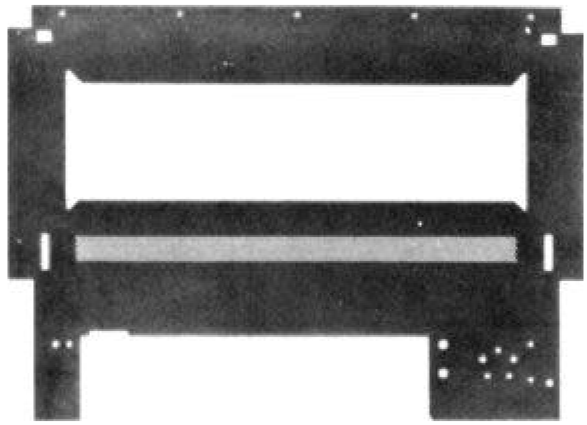
Pressure loss can be estimated beyond the range of the data on the basis of the ratio of the anticipated velocity to the highest tabulated velocity. This ratio squared multiplied by the tabulated pressure loss can be used to approximate the higher velocity loss. Pressure loss can be estimated from the 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 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 plate surface.



BOYLE ENGINEERING ABORATORIES
FEBRUARY 1985

Good Reasons for Calling in Your Perforating Specialist



Apart like 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 a 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 changes, 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 will make those holes 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 work piece 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 lay out 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 Ibs. 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 over 3". 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 remove the distortions, burrs and oil that the perforating process leaves behind. And, most perforators can do the secondary operations that will finish your part 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
- he set-up changes on your turret press
- The production cycle of your press
- Machining time
- Roller-leveling, de-burring 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."

When Choosing Between Perforated Metal, Expanded Metal or Wire Cloth, There Is More than 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 be considered.

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. But, you may be surprised at some of the less obvious capabilities of perforated metal. It's 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

Exhibit 1

	Perforated Metal	Expanded 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 I SORTING			
Control of flow rate	Y	Y	Y
Control of particle size contained	Y	Y	Y
AESTHETICS:			
Control of design	Y	N	N
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.	N	Y	Y

Material costs do not tell the whole story

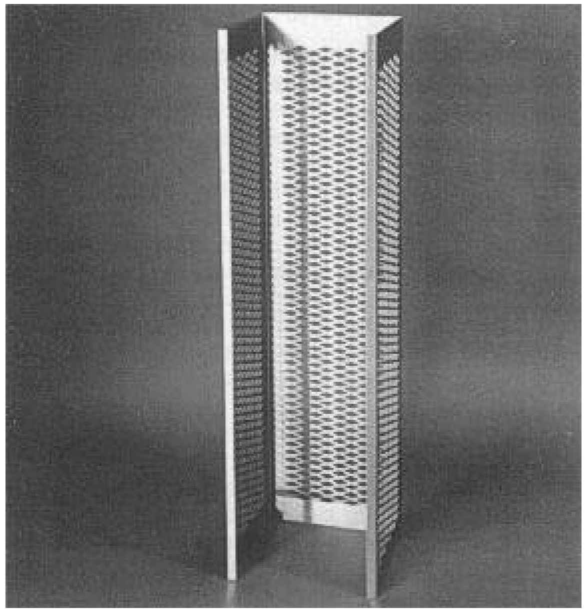
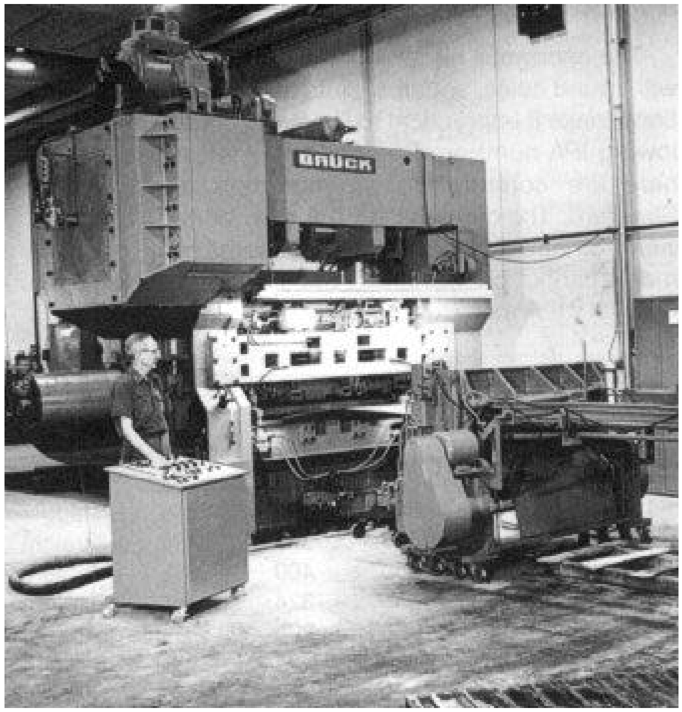
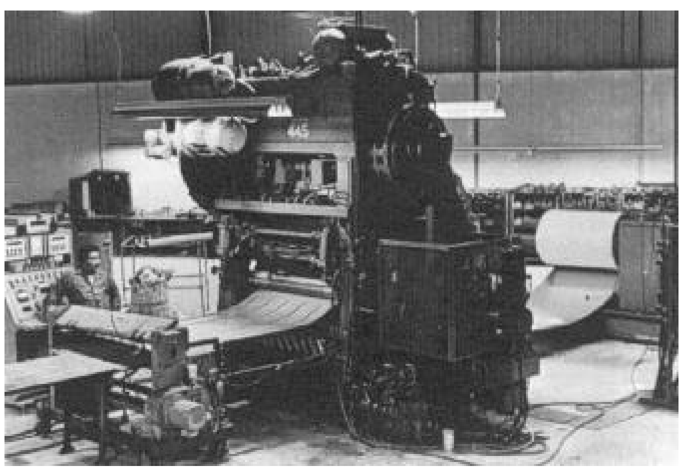


Exhibit 2

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 choices.


BRÜCK



IPA Standard Perforations

The enormous number of perforating patterns possible with round holes, squares, slots and other special perforations make it impractical to list every combination. The following IPA numbered perforations listed and illustrated here are common to all members and considered Standard. The die banks of IPA members hold tooling for literally thousands of additional patterns so, if your requirements cannot be met with a Standard perforation, consult with your IPA members supplier.

Round Holes:

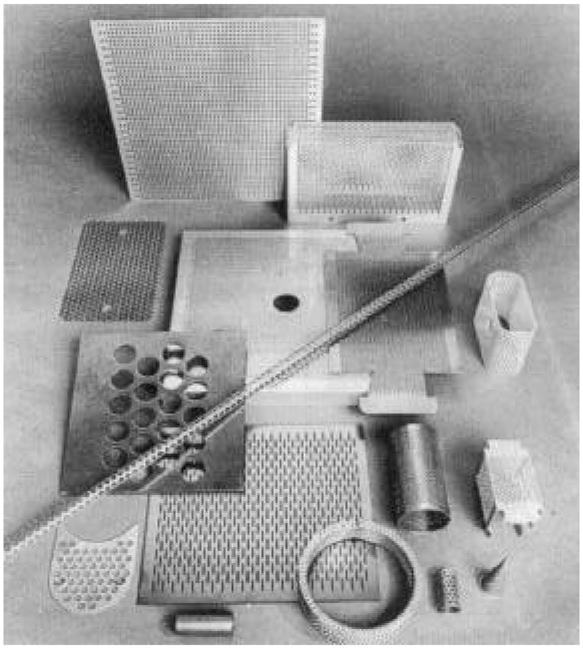
IPA Numbers	Perforations	Centers	Holes per sq. in.	Open Area	Line
100	.020”	.043”	625	20%	Staggered
101	.023”	.0415”	576	24%	Straight
102	.027”	.050”	400	23%	Straight
103	.032”	.055”	324	26%	Straight
104	.040”	.066”	335	30%	Straight
105	.045”	.066”	334	37%	Straight
106	1/16”	1/8”	74	23%	Staggered
107	5/64”	7/64”	97	46%	Staggered
108	5/64”	1/8”	74	36%	Staggered
109	3/32”	5/32”	47	32%	Staggered
110	3/32”	3/16”	33	23%	Staggered
111	3/32”	¼”	19	12%	Staggered
112	1/10”	5/32”	47	36%	Staggered
113	1/8”	3/16”	33	40%	Staggered
114	1/8”	7/32”	24	29%	Staggered
115	1/8”	¼”	19	23%	Staggered
116	5/32”	7/32”	24	46%	Staggered
117	5/32”	¼”	19	36%	Staggered
118	3/16”	¼”	19	51%	Staggered
119	3/16”	5/16”	12	33%	Staggered
120	¼”	5/16”	12	58%	Staggered
121	¼”	3/8”	8	40%	Staggered
122	¼”	7/16”	6	30%	Staggered
123	¼”	½”	5	23%	Staggered
124	3/8”	½”	5	51%	Staggered
125	3/8”	9/16”	4	40%	Staggered
126	3/8”	5/8”	3	33%	Staggered
127	7/16”	5/8”	3	45%	Staggered
128	½”	11/16”	2	47%	Staggered
129	9/16”	¾”	2	51%	Staggered
130	5/8”	13/16”	2	53%	Staggered
131	3/4”	1”	1	51%	Staggered

Squares:

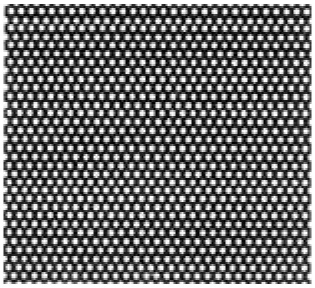
IPA Numbers	Perforations	Centers	Holes per sq. in.	Open Area	Line
200	2/10"	¼"	20	64%	Straight
201	¼"	3/8"	9	44%	Straight
202	3/8"	½"	5	56%	Straight
103	½"	11/16"	3	53%	Straight
204	¾"	1"	1	56%	Straight
205	1"	1 ¼"	.8	64%	Straight
206	1"	1 3/8"	.7	53%	Straight

Slots:

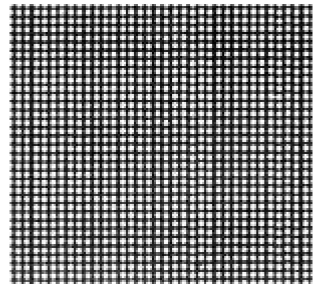
IPA Numbers	Perforations	Bars	Holes per sq. in.	Open Area	Line
207	¼" x ¾"	1/8"		41%	Side Staggered
208	1/8" x 1"	1/8"		43%	Side Staggered



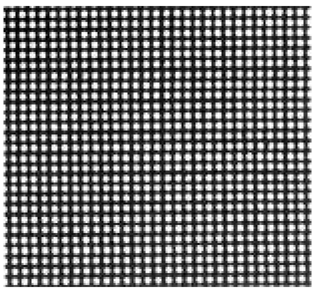
Round Holes



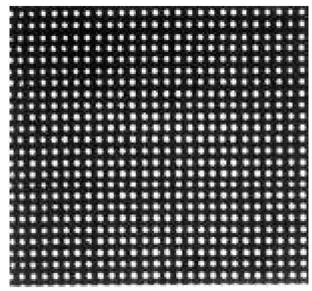
No. 100, .020” diam. 20% O.A.



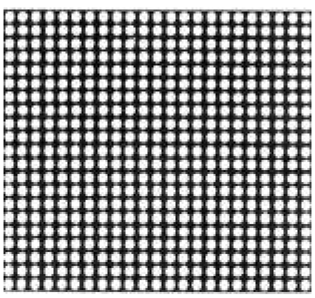
No.101, .023” diam. 23% O.A.



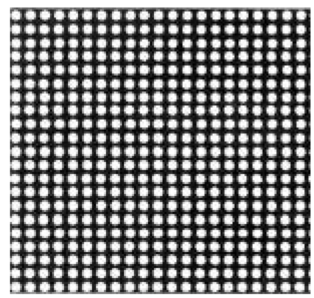
No. 102, .027” diam. 23% O.A.



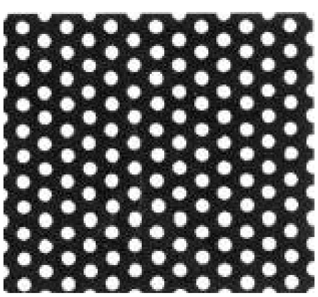
No. 103, .032” diam. 26% O.A.



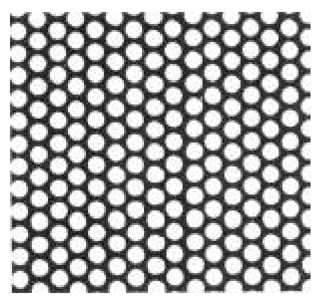
No. 104, .040” diam. 30% O.A.



No. 105, .045” diam. 37% O.A.

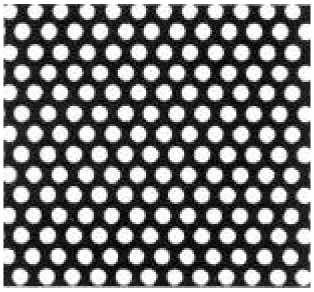


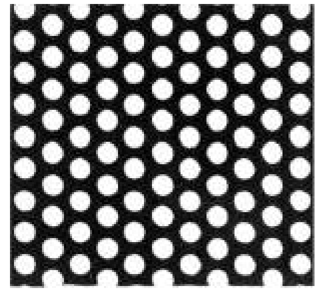
No. 106, 1/16” diam. 23% O.A.

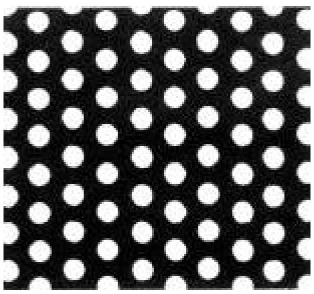


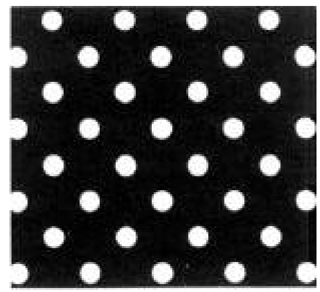
No. 107, 5/64“ diam. 12% O.A.

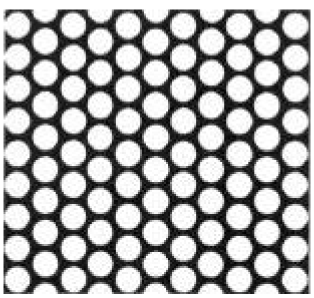
Round Holes Continued

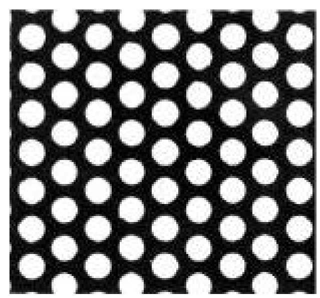

No.108, 3/32” diam 36% O.A.

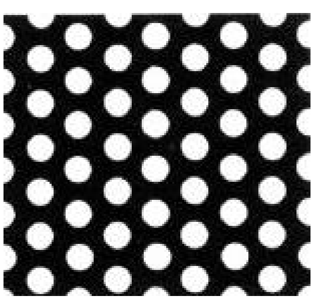

No. 109, 3/32” diam 32% O.A.

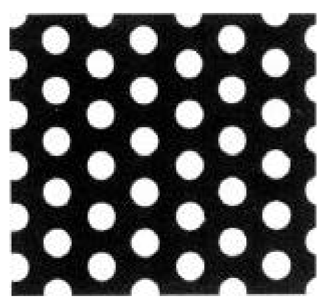

No. 110, 3/32” diam. 23% O.A.


No. 111, 3/32” diam 12% O.A.

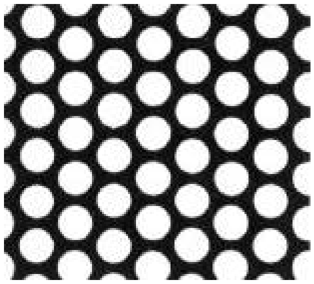

No. 112, 1/10” diam. 36% O.A.


No. 113, 1/8” diam. 40% O.A.

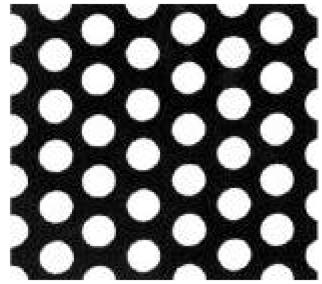

No. 114, 1/8” diam. 29% O.A.


No. 115, 1/8” diam. 23% O.A.

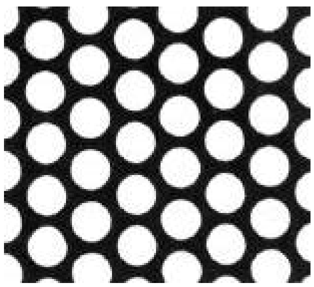
Round Holes Continued



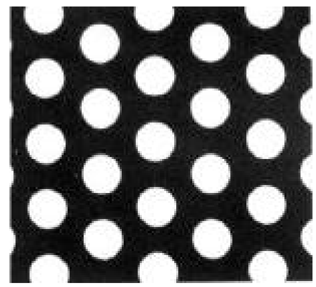
No. 116, 3/32” diam. 46% O.A.



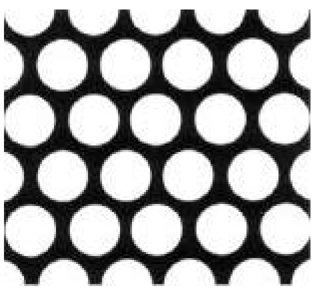
No.117, 3/32” diam. 36% O.A.



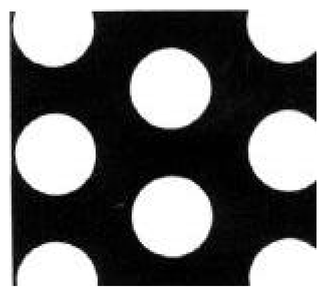
No. 116, 3/16” diam. 51% O.A.



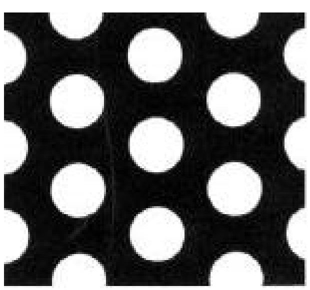
No. 119, 3/16” diam. 33% O.A.



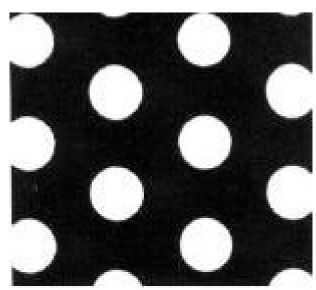
No. 120,. ¼” diam. 58% O.A.



No. 121, ¼” diam. 40% O.A.

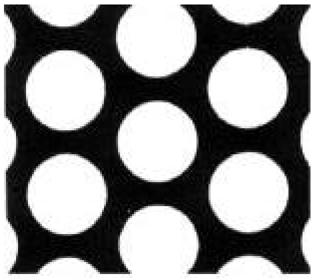


No. 122, ¼” diam. 30% O.A.

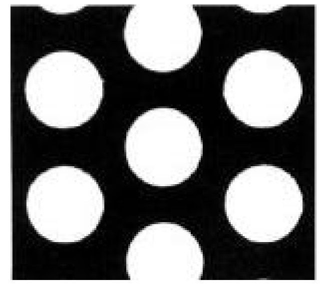


No. 123, ¼” diam. 23” O.A.

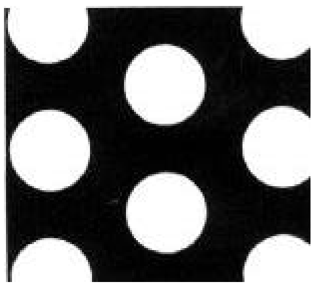
Round Holes Continued



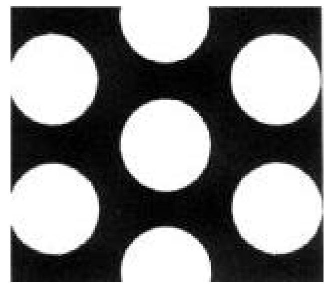
No. 124, 3/8” diam. 51% O.A.



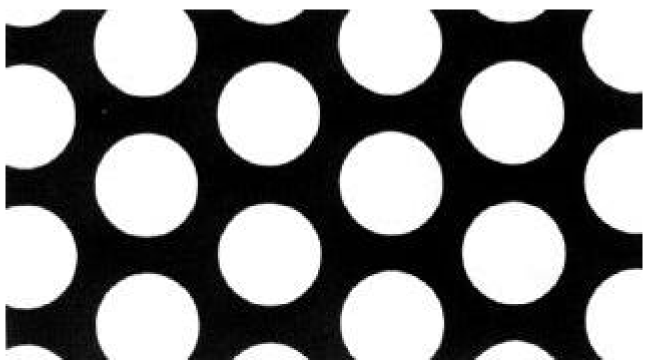
No. 125, 3/8” diam. 40% O.A.



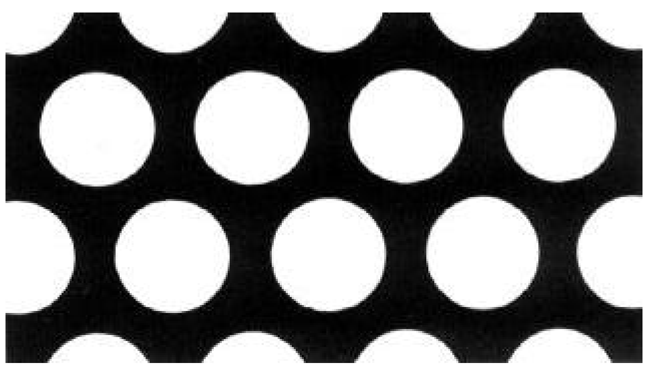
No. 126, 3/8” diam. 33% O.A.



No. 127, 7/16” diam. 45% O.A.

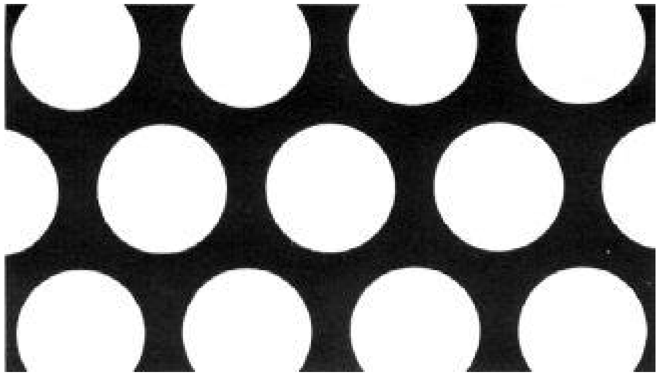


No. 128, ½” diam. 47% O.A.

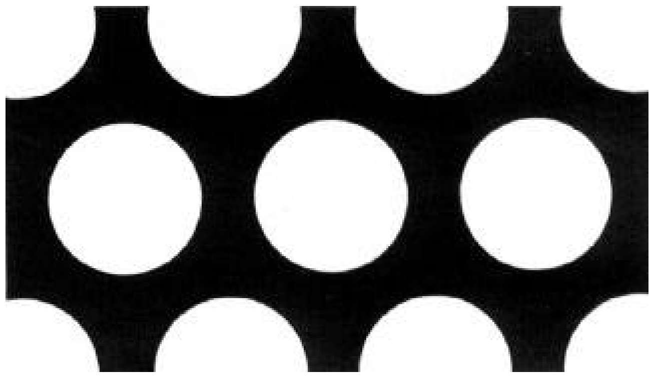


No. 129, 7/16” diam. 51% O.A.

Round Holes Continued

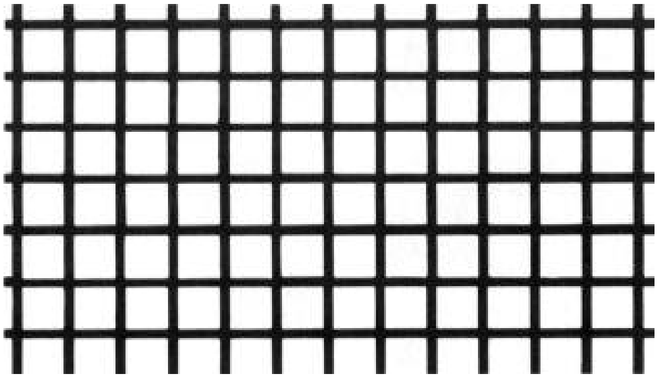


No. 130, 4/5” diam. 53% O.A.

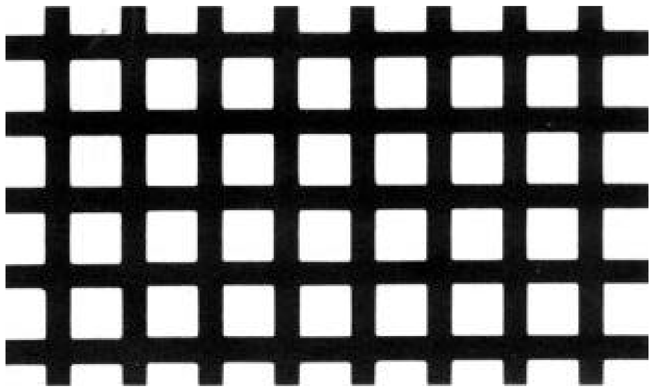


No. 131, ¾” diam. 51% O.A.

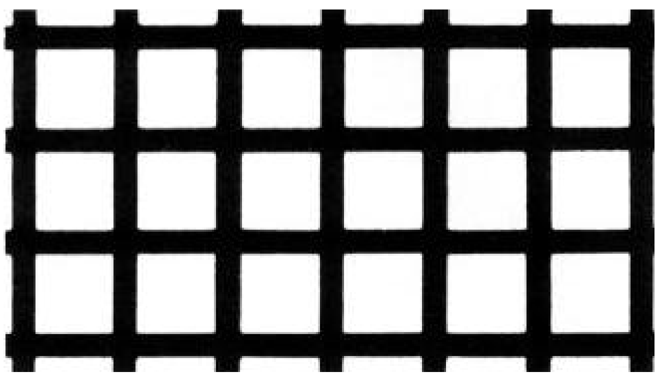
Square Holes



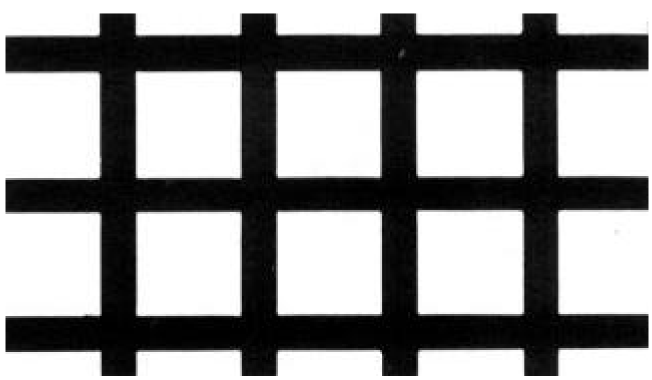
No. 200, 2/19” opening 64% O.A.



No. 201, ¼” opening 44% O.A.

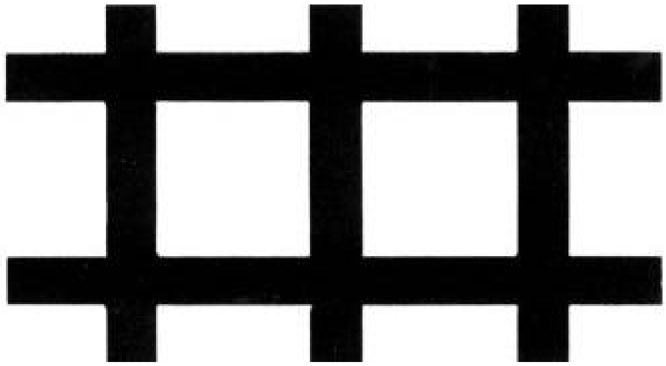


No. 202, 3/8” opening 56% O.A.

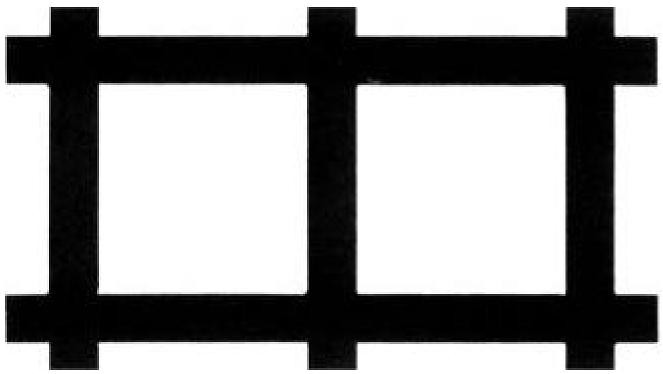


No. 203, ½” opening. 53% O.A.

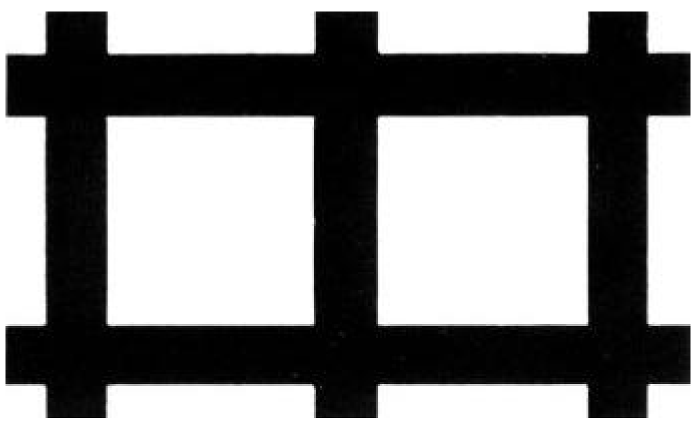
Square Holes Continued



No. 204, ¾” opening 56% O.A.

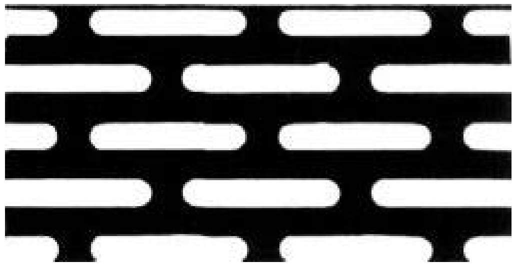


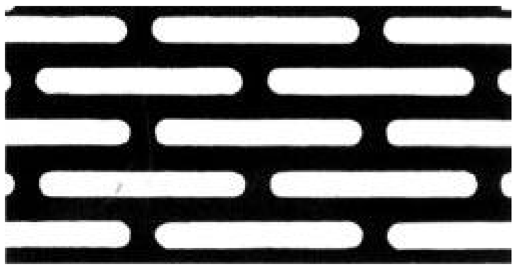
No. 205, 1” opening 64% O.A.



No. 206, 1” opening 53% O.A.

Slotted Holes

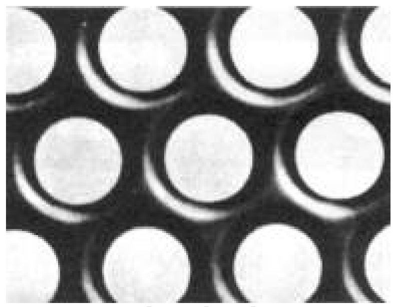

No 207, 1/8” x ¾” opening 41% O.A.

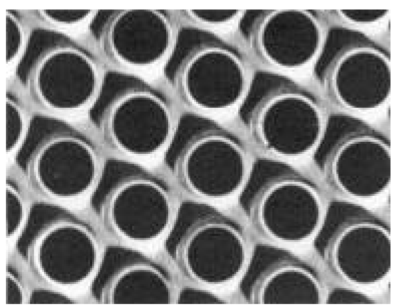

No. 208, 1/8” x 1” opening 43% O.A.

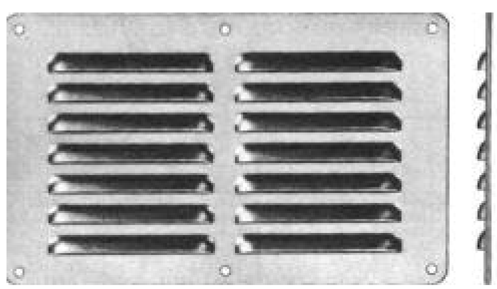
Other Popular Holes, Non-Standard

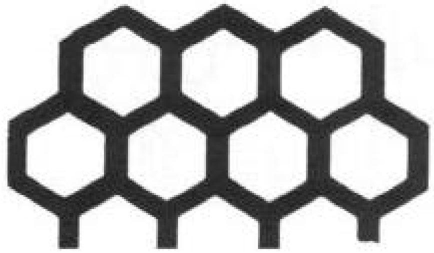
Though they are not standards, a broad assortment of hole shapes and patterns are offered by IPA members to meet special requirements. When non-standard hole shapes and patterns are needed, you should consult with your IPA member supplier. Always bear in mind that IPA members are equipped with tool design and tool-making facilities to produce whatever practical hole shapes, sizes and patterns your application requires. New tools are being added to IPA member die banks every day. Illustrated here are some of the most commonly used non-standard hole shapes.

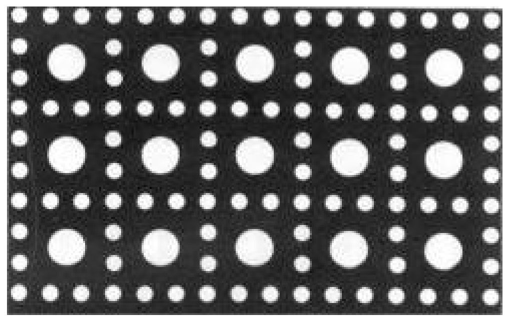
A list of IPA Standard Round and Standard hole patterns and popular non-standard patterns are available from many member companies begins on page 36.

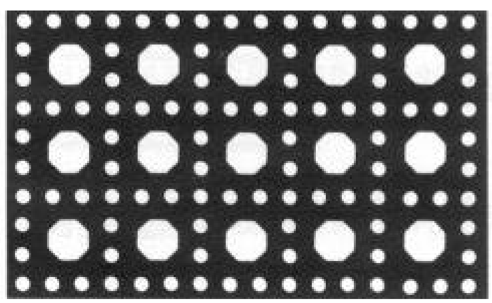

Indented Holes

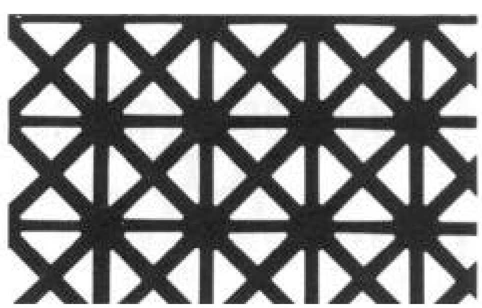

Collared Holes


Louvered Holes


Hexagonal Holes


Round Cane


Octagonal Cane


Grecian

Hexagonal Perforations – Staggered Centers

Perforation Size Inches	Perforation Size Decimal Equivalent	Staggered Centers 60° Inches	Staggered Centers 60° Decimal Equivalent	Bar Width	Approx. % Open Area	Max. Material Thickness
9/32	.2812	13/32	.4062	.1250	47.91	8 ga.
11/32	.3437	15/32	.4687	.1250	53.77	10 ga.
13/32	.4062	35/64	.5469	.1406	55.17	10 ga.
7/16	.4375	19/32	.5937	.1562	54.30	3/16
7/16	.4375	¾	.7500	.3125	33.40	5/16
15/32	.4687	5/8	.8250	.1562	56.23	8 ga.
½	.5000	11/16	.6875	.1875	52.88	¼
9/16	.5625	¾	.7500	.1875	56.25	¼
9/16	.5625	13/16	.8125	.2500	48.00	¼
5/8	.6250	13/16	.8125	.1875	59.16	¼
11/16	.6875	7/8	.8750	.1875	51.73	¼
13/16	.8125	1	1.0000	.1875	56.01	3/16
13/16	.8125	1 1/16	1.0625	.2500	58.47	¼
15/16	.9375	1 3/16	1.1875	.2500	62.31	¼
15/16	.9375	1 5/16	1.3125	.3750	51.02	3/8
1	1.0000	1 ¼	1.2500	.2500	64.00	5/16
1 1/8	1.1250	1 13/32	1.4062	.2612	64.00	3/8
1 5/16	1.3125	1 9/16	1.5625	.2500	70.56	3/8
1 3/8	1.3750	1 ¾	1.7500	.3750	61.73	½
1 ½	1.5000	1 7/8	1.8750	.3750	64.00	3/8
1 5/8	1.6250	2	2.0000	.3750	66.01	½
1 7/8	1.8750	2 ¼	2.2500	.3750	69.43	3/8
1 15/16	1.9375	2 5/16	2.3125	.3750	70.19	3/8

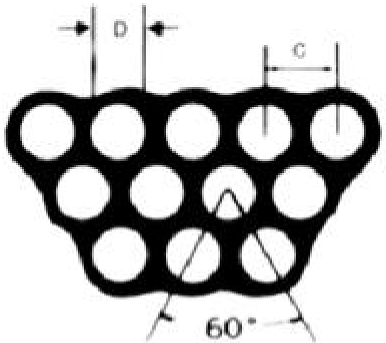
Hexagonal Perforations – Single Punch

(Staggered or straight pattern with any center distance for which bar width equals or exceeds material thickness.)

Perforation Size Inches	Perforation Size Decimal Equivalent	Max. Material Thickness
1 ¾	1.7500	¾
2	2.0000	¾
2 1/16	2.0625	3/8
2 1/8	2.1250	¾
2 3/16	2.1875	½
2 ¼	2.2500	½
2 5/16	2.3125	½
2 3/8	2.3750	¾
2 ½	2.5000	¾
2 ¾	2.7500	¾
2 7/8	2.8750	¾
3	3.0000	5/8
3 1/8	3.1250	5/8
3 1/4	3.2500	5/8
3 3/8	3.3750	¾
3 ½	3.5000	½
3 5/16	3.3125	½
3 9/16	3.5625	½
3 ¼	3.7500	3/8
3 7/8	3.8750	5/8
4 3/8	4.3750	5/8

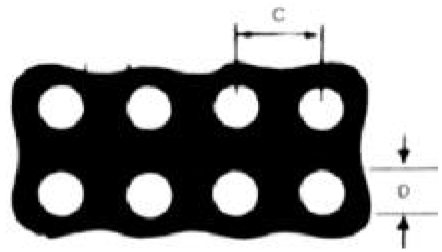
Formulas for Determining Percentage of Open Areas

Staggered Round Holes



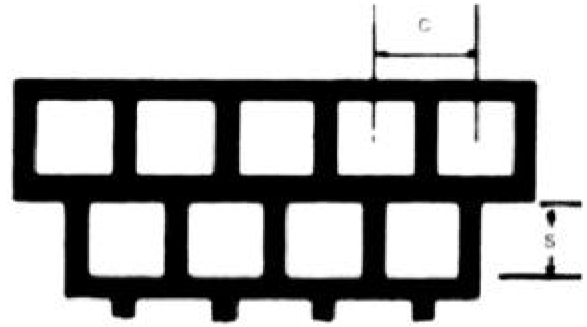
$$\frac{D^2 \times 90.69}{C^2} = \%$$

Straight Round Holes



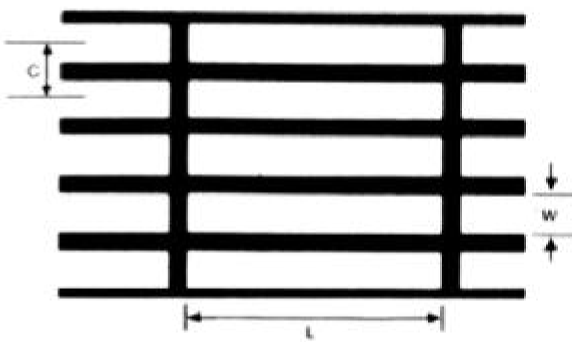
$$\frac{D^2 \times 78.54}{C^2} = \%$$

Squared Holes (Straight or Staggered)



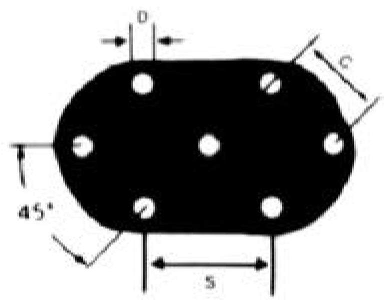
$$\frac{S^2 \times 100}{C^2} = \%$$

*Square End Slot



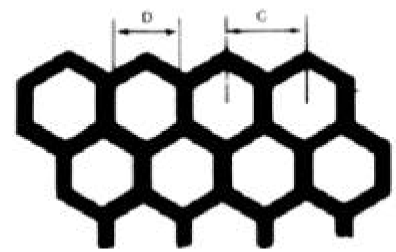
$$\frac{L \times W}{C^2} \times 100 = \%$$

45° Staggered Centers Pattern (Special)



$$\frac{157.08\ D^2}{S^2} = \%$$

Hexagon



$$\frac{100 \times D^2}{C^2} = \%$$

To Find the Holes Per Square Inch:

$$\text{H.P.S.I.} = \frac{\%\ \text{Open Area}}{78.54 \times D^2}$$

Checklist of Perforating Cost Influences

1. **Material type** – Remember the least expensive material may not be the lowest cost; a higher strength alloy may allow reducing thickness. Keep hardness below80 Rb.
2. **Material thickness** – Thinner materials perforate easier and faster.
3. **Hole shape and pattern** – Round holes are the most economical, 60” staggered round hole pattern strongest and most versatile.
4. **Hole size** – Do not go below 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 longer center distance.
7. **Open areas** – Extreme open area proportions 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 metal 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. Accept normal commercial burrs unless otherwise specified.

Checklist for Ordering Perforated Metal Sheets & Plates

1. **Quantity** – State the number of Perforated Pieces required.
2. **Thickness –** Specify in gage numbers or in decimal inches.
3. **Metal –** State kind of metal required.
4. **Width & Length** – Unless otherwise specified, the length will be the long dimension of sheet.
5. **Perforation Size –** specify the size of perforation in inches.
6. **Perforation Shape –** See the various types shown on Pages 36-47.
7. **Arrangement of Perforations** – Specify "Staggered" or "Straight Line" or other patterns. Normally the straight row of a staggered pattern will run the long way of the sheet.
8. **Spacing of Perforations** – This can be specified as the distance between hole centers, the percent of Open Area or, in the case of small holes, as the number of holes per square inch.
9. **Margins** – If margins are not important, specify "minimum or no margins."
10. **Other information** – For slotted perforations-specify whether the long dimension of the slot is parallel to the long or short dimension of the sheet or plate.

Note: if ordering Perforated Screen Plates for Vibrating or Revolving Screening Equipment, ask your perforator for IPA bulletin #512.

Table of Gauges and Weights

Weights and Gauges have been computed subject to standard commercial tolerances.

	Steel		Galv. Steel		Long Terne		Stainless – USS Gauge			Monel	
	USS Gauge Rev.		USS Gauge		USS Gauge			lbs. Per sq. ft.		USS Gauge	
Gauge	Decimal	lbs. Per sq. ft.	Decimal Thick.	lbs. Per sq. ft.	Decimal Thick.	lbs. Per sq. ft.	Decimal Thick.	Chrome Alloy	Chrome Nickel	Decimal Thick.	lbs. Per sq. ft.
32	.0100		.0130	.563			.0100	.418	.427		
31	.0110		.0140	.594			.0109	.450	.459		
30	.0120	.500	.0157	.656	.012	.518	.0125	.515	.525		
29	.0135	.563	.0172	.719	.014	.581	.0140	.579	.591		
28	.0149	.625	.0187	.781	.015	.643	.0156	.643	.656		
27	.0164	.688	.0202	.844	.017	.706	.0171	.708	.721		
26	.0179	.750	.0217	.906	.018	.768	.0187	.772	.787	.0187	827.
25	.0209	.875	.0247	1.031	.021	.893	.0218	.901	.918	.0218	.965
24	.0239	1.000	.0276	1.156	.024	1.018	.0250	1.030	1.050	.0250	1.148
23	.0269	1.125	.0306	1.281	.027	1.143	.0281	1.158	1.181	.0281	1.286
22	.0299	1.250	.0336	1.406	.030	1.268	.0312	1.287	1.312	.0312	1.424
21	.0329	1.375	.0366	1.531	.033	1.393	.0343	1.416	1.443	.0343	1.562
20	.0359	1.500	.0396	1.656	.036	1.518	.0375	1.545	1.575	.0375	1.700
19	.0418	1.750	.0456	1.906	.042	1.768	.0437	1.802	1.837	.0437	1.975
18	.0478	2.000	.0516	2.156	.048	2.018	.0500	2.060	2.100	.0500	2.297
17	.0538	2.250	.0575	2.406	.054	2.268	.0562	2.317	2.362	.0562	2.572
16	.0598	2.500	.0635	2.656	.060	2.518	.0625	2.575	2.625	.0625	2.848
15	.0673	2.812	.0710	2.969	.068	2.831	.0703	2.896	2.953	.0703	3.216
14	.0747	3.125	.0785	3.281	.075	3.143	.0781	3.218	3.281	.0781	3.583
13	.0897	3.750	.0934	3.906	.090	3.768	.0937	3.862	3.937	.0937	4.272
12	.1046	4.375	.1084	4.531	.105	4.393	.1093	4.506	4.593	.1093	5.007
11	.1196	5.000	.1233	5.156	.120	5.018	.1250	5.150	5.250	.1250	5.742
10	.1345	5.625	.1382	5.781	.134	5.643	.1406	5.793	5.906	.1406	6.431
9	.1494	6.250	.1532	6.406	.		.1562	6.437	6.562	.1562	7.166
8	.1644	6.875	.1681	7.031	.		.1718	7.081	7.218	.1718	7.855
7	.1793	7.500	.				.1875	7.590	7.752	.1875	8.590

Table of Gauges and Weights (continued)

	Brass		Copper		Aluminum		Zinc		Monel		
	B&S Gauge.		B.W. Gauge		B&S Gauge		Zinc Gauge		USS Gauge		
Gauge	Decimal	lbs. Per sq. ft.	Decimal Thick.	lbs. Per sq. ft.	Decimal Thick.	lbs. Per sq. ft.	Decimal Thick.	lbs. Per sq. ft.	Decimal Thick.	lbs. Per sq. ft.	Old Symbol
32	.0080	.353	.009	.418	.008	.115			.0061”	55	
31	.0089	.392	.010	.464	.009	.130			.0066”	60	
30	.0100	.441	.012	.557	.010	.144			.0072”	65	
29	.0113	.498	.013	.603	.011	.158			.0077”	70	
									.0083”	75	
28	.0126	.555	.014	.650	.012	.173			.0088”	80	
27	.0142	.626	.016	.742	.014	.202			.0094”	85	
26	.0159	.700	.018	.835	.016	.230			.0099”	90	
25	.0179	.789	.020	.928	.018	.259			.0105”	95	
									.0110”	100	ICL
24	.0201	.886	.022	1.022	.020	.286	.125	4.70	.0118”	107	IC
23	.0226	.996	.025	1.162	.022	.331	.100	3.75	.0123”	112	
22	.0254	1.115	.028	1.302	.025	.360	.090	3.37	.0130”	118	
21	.0285	1.256	.032	1.484	.028	.403	.080	3.00	.0141”	128	IXL
20	.0320	1.410	.035	1.627	.032	.461	.070	2.62	.0149”	135	1X
19	.0359	1.582	.042	1.952	.036	.518	.060	2.25	.0153”	139	DC
18	.0403	1.776	.049	2.280	.040	.576	.055	2.06	.0163”	148	2XL
17	.0453	1.996	.058	2.695	.045	.648	.050	1.87	.0171”	155	2X
16	.0508	2.238	.065	3.020	.050	.734	.045	1.68	.0185”	168	3XL
15	.0571	2.516	.072	3.338	.056	.821	.040	1.50	.0193”	175	3X
14	.0641	2.825	.083	3.860	.063	.992	.036	1.35	.0198”	180	DX
13	.0720	3.173	.095	4.410	.071	1.040	.032	1.20	.0207”	188	4XL
12	.0808	3.560	.109	5.065	.080	1.170	.023	1.05	.0215”	195	4X
11	.0907	3.997	.120	5.575	.090	1.310	.024	.90	.0229”	208	5XL
10	.10195	4.490	.134	6.225	.100	1.470	.020	.75	.0231”	210	D2X
9	.1144	5.041	.148	6.875	.112	1.640	.018	.67	.0237”	215	5X
8	.1285	5.662	.165	7.660	..125	1.760	.016	.60	.0251”	228	6XL
7	.1443	6.358	.180	8.360	.140	1.980	.014	.52	.0259”	235	6X
6	.1620	7.138	.203	9.420	.160	2.254	.012	.45	.0264”	240	D3X
5	.1819	8.015	.220	10.220	.190	2.685	.010	.37	.0273”	248	7XL

Selection Guide to Carbon Steel Sheets and Coils for Perforating Applications

TYPE	DESCRIPTION	RECOMMENDED SIZE					CAR BON CON TEN T	TYPICAL MECHANICAL PROPERTIES				APPROXIMATE RELATIVE COST (10 ga. H.R. Steel = 100)	
		SHEETS			COILS								
		T	W	L[1]	T	W		Tensile, PSI	Yield, PSI	% Elong. 2"	Hardnes s Rb.	SHEET S	COI LS
HOT ROLLED STEELS (see pages 54 to 56)													
COMMERCIAL QUALITY (SAE or AISI #1008; ASTM #A569	A low cost sheet steel with moderate drawing and forming qualities for use where finish is unimportant. For best perforating results specify PICKLED AND OILED for removal of oxides.	7 to 16 ga.	Up to 60"	Up to 144"	7 to 16 ga.	Up to 60"	.10 max.	45,000 to 60,000	30,000 to 40,000	28 to 38	55 to 70	100 Pickled and Oiled – 104	95 99
DRAWING QUALITY (SAE or AISI #1006; ASTM #A621	This quality is intended for use where forming requirements are too severe for Commercial Quality. Pickling and oiling to remove oxides is recommended. In-stock availability is not as great as Commercial Quality.	7 to 16 ga.	Up to 60"	Up to 144"	7 to 16 ga.	Up to 60"	.10 max.	45,000 to 60,000	30,000 to 40,000	28 to 38	55 to 70	103	98
HIGH-STRENGTH, LOW ALLOY* (USS Cor-Ten or equivalent; ASTM #A375)	Good formability because of low carbon content in combination with relatively high YIELD and TENSILE properties permit these steels to be used in lighter gauges to reduce weight in applications where strength is important. Readily weldable.	7 to 16 ga.	Up to 60"	Up to 144"	7 to 14 ga.	Up to 60"	.12 max.	70,000 min.	50,000 min.	22 min.	80 to 90	132	126
ABRASION RESISTING* (C .35-.50; Mn 1.50-2.00; P .050 max.; S .055 max.; Si .15-.35)	High manganese content in combination with intermediate carbon greatly enhances resistance to abrasion; can improve part life 2 to 10 times. Moderate formability.	7 to 16 ga.	Up to 60"	Up to 144"			.35 - .50	100,000 to 120,000	55,000 to 70,000	10 to 20	210 to 225 (Bhn.)	118	N.A.

Selection Guide to Carbon Steel Sheets and Coils for Perforating Applications (continued)

COLD ROLLED STEELS (see pages 57 to 59)													
COMMERCIAL QUALITY (SAE or AISI #1008; ASTM #A366)	Cold Rolled Steels have improved surface finishes and tighter size tolerances than Hot Rolled Steels. They are available in two classes: *Class 1* is intended for exposed applications; *Class 2* is for unexposed use. Three finishes can be specified: *Matte* is the standard finish. It is uniformly dull and suitable for painting. *Commercial Bright* finish is a relatively bright, intermediate finish. *Luster* finish is smooth and bright and most suitable for plating. Because perforating will alter surface appearance, surface preparation will alter surface appearance, surface preparation after perforating may be required before the application of the final finish.	7 to 28 ga.	Up to 60”	Up to 18 ft.	11 ga. To 28 ga.	Up to 60”	.10 max.	40,000 to 50,000	25,000 to 35,000	30 to 40	45 to 60	119 (16 ga.)	113
DRAWING QUALITY (ASTM #A619)	Recommended for use where forming requirements are too severe for Commercial Quality. Can be supplied (Class 1) free of fluting or stretcher straining when intended for use in a reasonably short time. Available in mill quantities.	7 to 28 ga.	Up to 60”	Up to 18 ft.	11 ga. To 28 ga.	Up to 60”	.10 max.	40,000 to 50,000	20,000 to 30,000	38 to 40	40 to 50	125 (16 ga.)	120
DRAWING QUALITY, SPECIAL KILLED (ASTM #A620)	This steel has special retarded aging characteristics and is recommended for use when the material must be free of surface disturbances without roller leveling immediately before using, and must be essentially free from significant changes in mechanical properties over an extended period of time. Available in mill order quantities.	7 to 28 ga.	Up to 60”	Up to 18 ft.	11 ga. To 18 ga.	Up to 60”	.10 max.	40,000 to 50,000	20,000 to 30,000	38 to 40	40 to 50	127 (16 ga.)	122
CORROSION RESISTANT STEELS (see pages 61 to 68)													
GALVANIZED (ASTM #525)	A versatile, low-cost, corrosion resistant steel with a zinc coating applied by a continuous hot-dip process. Available in Commercial, Drawing and other Qualities (refer to pages 61 to 64)	10 to 20 ga.	Up to 60”	Up to 18 ft.	12 to 28 ga.	Up to 60”	.10 max.	45, 000 to 55,000	35,000 to 45,000	25 to 35	50 to 65	147 (20 ga.)	145
MILL-BONDERIZED GALVANIZED	Galvanized sheet with a coating of mill-bonderized phosphate for immediate painting without flaking or peeling.	16 to 26 ga.	Up to 60”	Up to 18 ft.	16 to 26 ga.	Up to 60”	.10 max.	45, 000 to 55,000	35,000 to 45,000	25 to 35	50 to 65	149 (20 ga.)	N.A.
GALVANEALED (Coating Designation A60) (ASTM-A653)	Heat treated galvanized sheet, dull gray without spangles with a rough texture well suited to painting. Can withstand temperatures to 750 without flaking. Less ductile than regular galvanized coating.	14 to 26 ga.	Up to 48”	Up to 18 ft.	14 to 26 ga.	Up to 48”	.10 max.	40, 000 to 55,000	32,000 to 42,000	25 to 35	50 to 65	150 (20 ga.)	147
ELECTRO-GALVANIZED (ASTM #A591)	A thin zinc coating is applied to cold rolled steel by electro-plating so as not to appreciatively affect the weight-thickness relationship. Smoot, without spangles it is recommended as an undercoat for painted finishes. Available in Commercial and Drawing Quantities.	14 to 26 ga.	Up to 60”	Up to 18 ft.	14 to 26 ga.	Up to 60”	.10 max.	40, 000 to 50,000	25,000 to 35,000	30 to 40	45 to 60	146 (20 ga.)	144
ALUMINIZED, TYPE 1 (ASTM #463)	Sheet steel coated both sides with aluminum combines the properties of both metals. Type 1 is provide in two weights Regular and Light (see page 68) and is available in Commercial and Drawing Qualities. If the heavier Type 2 Aluminized coating is desired consult with your I.P.A. supplier or the steel manufacturer.	14 to 26 ga.	Up to 60”	Up to 18 ft.	14 to 26 ga.	Up to 60”	.10 max.	50, 000 to 60,000	35,000 to 45,000	18 to 28	60 to 70	162 (20 ga.)	157

Selection Guide to Stainless Steel (Ref. ASTM-A240)

TYPE	DESCRIPTION	TYPICAL COMPOSITION %	FORM	TYPICAL MECHANICAL PROPERTIES Annealed at Room Temperature Tensile	Yield (0.2% Offset)	Elongation (% in 2')	Hardness	Weldability	Relative Cost
Austenitic (Hardenable by cold working only)									
304 (S30400)	Low-carbon modification of type 302 for restriction of carbide precipitation during welding. Chemical and food processing equipment; brewing equipment; cryogenic vessels; gutters; downspouts: flashings.	18-20 Cr. 8-10.50 Ni 0.08 C. 2.0 Mn, 1.0 Si 0.045 P, 0.030 S	sheets plates	84,000 82,000	42,000 35,000	55 60	80 Rb 149 Bhn	A	100 100
304L (S30403)	Extra-low-carbon modification of type 304 for further re striction of carbide precipitation during welding. Coal hopper linings; tanks for liquid fertilizer and tomat paste.	18-20 Cr, 8-12 Ni. 0.03 C, 2.0 Mn, 1 0 Si 0.045 P, 0.030 S	sheets plates	81,000 79,000	39,000 33,000	55 60	79 Rb 143 Bhn	A	111 109
316 (S31600)	Higher corrosion resistance than types 302 and 304; high creep strength. Chemical and pulp handling equipment; photographic equipment; brandy vats@ fertilizer parts; ketchup cooking kettles; yeast tubs.	16-18 Cr, 10-14 Ni, 0.08 C, 2.0 Mn, 1.0 Si 0.045 P, 0.030 S, 2 0-3.0 Mo	sheets plates	84,000 82,000	42,000 36,000	50 55	79 Rb 149 Bhn	A	148 140
316L (S31603)	Extra-low-carbon modification of type 316 Welded construction where intergranular carbide precipitation must be avoided. Type 316 application requiring extensive welding.	16-18 Cr, 10-14 Ni, 0.03 C, 2.0 Mn, 1.0 Si 0.045 P, 0.030 S, 2,0-3.0 Mo	sheets plates	81,000 81,000	42,000 34,000	50 55	79 Rb 149 Bhn	A	159 149
316L (S31603)	Stabilized for weldments subject to severe corrosive conditions, and for service from 800 to 1600 F. Aircraft exhaust manifolds; boiler shells; process equipment; expansion joints; cabin heaters; fire walls; flexible couplings, pressure vessels.	17-19 Cr, 9-12 Ni, 0.08 C. 2.0 Mn, 1.0 Si, 0.045 @. 0.030 S (Ti, 5 X C min)	sheets plates	90,000 85,000	35,000 30,000	45 55	80 Rb 160 Bhn	A	130 128
Martensitic (Hardenable by heat treatment)									
410 (S41 000)	General-purpose heat treatable type. Machine parts; pump shafts; bolts; bushings; coal chutes; cutlery; finish ing tackle; hardware; jet engine parts; mining machinery; rifle barrels; screws; valves.	11.5-13.5 Cr, 0.15 C, 1.0 Mn, 1.0 Si. 0.040 P, 0.030 S	sheets plates	70,000 70,000	45,000 35,000	25 30	80 Rb 150 Bhn	C	90 81
Ferritic (Non-hardenable)									
430 (S43000)	General-purpose nonhardenable chromium type. Dec orative trim; nitric acid tanks; annealing baskets; com bustion chambers; dishwashers; heaters: mufflers; range	16-18 Cr, 0.12 C, 1.0 Mn, 1.0 Si, 0.040 P, 0.030 S	sheets plates	75,000 75,000	50,000 40,000	25 30	80 Rb 160 Bhn	C	87 84

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Selection Guide to Aluminum Sheet and Plate (Ref. ASTM-B209)

ALLOY & TEMPER	DESCRIPTION	TYPICAL MECHANICAL PROPERTIE			DENSITY	COMPARATIVE COST (APPROXIMATE) 1100 = 100	
		Tensile, PSI	Yield, PSI	% Elong. in 2”	lbs./cu. in.	SHEETS	COILS
Non-Heat-treatable Alloys							
1100—0 H14	Pure aluminum (.99% min.) is highly resistant to attack by chemicals and rural, industrial and marine atmo spheres. Easily worked and ductile enough for deep draws. For general use in applications where the essen tial qualities of aluminum will be beneficial.	13,000 18,000	5,000 17,000	35 9	.098 .098	110 110	100 100
3003—0 H14	The most widely used general purpose alloy. Stronger than 1100 but still readily formable. Excellent resistance to chemicals and weathering. Recommended for general use where the extra strength is required.	16,000 22,000	6,000 21,000	30 8	.099 .099	110 110	100 100
5050—H34	Very similar to 3003 in physical properties and corrosion resistance though slightly lighter. Recommended for anodized applications for best match with extruded aluminum components.	28,000	24,000	8	.097	110	101
5052—0 H32 H34	A versatile alloy for applications requiring greater strength. Readily formed, very good corrosion resis tance. Recommended for applications requiring high strength and formability.	28,000 33,000 38,000	13,000 28,000 31,000	25 12 10	.097 .097 .097	115 116 116	105 105 105
5086—H32 H34	Recommended for welded assemblies requiring both welding efficiency and high joint strength. Good cor rosion resistance, Typical applications include pressure vessels, marine super-structures and transportation equipment.	42,000 47,000	30,000 37,000	12 10	.090 .096	144 139	— —

Selection Guide to Aluminum Sheet and Plate (Ref. ASTM-B209) (continued)

Heat-treatable Alloys							
2024—0	These are high strength, heat-treatable alloys	27,000	11,000	20	.100	149	117
T3	with nearly twice the strength of 5052 and	70,000	50,000	18	.100	159	153
Alclad	fair corrosion resistance. Alclad 2024						
2024—0	provides improved corrosion resistance.	26,000	11,000	20	.100	160	129
T3		65,000	45,000	18	.100	170	165
6061—0	This high-strenght, heat-treatable alloy	18,000	8,000	25	.098	120	105
T4	provides good formability and weldability	32,000	21,000	22	.098	140	132
T6	and good corrosion resistance. Suitable for a wide variety of structural and architectural applications.	45,000	40,000	12	.098	142	133
7075—T6	This alloy is intended for aircraft applications	76,000	68,000	11	.101	154	—
Alclad	requiring the highest strength. Alclad 7075						
7075—0	provides improved corrosion resistance.						
T6		32,000	14,000	17	.101	180	—

For other aluminum alloys, tempers and sizes, consult your IPA member supplier for availability.

All of the above materials are furnished with mill finish unless otherwise specified. Aluminum is available in a variety of finishes including mechanical surface treatments produced by grinding, polishing, burnishing and sand blasting; chemical surface treatments produced by caustic etching, bonderizing, anodizing, phosphatizing and chemical polishing; and, electrolytic oxide treatment, electroplating, painting, embossing and texturing.

Galvanized Sheet Steel Selector

Source: The AISI Committee of Galvanized Sheet Producers.

		Hot Dipped Galvanized				Electrolytic Zinc Coated		
Trade Name	Steel Producer	#1	#2	#3	#4	#5	#6	#7
Zincgrip	Armco	X						
Zincgrip A	Armco		X					
Zincgrip A Paintgrip	Armco		X					
Zincgrip Paintgrip	Armco			X				
Zincgrip DC	Armco							
Cold Rolled Paintgrip	Armco				X			X
Bethcon	Bethlehem	X						
Bethcon Jetcoat	Bethlehem		X					
Bethcon Galvannealed	Bethlehem							
Bethzin	Bethlehem					X		
Belhzin Gripcoat	Bethlehem						X	
Bethzin Palntfast	Bethlehem							X
Premier	Dofasco	X						
Satincoat	Dofasco		X					
Reeves-Titekote	Empire-Detroit	X			X			
Softforrn	Granite City	X						
Ti-Co	Inland	X						
Paint-Tite	Irland		X					
Jai-Zinc	J&L	X		X	X			
Jal-Zinc Galvanneated	J&L		X					
Kaiser Galvanized	Kaiser	X	X	X				
Kaiser Galvannealed	Kaiser		X					
Green Dot Galvanized	Republic	X		X	X			
Electro Zincbond	Republic					X		
Electro Paintlok	Republic						X	
Electro Flashcote	Republic							X
Brite-Zinc	Sharon	X		X				
Galva-Brite	Sharon		X	X				
Galvanite	Sharon		X	X				
Electro Galvanized	Sharon					X	X	X
Stelcoat	Stelco	X						
Colourbond	Stelco		X					
USS Galvanized	USS	X						
USS Galvannealed	USS		X					
Redi-Kote	USS		X					
Paintbond	USS			X				
Weirkole	Midwest	X			X			
	Weirton	X			X			
Weirkole Type JP	Midwest		X					
	Weirton		X					
Weirzin	Weirton					X		
Weirzin Bonderized	Weirton						X	
Weirzin Paintrite	Weirton							X
Sof-Tite	Wheeling-Pittsburgh	X	X	X	X			
Lifekole #2	Wheeling-Pittsburgh					X		
Lifekote #1	Wheeling-Pittsburgh						X	
Lifekote #3	Wheeling-Pittsburgh							X
Tufkote	Youngstown	X	X	X	X			

Galvanized Sheet Steel Selector (continued)

No. 1 is Hot Dipped Galvanized steel produced continuously which includes regular spangled and minimized spangled in a wide range of coaling designations.

No. 2 is Hot Dipped Galvanized produced continuously, heat treated or wiped to produce a fully alloyed zinc-iron coating in a wide range of coating designations intended for painting. Where heat treatment after coating is utilized, it may be described as "Galvannealed." Weldability and formability are improved in the lighter coating designations.

No. 3 is Hot Dipped Galvanized as 1, surface treated for painting, such as by phosphatizing.

No. 4 is Hot Dipped Galvanized produced continuously which includes regular spangled and minimized spangled in a wide range of coating designations-with a specified coating weight on one surface and a significantly lighter coating weight on the other surface, normally referred to as Differentially Coated.

No. 5 is Electrolytic Zinc Coated by continuous electroplating with zinc-0.1 oz. to 0.2 oz. per sq. ft. total on both sides.

No. 6 is Electrolytic Zinc Coated as 5, surface treated for painting, such as by phosphatizing.

No. 7 is Electrolytic Flash Zinc Coated by continuous electroplating on both sides, and surface treated for painting, such as by phosphalizing.

Nos. 1, 3, & 4 can be produced in all ASTM and AISI Regular Coating Designations-G-235, G-210, G-185, G-165, G-140, G-115, G-90, G-60,

No. 2 can be produced in all ASTM and AISI Alloyed Coating Designations-A-60, A-40, A-01.

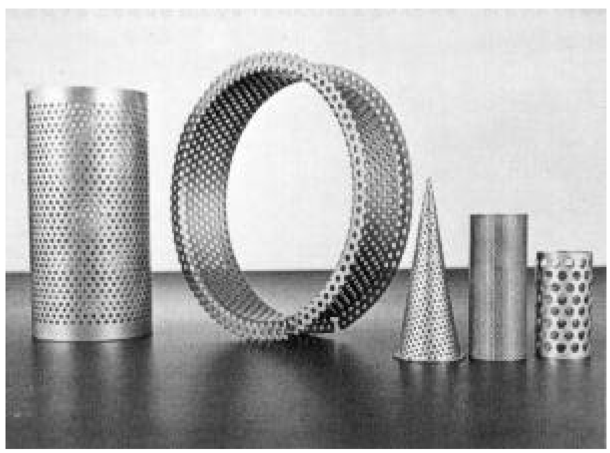
The IPA Sets the Standards

The members of the IPA have established the basic product and manufacturing standards for the industry as set forth in this Handbook. In addition, they have had a member on the International Standards Organization committee which has developed the standards for round and square hole sizes and patterns which have been provided here.

It has also been a consistent aim of the IPA to develop sound business practices among its members and the highest standards for manufacturing efficiency and quality control.

With the publication of this Handbook, the members of the IPA have tried to provide you with a book of answers. But equally important, they hope they have contributed to your creative capacities. We have endeavored to demonstrate the versatility of perforated metals by showing you how and where they have been successfully applied. Further, we explain our manufacturing process so that you can make the most of it in your designs. We want you to understand the economic implications of perforated metals and all of the design considerations related to material dimensions, hole shapes, and patterns. The Handbook illustrates and lists the standard round and square hole sizes and patterns along with an extensive variety of other hole configurations and patterns for which dies are available among IPA members. You will also find throughout the Handbook a host of useful reference tables pertinent to your designing activities with perforated materials.

It is expected that this will be a living reference book that will be constantly improved through your suggestions and contributions.



IPA Voluntary Standard Tolerances

THESE THREE QUALITIES ARE AVAILABLE:

1. Commercial Quality
2. Superior Quality – IPA
3. Special Quality*

*To Be Set By Mutual Agreement Between Customer and IPA Member

IPA VOLUNTARY STANDARD TOLERANCES
TABLE OF CONTENTS

CARBON STEEL - Not Resquared

COMMERCIAL QUALITY - Hot rolled mill edge sheets produced from coils and cut lengths including pickled.

Sheet Thickness	Inches Width	Width Tolerances	Inches Length	Length Tolerances
30GA-7GA ↓	12-14	-0 +9/16”	Up To 601	1”
	15-17	-0 +5/8”	Over 60”-120”	-0 +1 -1/2”
	18-19	-0 +11/16”	Over 120”	-0 +2"
	20-21	-0 +3/4”		
	22-24	-0 +13/16"		
	25-26	-0 +1 -1/16”		
	27-30	-0 +1 -3/16”		
	31-50	-0 +1 -3/8"		
	51-78	-0 +1 -3/4”		

SUPERIOR QUALITY - Hot rolled (mill cut edge), cold rolled and hot dipped galvanized sheets, coils and mill cut lengths including pickled sheets.

Sheet Thickness	Inches Width	Width Tolerance	Inches Length	Length Tolerance
30GA-7GA ↓	To 30"	-0 +1/4”	To 60"	-0+1”
	Over 30”-48”	-0 +5/16"	Over 60-120”	-0+1-1/2”
	Over 48"-60"	-0 +3/8"	Over 120”	-0 +2”

COMMERCIAL QUALITY - Mill Edges and Mill Sheared Plates.

Specified Lgth. or Width Inches	Thickness Range: 3/16" to 3/8" — Lgth. or Width Tolerance	Thickness Range: Over 3/8" to 5/8" — Lgth. or Width Tolerance	Thickness Range: Over 5/8" to 1" — Lgth. or Width Tolerance
To 24”	-0 +7/16”	-0 +1/2”	-0 +9/16”
Over 24”1-36”	-0+5/8”	-0 +11/16”	-0 +3/4”
Over 36”-48"	-0 +3/4"	-0 +13/16"	-0 +7/8"
Over 48”-60"	-0 +7/8”	-0 +15/16"	-0+1”
Over 60” -84”	-0 +1 -1/8”	-0 +1 -3/16”	-0 +1 -1/4”
Over 84” -120	-0 +1 -1/4”	-0 +1 -5/16”	-0 +1 -3/8"
Over 120”	-0 +1 –1/2”	-0 +1 -9/16”	-0 +1 -5/8"

STAINLESS STEEL - Not Resquared

COMMERCIAL QUALITY- Hot rolled and cold rolled sheets and cold rolled sheets produced from coils.

Width Tolerance

Thickness	Up To 60" Wide
30GA-16GA	+3/8" -0"
Over 16GA-7GA	+1/2" -0"

Length Tolerance

Thickness	Length	Tolerance
30GA-7GA	0"-120"	+2"
	Over 120"	+2-1/4"

COMMERCIAL QUALITY - Sheared Mill and Universal Mill Plates.

		Thickness		
		3/16"-3/8"	Over 3/8"-1/2"	Over 1/2"-1"
Width	**Length**	**Width Tolerances**		
0"-60"	-	-1/4"+1/2"	-1/4"+5/8"	-1/4"+3/4"
Over 60"-84"	-	-1/4+11/16"	-1/4+13/16"	-1/4+15/16
		Length Tolerances		
-	0"-144"	-1/4"+2-1/4"	-1/4"+2-1/4"	-1/4"+2-1/4"

ALUMINUM - Not Resheared

COMMERCIAL QUALITY - Length and width tolerances for aluminum flat sheets and sheets from coil.

Width Tolerance

Thickness	Up To 60' Wide
.006" to .060"	+3/8"-1/8"
Over .060" to .1875"	+1/2" -1/8"

Length Tolerance

Thickness	Length	Tolerance
.006" to .1 875"	0"-120"	+2"
	Over 120"	+2-1/4"

COMMERCIAL QUALITY - Plate.

		Thickness		
		.1876"-.375"	.376"-.500"	.501"-1"
Width	**Length**	**Width Tolerances**		
0"-60"	-	-1/4"+1/2"	-1/4"+5/8"	-1/4"+3/4"
Over 60"-72"	-	-1/4"+11/16"	1/4"+13/16"	-1/4"+15/16"
		Length Tolerances		
-		-1/4"+2-1/4"	-1/4"+2-1/4"	-1/4"+2-1/4"

IPA standard overall length and width tolerances of resheared sheets and plates, of all metals, and plastics sheared after perforating.

Tolerances

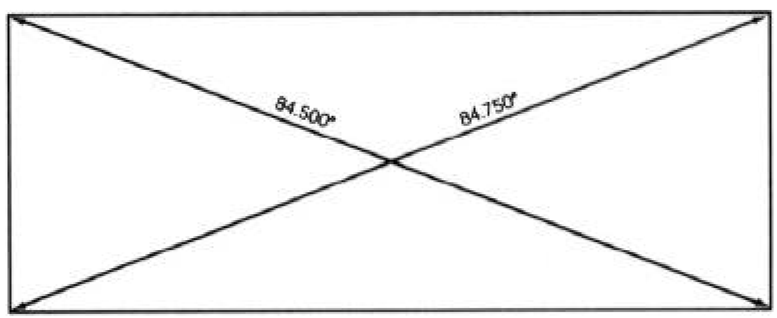
Thickness	Commercial Quality	Superior Quality	Special Quality*
30GA-10GA	± 1/8"	± 1/16"	
8GA-1/4"	± 1/4"	± 1/8"	
5/16"- 1/2"	± 5/16"	± 5/32"	
9/16"-3/4"	± 3/8"	± 3/16"	
11/16"-1"	± 1/2"	± 1/4"	

*If other special resheared tolerances are required, check with your IPA member supplier.

When steel plates or aluminum sheets and plates are purchased from the mill or service center as a sheared product, the above tolerances may not be achievable.

SQUARENESS OF SHEETS AND PLATES

Definition: "Out of square" is the greatest deviation of an end edge from a straight line at right angle to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the sheet. The out of square deviation is one-half of that difference. See example below:



84.750”
\- 84.500”
.250” / 2 = .125” Out of Square

TOLERANCE OF RESQUARED SHEETS AND PLATE

Thickness Range	Up to 72" Max. Tol. out of Sq.	Up to 72" Diff . of Diagonal Measure.	Up to 120" Max. Tol. out of Sq.	Up to 120" Diff. of Diagonal Measure.	Over 120" *
30-20GA Shts.	1/32"	1/16"	1/16"	1 /B"	
19-16GA Shts.	1/16"	1 /8"	1/8"	1/4"	
15-12GA Shts.	3/32"	3/16"	3/16"	3/8"	
1 1 -7GA Shts.	3/16"	3/8"	3/8"	314"	
3/16"-318" Plate	1/4"	1/2"	1/2"	1"	
3/8"-5/B" Plate	3/8"	3/4"	3/4"	1-1/2"	
5/8"-1" Plate	3/4"	1-1 /2"	1-1/2"	3"	

*Check with your member IPA supplier.

OPENINGS TOLERANCES

Table 2: Tolerances on Opening of USA Standard Specifications for Industrial Perforated Plate and Sheets.

Perforated Opening			Tolerance on Openings	
Standard (metric) MM	**USA Industial Standard Inch**	**Additional Sizes Inch**	**Standard (metric) MM**	**USA Industrial Standard Inch**
125.0	5	-	±2.5	±0.100
-	-	4-1/2	-	±0.090
106.0	4-1/4	-	±2.1	±0.085
100.0	4	-	±2.0	±0.080
-	-	3-3/4	-	±0.075
90.0	3-1/2	-	±1.8	±0.070
-	-	3-1/4	-	±0.065
75.0	3	-	±1.5	±0.060
-	-	2-3/4	-	±0.055
63.0	2-1/2	-	±1.3	±0.050
-	-	2-1/4	-	±0.045
53.0	2-1/8	-	±1.1	±0.043
50.0	2	-	±1.0	±0.040
-	-	1-7/8	-	±0.038
45.0	1-3/4	-	±0.9	±0.035
-	-	1-5/8	-	±0.033
37.5	1-1/2	-	±0.8	±0.030
-	-	1-3/8	-	±0.028
31.5	1-1/4	-	±0.6	±0.025
-	-	1-3/16	-	±0.024
-	-	1-1/8	-	±0.023
26.5	1-1/16	-	±0.5	±0.021
25.0	1	-	±0.5	±0.020
-	-	15/16	-	±0.019
22.4	7/8	-	±0.46	±0.018
-	-	13/16	-	±0.016
19.0	3/4	-	±0.38	±0.015
-	-	11/16	-	±0.014
16.0	5/8	-	±0.32	±0.013
-	-	9/16	-	±0.012
13.2	17/32	-	±0.30	±0.012
12.5	1/2	-	±0.28	±0.011
-	-	15/32	-	±0.011
11.2	7/16	-	±0.28	±0.011
9.5	3/8	-	±0.28	±0.010
8.0	5/16	-	±0.26	±0.010
6.7	17/64	-	±0.25	±0.009
6.3	1/4	-	±0.25	±0.009
5.6	7/32	-	±0.24	±0.009
4.75	3/16	-	±0.21	±0.008
4.00	5/32	-	±0.19	±0.007
3.35	0.127	-	±0.17	±0.006
*	(1/8)	*	*	*
2.80	7/64	-	±0.150	±0.006
2.36	3/32	-	±0.135	±0.005
2.00	0.078	-	±0.125	±0.005
1.70	0.066	-	±0.110	±0.004
1.40	0.055	-	±0.100	±0.004
1.18	0.045	-	±0.085	±0.003
1.00	0.039	-	±0.070	±0.003
.830	0.032	-	±60 p.m	±0.002
.710	0.027	-	±50 p.m	±0.002
.600	0.023	-	±45 p.m	±0.002
.500	0.020	-	±40 p.m	±0.002

*Round holes only.

Table 3: Tolerances on Bars of USA Standard Specifications for Industrial Perforated Plate and Sheets.

Perforated Opening			**Tolerance on Avg. Bars**	
Standard (metric) MM	**USA Industrial Standard Inch**	**Additional Sizes Inch**	**Standard (metric) MM**	**USA Industrial Standard Inch**
125.0	5	-	±3.2	±0.125
-	-	4-1/2	-	±0.122
106.0	4-1/4	-	±2.9	±0.113
100.0	4	-	±2.7	±0.107
-	-	3-3/4	-	±0.102
90.0	3-1/2	-	±2.5	±0.097
-	-	3-1/4	-	±0.089
75.0	3	-	±2.1	±0.081
-	-	2-3/4	-	±0.076
63.0	2-1/2	-	±1.8	±0.069
-	-	2-1/4	-	±0.063
53.0	2-1/8	-	±1.5	±0.059
50.0	2	-	±1.4	±0.056
-	-	1-7/8	-	±0.054
45.0	1-3/4	-	±1.3	±0.051
-	-	1-5/8	-	±0.047
37.5	1-1/2	-	±1.1	±0.043
-	-	1-3/8		±0.040
31.5	1-1/4	-	±0.9	±0.037
-	-	1-3/16	-	±0.035
-	-	1-1/8	-	±0.034
26.5	1-1/16	-	±0.8	±0.032
25.0	1	-	±0.8	±0.030
-	-	15/16	-	±0.029
22.4	7/8	-	±0.7	±0.028
-	-	13/16	-	0.026
19.0	3/4	-	±0.6	±0.024
-	-	11.16	-	±0.022
16.0	5/8	-	±0.5	±0.021
-	-	9.16	-	±0.019
13.2	17/32	-	±0.46	±0.018
12.5	1/2	-	±0.44	±0.017
-	-	15/32	-	±0.017
11.2	7/16	-	±0.41	±0.016
9.5	3/8	-	±0.36	±0.014
8.0	5/16	-	±0.32	±0.013
6.7	17.64	-	±0.29	±0.011
6.3	1/4	-	±0.28	±0.011
5.6	7/32	-	±0.27	±0.011
4.75	3/16	-	±0.23	±0.009
4.00	5/32	-	±0.22	±0.009
3.35	0.127	-	±0.20	±0.008
*	(1/8)	*	*	*
2.80	7/64		±0.18	±0.007
2.36	3/32		±0.16	±0.006
2.00	0.078		±0.150	±0.006
1.70	0.066		±0.135	±0.005
1.40	0.055		±0.125	±0.005
1.18	0.045		±0.110	±0.004
1.00	0.039		±0.090	±0.004
0.830	0.032		±80 P.M	±0.003
0.710	0.027		±70 p.m.	±0.003
0.600	0.023		±65 p.m	±0.003
.500	0.020		±60 p.m	±0.002

*Round holes only.

FLATNESS TOLERANCE

The maximum deviation from a horizontal flat surface-the material is to be placed on a perfectly flat table. A ruler which does not flatten the material will give the degree of flatness. The measurement being from the highest point (or points) of the sheet or plate to the table surface minus the material thickness. Note: If not otherwise specified, **commercial quality is supplied**. Flatness tolerances listed are of roller leveled sheets or plates with no or minimum margins. For material 10' or less in length, variation should not exceed amount shown in table. For material longer than 10' , the variation in flatness for any 10 feet of length should not exceed the amount shown. Where the longer dimension is under 36" the variation in flatness along the length and across the width should not exceed 1/4" in each direction. When the longer dimension is from 36" to 72" the flatness variation should not exceed 75% of the amount shown for the specified width, but in no case less than 1/4". Margins will usually increase the maximum deviation, please consult your IPA member supplier.

Three levels of quality are available.

Commercial Quality – Superior Quality – Special Quality

H.R. & C.R. Steel Sheet, Plate & Hot Dipped Galvanized Sheets

Thickness Range	To 36" Width		
	Tolerance		
	Comm.	Sup.	Spec.
28-20GA	3/8"	5/16"	
19-16GA	1/2"	7/16"	
15-12GA	5/8"	1/2"	
11 GA-1/4"	5/8"	1/2"	
5/16"-3/8"	9/16"	15/32"	
7/16"-1/2"	1/2"	7/16"	
9/16"-3/4"	7/16"	11/32"	

Heat Treated Steel Plate (Hardness Range 185-360 Brinell)

To 1/4"	1-5/16"	1-5/32"	
1/4"-3/8"	1-1/4"	1-1/8"	
7/16"-1/2"	1-1/4"	1-1/8"	
9/16"-3/4"	1-1/8"	1"	

Stainless Steel and Other Heat Resistant Alloys Sheet & Plate

30-20GA	1/2"	7/16"	
19-16GA	5/8"	1/2"	
15-12GA	3/4"	5/8"	
11 GA-1 /4"	3/4"	5/8"	
5/16"-3/8"	11/16"	9/16"	

Aluminum & Copper

.012"-.032"	5/16"	1/4"	
.033"-.063"	7/16"	11/32"	
.064"-.125"	9/16"	15/32"	
.126"-.500"	5/8"	9/16"	
.501"-.750"	11/16"	5/8"	

FLATNESS TOLERANCE, continued

H.R. & C.R. Steel Sheet, Plate & Hot Dipped Galvanized Sheets

Thickness Range	Over 36"-48" Width		
	Tolerance		
	Comm.	**Sup.**	**Spec.**
28-20GA	1/2"	7/16"	
19-16GA	5/8"	1/2"	
15-12GA	3/4*	5/8"	
11GA-1/4"	7/8"	23/32"	
5/16"-3/8"	3/4"	5/8"	
7/16"-1/2"	5/8"	1/2"	
9/16"-3/4"	9/16"	15/32"	

Heat Treated Steel Plate (Hardness Range 185-360 Brinell)

To 1/4"	1-5/8"	1-7/16"	
1/4"-3/8"	1-7/16"	1-1/4"	
7/16"-1/2"	1-3/8"	1-7/32"	
9/16"-3/4"	1-1/4"	1-1/8"	

Stainless Steel and Other Heat Resistant Alloys Sheet & Plate

30-20GA	5/8"	1/2"	
19-16GA	3/4"	5/8"	
15-12GA	7/8"	23/32"	
11 GA-1 /4"	1"	13/16"	
5/16"-3/8"	13/16"	21/32"	

Aluminum & Copper

.012"-.032"	7/16"	11/32"	
.033"-.063"	9/16"	15/32"	
.064"-.125"	11/16"	9/16"	
.126" -.500"	3/4"	11/16"	
.501" -.750"	13/16"	3/4"	

FLATNESS TOLERANCE, continued

H.R. & C.R. Steel Sheet, Plate & Hot Dipped Galvanized Sheets

Thickness Range	Over 48"-60" Width		
	Tolerance		
	Comm.	Sup.	Spec.
28-20GA	5/8"	1/2"	
19-16GA	3/4"	5/8"	
15-12GA	1"	13/16"	
11 GA-1/4"	1-1/16"	27/32"	
5/16"-3/B"	7/8"	23/32"	
7/16"-1 /2"	11/16"	9/16"	
9/16"-3/4"	5/8"	1/2"	

Heat Treated Steel Plate (Hardness Range 185-360 Brinell)

To 1/4'	1-7/8"	1-5/8"	
1/4"-3/8"	1-5/8"	1-7/16"	
7/16"-1/2"	1-7/16"	1-1/4"	
9/16"-3/4"	1-5/16'	1-5/32"	

Stainless Steel and Other Heat Resistant Alloys Sheet & Plate

30-20GA	3/4"	5/8'	
19-16GA	1"	13/16"	
15-12GA	1-1/8"	15/16"	
11 GA-1/4"	1-3/16"	31/32"	
5/16"-3/8"	7/8"	23/32"	

Aluminum & Copper

.012"-.032"	9/16"	15/32"	
.033"-.063"	11/16"	9/16"	
.064"-.125"	15/16"	3/4"	
.126"-.500"	13/16"	3/4"	
.501"-.750"	3/4"	11/16"	

FLATNESS TOLERANCE, continued

H.R. & C.R. Steel Sheet, Plate & Hot Dipped Galvanized Sheets

Thickness Range	Over 60"-72" Width		
	Tolerance		
	Comm.	Sup.	Spec.
28-20GA	3/4"	5/8"	
19-16GA	1"	13/16"	
15-12GA	1-1/4"	1"	
11GA-1/4"	1-3/8"	1-1/8"	
5/16"-3/8"	1-1/16"	27/32"	
7/16"-l /2"	3/4"	5/8"	
9/16"-3/4"	11/16"	9/16"	

Heat Treated Steel Plate (Hardness Range 185-360 Brinell)

To 1/4'	2-3/8"	2"	
1/4"-3/8"	1-7/8"	1-5/8"	
7/16"-l /2"	1-7/16"	1-1/4"	
9/16"-3/4"	1-3/8"	1-7/32"	

Stainless Steel and Other Heat Resistant Alloys Sheet & Plate

30-20GA	1"	13/16"	
19-16GA	1-1/4"	1"	
15-12GA	1-1/2"	1-1/4"	
11 GA-1/4"	1-1/2"	1-1/4"	
5/16"-3/8"	1"	13/16"	

Aluminum & Copper

.012"-.032"	11/16"	9/16"	
.033" -.063"	7/8"	23/32"	
.064"-.125"	1-1/8"	15/16"	
.126"-.500"	7/8"	13/16"	
.501"-.750"	15/16"	7/8"	

FLATNESS TOLERANCE, continued

H.R. & C.R. Steel Sheet, Plate & Hot Dipped Galvanized Sheets

Thickness Range	Over 72”-84' Width		
	Tolerance		
	Comm.	Sup.	Spec.
28-20GA			
19-16GA			
15-12GA			
11GA-1/4"	1-1/2"	1-1/4"	
5/16"-3/8"	1-1/4"	1"	
7/16"-1/2"	7/8"	23/32"	
9/16"-3/4"	3/4"	5/8"	

Heat Treated Steel Plate (Hardness Range 185-360 Brinell)

To 1/4"	2-1/2'	2-1/8"	
1/4"-3/8"	2-1/4"	1-15/16"	
7/16"-1/2"	1-5/8"	1-7/16"	
9/16"-3/4"	1-1/2"	1-5/16"	

Stainless Steel and Other Heat Resistant Alloys Sheet & Plate

30-20GA			
19-16GA			
15-12GA			
11 GA-1/4"	1-3/4"	1-7/16"	
5/16"-3/8"	1-3/8"	1 -1/8"	

Aluminum & Copper

.012"-.032"			
.033"-.063"			
.064"-.125"			
.126"-.500"	1"	7/8"	
.501"-.750"	1-1/16"	1"	

FLATNESS TOLERANCE, continued

H.R. & C.R. Steel Sheet, Plate & Hot Dipped Galvanized Sheets

Thickness Range	Over 72” – 84” Width		
	Tolerance		
	Comm,	Sup.	Spec.
28-20GA			
19-16GA			
15-12GA			
11GA-1/4"	1-5/8"	1-3/8"	
5/16"-3/8"	1-1/2"	1-1/4"	
7/16"-1/2"	1-1/8"	7/8"	
9/16"-3/4"	1"	3/4"	

Heat Treated Steel Plate (Hardness Range 185-360 Brinell)

To 1/4"	2-5/8"	2-3/8"	
1/4"-3/8"	2-1/2"	2-1/4"	
7/16"-1/2"	2-1/8"	1-7/8"	
9/16"-3/4"	2"	1-3/4"	

Stainless Steel and Other Heat Resistant Alloys Sheet & Plate

30-20GA			
19-16GA			
15-12GA			
11 GA-1/4"	2"	1-3/4"	
5/16"-3/8"	1-5/8"	1-3/8"	

Aluminum & Copper

.012"-.032"			
.033"-.063"			
.064"-.125"			
.126"-.500"	1-1/8"	1"	
.501"-.750"	1-1 /4"	1-1/2"	

H.R. & C.R. Steel Sheet, Plate & Hot Dipped Galvanized Sheets

Thickness Range	Over 120" Wide		
	Tolerance		
	Comm.	Sup.	Spec.
28-20GA			
19-16GA			
15-12GA			
11 GA-1/4"	2-1/8"	1-7/8"	
5/16"-3/8"	2"	1-5/8"	
7/16"-1/2"	1-7/8"	1-1/4"	
9/16"-3/4"	1-1/2"	1-1/8"	

Heat Treated Steel Plate (Hardness Range 185-360 Brinell)

To 1/4'	3-1/8"	2-7/8"	
1/4"-3/8"	3"	2-5/8"	
7/16"-1/2"	2-7/8"	2-1/4"	
9/16"-3/4"	2-1/2"	2-1/8"	

If your requirement is within one of the following categories, it is recommended that you discuss your flatness requirements with your IPA member supplier.

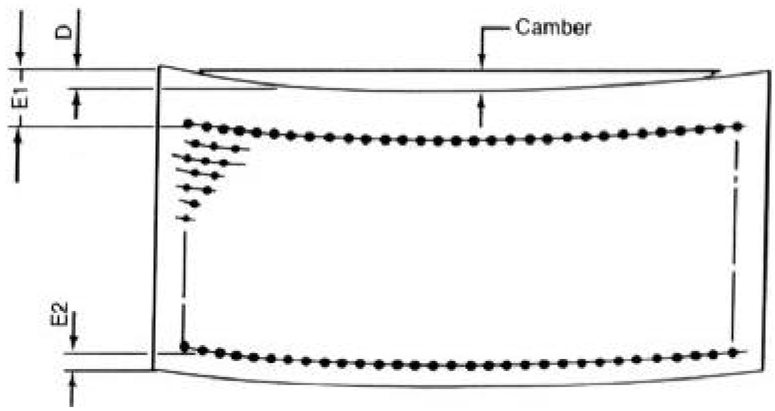
1. Perforated sheets with other than “safe” or “no” margins.
2. Stresses imposed during the perforating process may cause a deviation in the flatness of the edges. The wavy edge may occur in perforated sheets and coils with wide or unequal wide unperforated blank edges on the long sides or when making special perforations, such as countersunk or ringed perforations, especially when using soft materials such as aluminum or copper.
3. Blank areas required within perforated area.
4. Perforated sheets with a very large percentage of open area.
5. When hole diameter and/or bar between holes is less than material thickness.
6. Special alloys.

CAMBER

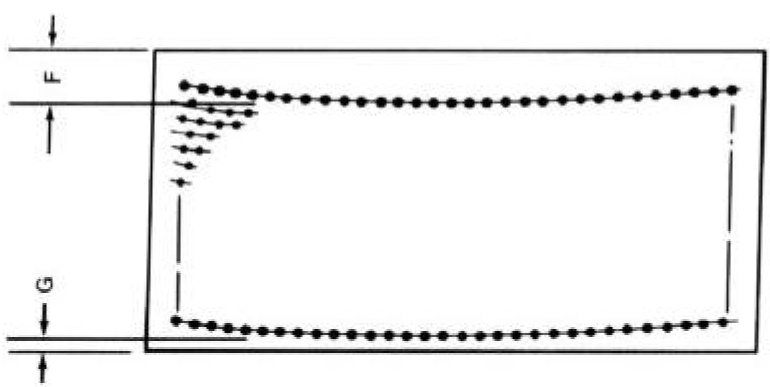
Camber is the greatest deviation of a side edge from a straight line. The measurement is taken over the entire length of the concave side with a straight line.

On perforated sheets with different side margins it is possible to produce a camber effect. This effect is the deflection (d) between one of the longitudinal edges and a straight line supported by the ends of the sheet.

The magnitude of the deflection (d) depends on the length, width, thickness, open area, type of material and relation of e-2 to e-l.



If sheets are cut after perforation, the camber refers only to the perforated pattern. (See sketch below F & G.)



Designers are requested to avoid different margins whenever possible.

Max. Camber All Metals After Perforating

Coils and Cut Length Ft.	Commercial Quality	Superior Quality	Special Quality
To 4 Feet Inclusive	1/8”	4’ = .062”	
Over 4-6 Ft. Inclusive	3/16”	5’ = .098”	
Over 6-8Ft. Inclusive	1/2"	6’ = .140”	

Camber measurement is taken by placing an 8 ft. straight edge on the concave side and measuring the greatest distance between the sheet edge and the straight edge.

Due to the nature of the perforating process, camber can be as great as 2” in 20 ft. when processing coil to coil.

For sheets with wider than standard or unequal side margins, camber must be discussed with the IPA member supplier. Camber doesn’t vary in direct proportion to length. Camber is always expressed in 8 ft.

$$\frac{L^2 \text{ x } C_1}{8^2} = C_2$$

L^2 = Any Given Length
C_1 = Camber in 8 Ft.
C_2 = Camber in any Given Length

Example: L^2 = 6 Ft. (Given Length); C_1 = .250” (1/4”)

$$\frac{6^2 \text{ x } .250”}{8^2 \text{ or } (64)} = \frac{36” \text{ x } .25”}{8^2 \text{ or } (64)} = \frac{9}{64} = .140”$$

Sheet Thickness Tolerances

Steel Hot Rolled - Hot Rolled Pickled & Oiled				
Gage	**Mean of Gage**	**Min. of Gage**	**Max. of Gage**	**Lbs. Per Sq. Ft.**
7	0.1793	0.1713	0.1873	7.500
8	0.1644	0.1564	0.1724	6.875
9	0.1495	0.1415	0.1575	6.250
10	0.1345	0.1265	0.1425	5.625
11	0.1196	0.1116	0.1276	5.000
12	0.1046	0.0966	0.1126	4.375
13	0.0897	0.0827	0.0967	3.750
14	0.0747	0.0677	0.0817	3.125
15	0.0673	0.0613	0.0733	2.813
16	0.0598	0.0538	0.0658	2.500
17	0.0538	0.0478	0.0598	2.250
18	0.0478	0.0428	0.0528	2.000

Sheet Thickness Tolerances

Cold Rolled Steel Electro Galvanized - Long Terne				
Gage	**Mean of Gage**	**Min. of Gage**	**Max. of Gage**	**Lbs. Per Sq. Ft.**
7	0.1793	0.1713	0.1873	7.500
8	0.1644	0.1564	0.1724	6.875
9	0.1495	0.1415	0.1575	6.250
10	0.1345	0.1285	0.1405	5.625
11	0.1196	0.1136	0.1256	5.000
12	0.1046	0.0986	0.1106	4.375
13	0.0897	0.0847	0.0947	3.750
14	0.0747	0.0697	0.0797	3.125
15	0.0673	0.0623	0.0723	2.813
16	0.0598	0.0548	0.0648	2.500
17	0.0538	0.0498	0.0578	2.250
18	0.0478	0.0438	0.0518	2.000
19	0.0418	0.0378	0.0458	1.750
20	0.0359	0.0329	0.0389	1.500
21	0.0329	0.0299	0.0359	1.375
22	0.0299	0.0269	0.0329	1.250
23	0.0269	0.0239	0.0299	1.125
24	0.0239	0.0209	0.0269	1.000
25	0.0209	0.0179	0.0239	0.875
26	0.0179	0.0159	0.0199	0.750
27	0.0164	0.0144	0.0184	0.688
28	0.0149	0.0129	0.0169	0.625

THICKNESS TOLERANCES PLATE

Permissible Variation in Thickness for Rectangular Carbon, High-Strength Low Alloy, and Alloy-Steel Plates, When Ordered to Thickness.

Note 1 – Permissible variation under specified thickness, 0.01 inch.

Note 2 – Thickness to be measured at 3/8 to 3/4 inch from the longitudinal edge.

Note 3 – For thickness measured at any location other than that specified in Note 2, the permissible maximum over tolerance shall be increased by 75%, rounded to the nearest 0.01 inch.

Tolerance Over Specified Thickness for Width in Inches

Specified Thickness Inches	Wt. Per Sq. Ft. In Lbs	To 84" Excl.	84" To 96" Excl.	96" To 108" Excl.
3/16"	7.66	.03"	.03"	.03"
1/4"	10.21	.03"	.03"	.03"
5/16"	12.76	.03"	.03"	.03"
3/8"	15.32	.03"	.03"	.03"
7/16"	17.87	.03"	.03"	.03"
1/2"	20.42	.03"	.03"	.03"
9/16"	22.97	.03"	.03"	.03"
5/8"	25.53	.03"	.03"	.03"
3/4"	30.63	.03"	.03"	.04"
7/8"	35.74	.03"	.04"	.04"
1"	40.84	.06"	.06"	.07"

Source: ASTM A6, Table 1.

Sheet Thickness Tolerances

Stainless Steel				Lbs. Per Square Foot	
Gage	Mean of Gage	Min. of Gage	Max. of Gage	All 300 Series	All 400 Series
7	0.1874	0.1735	0.2015	7.871	7.7
8	0.165	0.151	0.179	6.93	6.78
9	0.15	0.136	0.164	6.3	6.165
10	0.135	0.129	0.141	5.67	5.562
11	0.12	0.115	0.125	5.04	4.944
12	0.1054	0.1004	0.1104	4.427	4.342
13	0.09	0.086	0.094	3.78	3.708
14	0.0751	0.0711	0.0791	3.154	3.094
15	0.0673	0.0643	0.0703	2.826	2.766
16	0.0595	0.0565	0.0625	2.499	2.451
17	0.0538	0.0508	0.0568	2.259	2.211
18	0.048	0.045	0.051	2.016	1.978
19	0.042	0.039	0.045	1.764	1.726
20	0.0355	0.0335	0.0375	1.491	1.463
21	0.0324	0.0304	0.0344	1.36	1.33
22	0.0293	0.0273	0.0313	1.231	1.207
23	0.0264	0.0249	0.0279	1.1088	1.085
24	0.0235	0.022	0.025	0.987	0.968
25	0.0209	0.0194	0.0224	0.8778	0.8589
26	0.0178	0.0163	0.0193	0.748	0.7315
27	0.0165	0.015	0.018	0.693	0.6781
28	0.0151	0.0136	0.0166	0.634	0.6206
29	0.0138	0.0123	0.0153	0.5796	0.5671
30	0.0125	0.011	0.014	0.525	0.5137

Stainless Steel Plate Thickness

Thickness Tolerance Over Variation * In Inches

Thickness In Inches	Est. Wt. Sq. Ft. In Lbs.	Widths TO 84" lncl.	Widths Over 84" To 120"lncl.	Widths Over 120" To 144" lncl.	Widths Over 144' lncl.
3/16"	8.58	.045"			
1/4"	11.16	.045"			
5/16"	13.75	.045"			
3/8"	16.49	.055"	.060"	.075"	.090"
1/2"	21.66	.055"	.060"	.075"	.090"
5/8"	26.83	.055"	.060"	.075"	.090"
3/4"	32.12	.060"	.065"	.085"	.100"
7/8"	37.29	.060"	.065"	.085"	.100"
1"	42.66	.060"	.075"	.095"	.115"

*Thickness is measured along the longitudinal edges of the plate at least 3/8”, but not more than 3” in from the edge. No plate shall vary more than .0l” under the thickness ordered. Source: ASTM A480 Table Al .17.

Sheet Thickness Tolerances

Hot Dipped Galvanized - Aluminized Steel				
Gage	Mean of Gage	Min. of Gage	Max. of Gage	Lbs. Per Sq. Ft.
8	0.1681	0.1591	0.1771	7.031
9	0.1532	0.1442	0.1622	6.406
10	0.1382	0.1292	0.1472	5.781
11	0.1233	0.1143	0.1323	5.156
12	0.1084	0.0994	0.1174	4.531
13	0.0934	0.0854	0.1014	3.906
14	0.0785	0.0705	0.0865	3.281
15	0.071	0.065	0.077	2.969
16	0.0635	0.0575	0.0695	2.656
17	0.0575	0.0525	0.0625	2.406
18	0.0516	0.0466	0.0566	2.156
19	0.0456	0.0406	0.0506	1.906
20	0.0396	0.0356	0.0436	1.656
21	0.0366	0.0326	0.0406	1.531
22	0.0336	0.0296	0.0376	1.406
23	0.0306	0.0266	0.0346	1.281
24	0.0276	0.0236	0.0316	1.156
25	0.0247	0.0207	0.0287	1.031
26	0.0217	0.0187	0.0247	0.906
27	0.0202	0.0172	0.0232	0.844
28	0.0187	0.0157	0.0217	0.781
29	0.0172	0.0142	0.0202	0.719
30	0.0157	0.0127	0.0187	0.656

Sheet Thickness Tolerances

Electrolitic Tin Plate				
Lb. Per Base Box	**Mean of Gage**	**Min. of Gage**	**Max. of Gage**	**Lb. Per Sq. Ft.**
55	0.0061	0.0055	0.0067	0.253
60	0.0066	0.0059	0.0073	0.276
65	0.0072	0.0065	0.0079	0.298
70	0.0077	0.0069	0.0085	0.321
75	0.0083	0.0075	0.0091	0.344
80	0.0088	0.0079	0.0097	0.367
85	0.0094	0.0085	0.0103	0.39
90	0.0099	0.0089	0.0109	0.413
95	0.0105	0.0094	0.0116	0.436
100	0.011	0.0099	0.0121	0.459
107	0.0118	0.0106	0.013	0.491
112	0.0123	0.0111	0.0135	0.514
118	0.013	0.0117	0.0143	0.542
128	0.0141	0.0127	0.0155	0.588
135	0.0149	0.0134	0.0164	0.62
148	0.0163	0.0143	0.0183	0.68
155	0.017	0.015	0.019	0.712
175	0.0192	0.0162	0.0222	0.804
180	0.0198	0.0168	0.0228	0.827
195	0.0214	0.0184	0.0244	0.895
210	0.0231	0.0201	0.0261	0.964
215	0.0236	0.0206	0.0266	0.987
235	0.0258	0.0228	0.0288	1.079
240	0.0264	0.0234	0.0294	1.102
255	0.028	0.025	0.031	1.171
270	0.0297	0.0267	0.0327	1.24
275	0.0302	0.0272	0.0332	1.263

Aluminum Sheet Thickness Tolerances

36”-48” Wide

Alloys 1100, 3003, 3005, 3105, 5005, 5457

Aluminum			Lbs. Per Square Foot						
Mean Of Gage	**Min. of Gage**	**Max. Of Gage**	**1100 & 3105**	**3003 & 3005**	**5005 & 5457**	**5052 & 5252**	**2024**	**6061**	**5086 & 5083**
0.012	0.01	0.014	0.169	-	0.169	-	-	-	0.165
0.016	0.014	0.018	0.226	0.228	0.226	-	0.232	-	0.221
0.02	0.018	0.022	0.282	0.285	0.282	0.279	0.288	0.282	0.276
0.025	0.023	0.027	0.353	0.356	0.353	0.349	0.36	0.353	0.346
0.032	0.0295	0.0345	0.452	0.456	0.452	0.447	0.461	0.452	0.443
0.04	0.0365	0.0435	0.564	0.57	0.564	0.559	0.576	0.564	0.552
0.05	0.0485	0.0535	0.706	0.713	0.706	0.698	0.72	0.706	0.692
0.063	0.0595	0.0665	0.889	0.898	0.889	0.88	0.907	0.889	0.871
0.08	0.0755	0.0845	1.13	1.14	1.13	1.12	1.15	1.13	1.110
0.09	0.0855	0.0945	1.27	1.28	1.27	1.26	1.3	1.27	1.240
0.1	0.0945	0.1055	1.41	1.43	1.41	1.4	1.45	1.41	1.380
0.125	0.1195	0.1305	1.76	1.78	1.76	1.75	1.8	1.76	1.720
0.16	0.151	0.169	2.27	2.28	2.27	2.23	2.3	2.25	2.220
0.19	0.181	0.199	2.69	2.71	2.69	2.65	2.74	2.69	2.640
0.249	0.235	0.263	3.52	-	3.52	3.49	-	-	3.450

Tolerances

(In Plus and Minus)

Aluminum Plate Thickness

Alloys 1100, 3003, 3005, 3105, 5005, 5457

Thickness Inches	Approx. Wt. Per Sq. Ft.	Thru 39.37	Over 39.37 Thru 59.06	Over 59.06 Thru 78.74
.250"	3.456	0.012	0.014	0.015
.313"	4.31	0.012	0.014	0.015
.375"	5.184	0.017	0.017	0.02
.500"	6.912	0.023	0.023	0.027
.625"	8.64	0.023	0.023	0.027
.750"	10.37	0.031	0.031	0.037
.875"	12.6	0.031	0.031	0.037
1.000"	14.11	0.039	0.039	0.047

Aluminum Sheet Thickness Tolerances
36"-48" Wide
Alloys 5052, 5083, 5086, 5252, 6061

Aluminum			Lbs. Per Square Foot						
Mean of Gage	**Min. of Gage**	**Max. Of Gage**	**1100 & 3105**	**3003 & 3005**	**5005 54&57**	**5052 & 5252**	**2024**	**6061**	**5086 & 5083**
0.012	0.0095	0.0145	0.169	-	0.169	-	-	-	0.165
0.016	0.0135	0.0185	0.226	0.228	0.226	-	0.232	-	0.221
0.02	0.0175	0.0225	0.282	0.285	0.282	0.279	0.288	0.282	0.276
0.025	0.0225	0.0275	0.353	0.356	0.353	0.349	0.36	0.353	0.346
0.032	0.0285	0.0355	0.452	0.456	0.452	0.447	0.461	0.452	0.443
0.04	0.036	0.044	0.564	0.57	0.564	0.559	0.576	0.564	0.552
0.05	0.0445	0.0545	0.706	0.713	0.706	0.698	0.72	0.706	0.692
0.063	0.0585	0.0675	0.889	0.898	0.889	0.88	0.907	0.889	0.871
0.08	0.074	0.086	1.13	1.14	1.13	1.12	1.15	1.13	1.11
0.09	0.084	0.096	1.27	1.28	1.27	1.26	1.3	1.27	1.24
0.1	0.093	0.107	1.41	1.43	1.41	1.4	1.45	1.41	1.38
0.125	0.118	0.132	1.76	1.78	1.76	1.75	1.8	1.76	1.72
0.16	0.15	0.17	2.27	2.28	2.27	2.23	2.3	2.25	2.22
0.19	0.18	0.2	2.69	2.71	2.69	2.65	2.74	2.69	2.64
0.249	0.234	0.264	3.52	-	3.52	3.49	-	-	3.45

Tolerances
(In Plus and Minus)
Aluminum Plate Thickness
Alloys 5052, 5083, 5086, 5252, 6061

Thickness Inches	Approx. Wt. Per Sq. Ft.	Thru 39.37	Over 39.37 Thru 59.06	Over 59.06 Thru 78.74
.250"	3.456	0.012	0.015	0.019
.313"	4.31	0.012	0.015	0.019
.375"	5.184	0.017	0.018	0.022
.500"	6.912	0.023	0.023	0.028
.625"	8.64	0.023	0.023	0.028
.750"	10.37	0.031	0.031	0.037
.875"	12.6	0.031	0.031	0.037
1.000"	14.11	0.039	0.039	0.047

Aluminum Plate Thickness Tolerances
(In Plus and Minus)
Alloys 2024, 7075

Aluminum			Lbs. Per Square Foot						
Mean of Gage	**Min. of Gage**	**Max. of Gage**	**1100 & 3105**	**3003 & 3005**	**5005 & 5457**	**5052 & 5252**	**2024**	**6061**	**7075**
0.012	0.0095	0.0145	0.169	-	0.169	-	-	-	0.175
0.016	0.0135	0.0185	0.226	0.228	0.226	-	0.232	-	0.232
0.02	0.0175	0.0225	0.282	0.285	0.282	0.279	0.288	.2B2	0.291
0.025	0.0225	0.0275	0.353	0.356	0.353	0.349	0.36	0.353	0.364
0.032	0.03	0.0345	0.452	0.456	0.452	0.447	0.461	0.452	0.466
0.04	0.038	0.042	0.564	0.57	0.564	0.559	0.576	0.564	0.582
0.05	0.047	0.053	0.706	0.713	0.706	0.698	0.72	0.706	0.727
0.063	0.06	0.066	0.889	0.898	0.889	0.88	0.907	0.889	0.916
0.08	0.0765	0.0835	1.13	1.14	1.13	1.12	1.15	1.13	1.16
0.09	0.0885	0.0935	1.27	1.28	1.27	1.26	1.3	1.27	1.31
0.1	0.0965	0.1035	1.41	1.43	1.41	1.4	1.45	1.41	1.45
0.125	0.1215	0.1285	1.76	1.78	1.76	1.75	1.8	1.76	1.82
0.16	0.153	0.167	2.27	2.28	2.27	2.23	2.3	2.25	2.32
0.19	0.183	0.197	2.69	2.71	2.69	2.65	2.74	2.69	2.77
0.249	0.234	0.264	3.52	-	3.52	3.49	-	-	3.62

Tolerances
(In Plus and Minus)
Aluminum Plate Thickness
Alloys 2024,7075

Thickness Inches	**Approx. Wt. Per Sq. Ft.**	**Thru 39.37**	**Over 39.37 Thru 47.24**	**Over 47.24 Thru 55.12**	**Over 55.12 Thru 59.06**	**Over 59.06 Thru 70.87**	**Over 70.87 Thru 78.74**
.250"	3.456	0.012	0.015	0.015	0.015	0.019	0.019
.313"	4.31	0.012	0.015	0.015	0.015	0.019	0.019
.375"	5.184	0.017	0.018	0.018	0.018	0.022	0.022
.500"	6.912	0.023	0.023	0.023	0.023	0.028	0.028
.625"	8.64	0.023	0.023	0.023	0.023	0.028	0.028
.750"	10.37	0.031	0.031	0.031	0.031	0.037	0.037
.875"	12.6	0.031	0.031	0.031	0.031	0.037	0.037
1.000"	14.11	0.039	0.039	0.039	0.039	0.047	0.047

International Thickness Tolerance of Perforated Plates and Sheets

Table 4: Tolerance on Thickness of USA Standard Specifications For Industrial Perforated Plate and Sheets.

Gage	**Steel**		**Tolerance on Gage**	
Standard (metric) mm	**USA Industrial Standard in.**	**USA Industrial Decimal Equivalent in.**	**Standard (metric) mm**	**USA Industrial Standard in.**
25.40	1		+1.00	+0.04
			-0.25	-0.01
22.40	7/8		-0.25	+0.035
			+0.89	-0.01
19.00	3/4		+0.84	+0.033
			-0.25	-0.01
16.00	5/8		+0.79	+0.031
			-0.25	-0.01
12.50	1/2		+0.76	+0.03
			-0.25	-0.01
9.50	3/8		+0.66	+0.026
			-0.25	-0.01
8.00	5/16		+0.64	+0.025
			-0.25	-0.01
6.30	1/4		+0.53	+0.021
			-0.25	-0.01
4.75	3/16		+0.51	+0.02
			-0.25	-0.01
4.25	No. 8 USS gage	0.1644	±0.25	±0.010
3.35	10	0.1345	±0.25	±0.010
3.00	11	0.1196	±0.25	±0.010
2.65	12	0.1046	±0.25	±0.010
1.90	14	0.0747	±0.18	±0.007
1.52	16	0.0598	±0.13	±0.005
1.21	18	0.0478	±0.10	±0.004
0.91	20	0.0359	±0.08	±0.003
0.76	22	0.0299	±0.08	±0.003
0.61	24	0.0239	±0.08	±0.003
0.45	26	0.0179	±0.05	±0.002
0.38	28	0.0149	±0.05	±0.002
0.30	30	0.0120	±0.05	±0.002

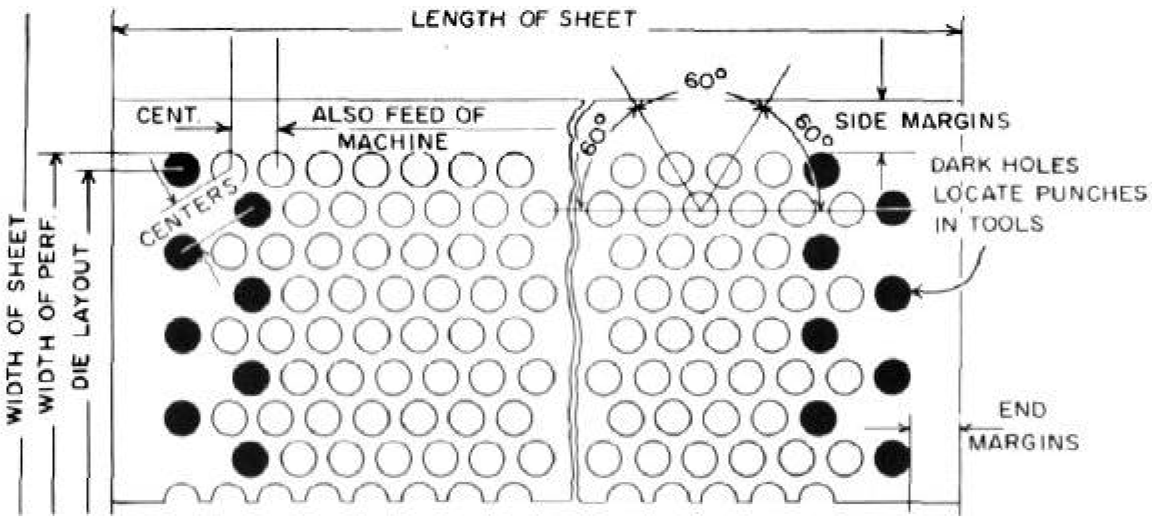
HOLE PATTERNS

Round Holes

Round holes ranging from under .020" to over 6" account for 80% of the production of the perforating industry. This shape is the most versatile in its application and provides a wide range of open areas as well as a handsome appearance. Round holes are produced with greater efficiency and less expense than any other hole shape. The dies and punches that make round holes are the most cost efficient to build and maintain.

The 60° Staggered Round Hole Pattern

The 60° staggered formation is the most popular hole arrangement because of its inherent strength and the wide range of open areas it provides. The diagram below illustrates the essential die design and perforating practices for producing l/4" round holes on 3/8" centers in a 60° staggered formation. The basic perforating die layout includes two rows of punches, arranged as the illustration shows, in an open staggered pattern. The actual punches in the die are indicated by the solid black holes. The feed of the press is from right to left.



The Step and a Half Punching Process

Notice first that the arrangement of the punches is more open than the hole pattern produced in the perforating process. The finished hole pattern is produced by feeding the sheet through the press in increments equal to the required center distance. The wide spacing of the punches is necessary to give sufficient strength to the die and to provide adequate punching force to each punch. Notice that the pattern at the beginning and at the end of the sheet is not complete. This is the result of the open spacing of the punches and is explained later under the heading, **End Margins**.

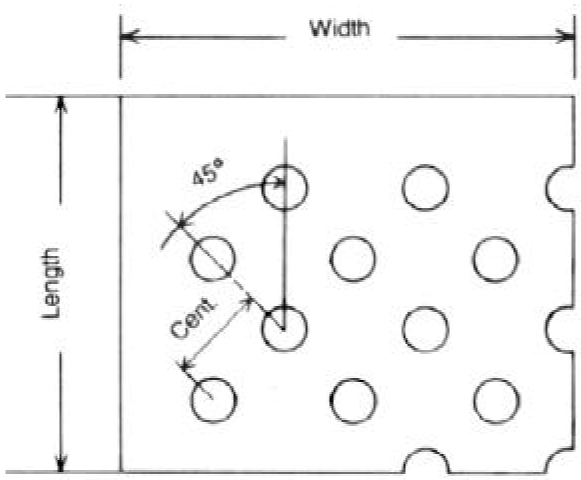
The fact that the arrangement of the punches in the die and the holes in the perforated pattern are different indicates that two different staggered hole patterns can be produced from the same die.

The Closed Hole Pattern: To produce a hole pattern on 3/8" centers as illustrated, the material is fed through the press in increments equal to the center distance of 3/8". This results in the "closed pattern" for this particular die.

The Open Pattern: The open pattern from the same die arrangement results when the feed is increased to produce a hole pattern with the actual center distance of the punch arrangement. A straight line hole pattern is also possible from this die if one of the rows of punches is removed or "idled."

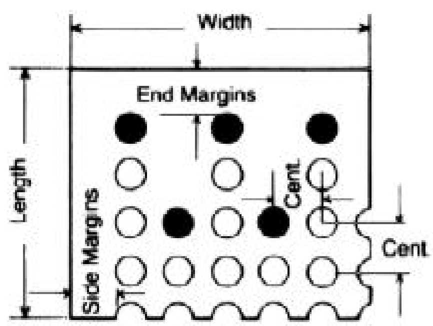
The 45" Staggered Round Hole Pattern

This pattern is a standard IPA option. Although it is stronger than straight row patterns it is not as strong, nor is it as versatile in providing compact hole spacing and high open areas as the 60º pattern.

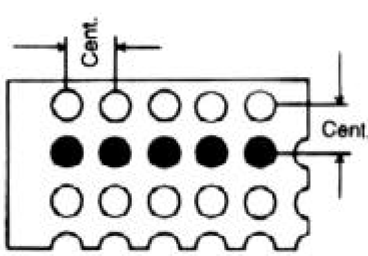


The Straight Line Pattern

The straight line patterns can be produced by an open punch arrangement with a stepped punching procedure or with a closed punch arrangement; both methods are illustrated below. The stepped procedure produces an unfinished end pattern while the closed punch arrangement produces a finished end pattern. A straight line pattern of holes is weaker than a staggered arrangement and has a tendency to stretch the material to a greater degree.



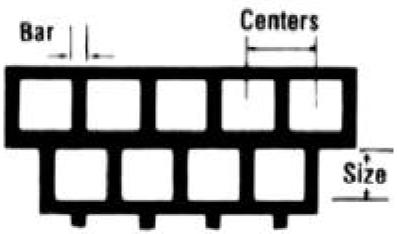
Open Punch Arrangement



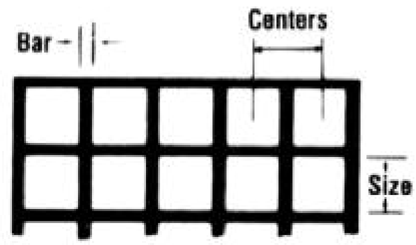
Closed Punch Arrangement

Square Holes

Square holes are principally used for grills and machine guards offering a maximum of open area to permit good visibility and through-put while providing the necessary protection or decorative cover. Available in both straight line and staggered patterns, the straight line pattern is standard for square holes. Both variations are weaker than he round hole patterns. The sharp corners on square hole tooling makes it more subject to wear and vulnerable to the stresses of the punching process, increasing tooling costs and reducing production rates. Square hole patterns are generally more expensive than the equivalent round hole pattern.



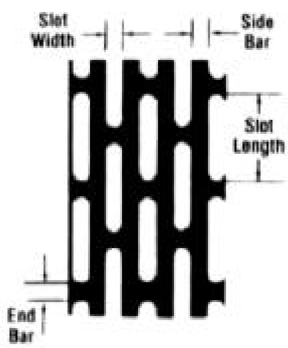
Square Perforations
Staggered



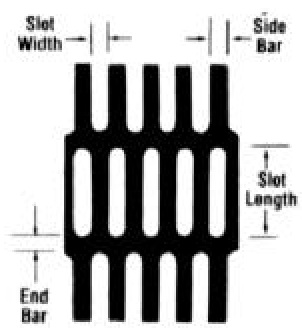
Square Perforations
Straight Lines

Slots

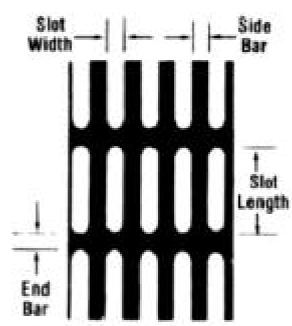
Slots in the Side Staggered, End Staggered and Straight Line arrangements illustrated below are also IPA standards. They are particularly well suited to sorting and grading of solid objects. Typical applications include the sizing of ball bearings or the separation of fingerlings at fish hatcheries. In both applications a single dimension of the object determines the size. The elongated slot increases the through-put in such applications.



Slots
Side Stagger



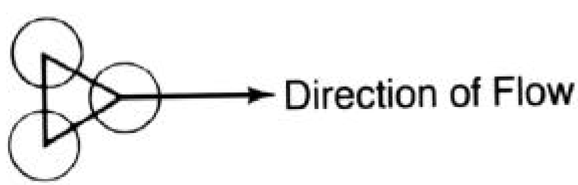
Slots
End Stagger



Slots
Straight Lines

Flow of Material

If the sieving process requires a specified arrangement of holes the direction of flow must be clearly stated.



MARGINS

A. End Margins: The stepped perforating procedure (see page 88) results in an unfinished pattern at the beginning and at the end of the workpiece. This unfinished pattern is the standard IPA end pattern.

The finished end pattern required special tooling or at best idling of the last row of punches to complete the pattern, thus slowing the perforating process and increasing costs. The finished end pattern is non standard and must be specified if desired. Some special dies may also be made with the finished end pattern.

Note: Cost savings may be attained by specifying minimum or no end margins.

IPA members with roll fed perforating presses may require +2-l/4" blank margins on one end of 16ga thru 1" thicknesses when producing certain hole patterns through these particular machines.

B. Side Margins: Margins along the sides of the perforated sheet introduce stresses into the sheet and cause distortion. The wider the side margin the greater the distortion, so they should be kept to a minimum width. Excessive or uneven margins can actually cause buckling or a degree of distortion that cannot be completely corrected by roller leveling. Additionally, when holes are small and the percentage of open area is high, distortion can become exaggerated.

The minimum side margin is determined by the die layout and the width of the material.

Consult with your IPA member supplier.

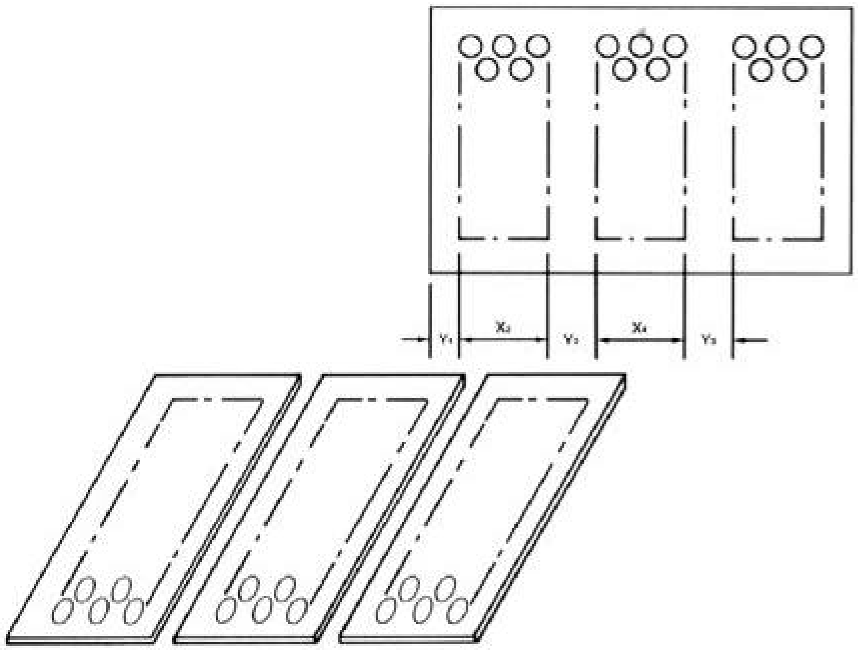
Approximate side margins of perforated metal in sheet, plate or coil form as produced thru presses and limited by the die layout.

Thickness	Approximate Minimum Unperforated Side Margins
30GA-20GA	Sale Edge
Over 20GA-14GA	1/5"
Over 14GA-8GA	¼"
Over 8GA-3/8"	½"
Over 3?8"-5/8"	¾"
Over 5/8"-1"	1"

BLANK AREAS

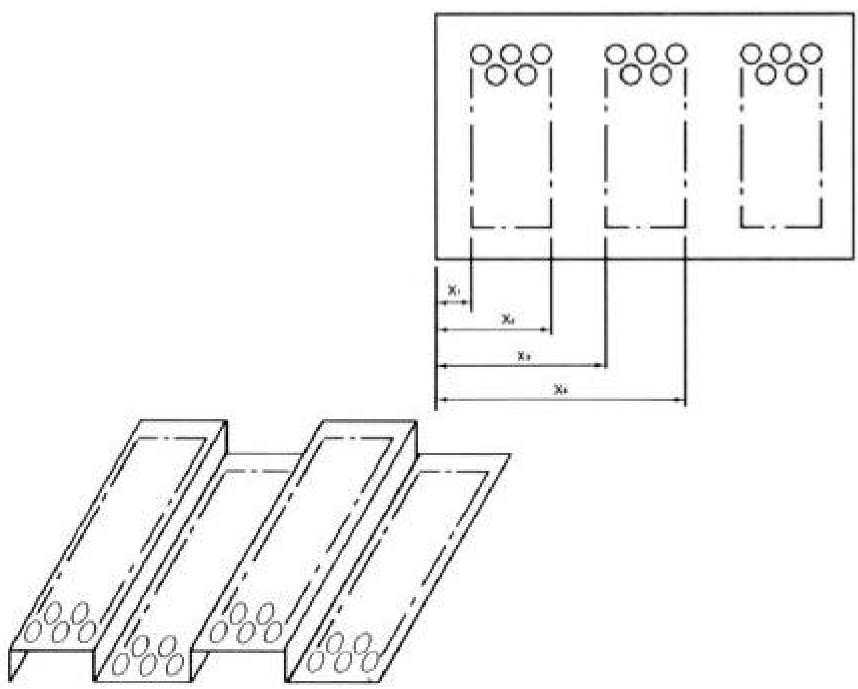
According to the application user should give the dimensions as per figure A or B.

Figure A - Standard Design



Each single value X is subject to the permitted tolerance of pitch. Tolerance must be arranged between user and supplier.

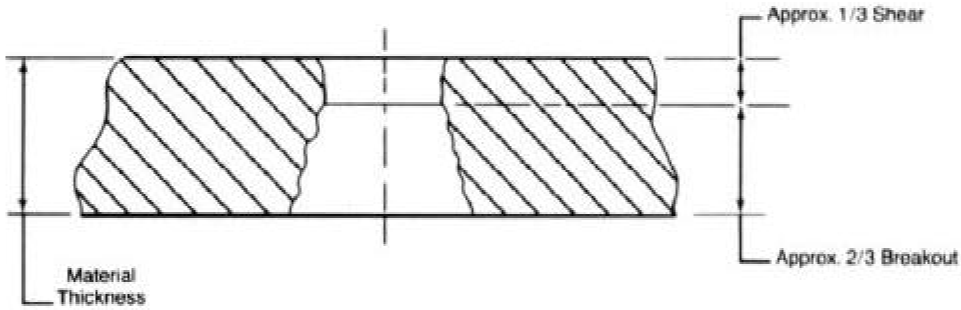
Figure B - Special design to avoid cumulative errors entails more work **-** Higher Costs!



Requirements of the client must correspond to the capabilities of the manufacturer. Tolerance of each value = Tolerance on Pitch + Tolerance of Feeding System (repeatability on interrupted work).

BREAKOUT OF HOLES

When perforating, the resulting hole in the metal shows a slight unevenness on its inside perimeter, as well as a slight taper from the punch entry side to the breakout side of the hole.



Cross Section of Hole

The general result of the breakout in the hole indicates approximately a l/3 penetration or shear and a 2/3 breakout. The taper in the hole depends on the type and thickness of the metal and the size of the hole.

HOLE BURRS AND SHEARING BURRS

The normal view of drawings (upper side) is the punch entry side. The burr-side is the underside. Burr-side must be stated explicitly for asymmetrical plates and sheets which require additional work after perforating.

Shearing burrs normally are placed on the same side as hole burrs. Due to rational manufacturing, shearing burrs may also be placed on the opposite side if not otherwise specified.

In the flattening process, burrs may be pushed back into the holes, reducing the open area slightly.

The burr height should be determined by measuring with a micrometer the thickness of the sheet close to the perforated holes (bridge, if possible, or unperforated edge), and repeating the same measurement on the perimeter of the hole.

The burr height will result from the difference between these two measurements.

These measurements must be taken reasonably close to each other so that they are not influenced by the sheet thickness tolerances.

Acceptable burr heights at normal perforating & shearing conditions.

Thickness of Sheet	**Commercial Burr Height (Max.)**	**Superior**
Up-24 GA	.005”	.003”
Over 24GA-16GA	.006”	.005”
Over 16GA-1/8”	.008”	.006”
Over 1/8”-1/4”	.012”	.008”
Over ¼”-7/16”	.022”	.018”
Over 7/16”	.028”	.020”

MISSING HOLES

During the perforating process punches may break, resulting in imperfect or missing holes in the metal. The riskof imperfect or missing holes is greatest with critical perforating; i.e., small holes, stainless steel, large open area and as the holes approach the minimum hole size and bar width.

The number and/or percentage of missing or imperfect holes per square foot of material have a direct relationship to the spoilage factor and resultant cost of the perforated items. This requirement **must** be discussed with the perforator in order to establish the price of the perforated product prior to the placement of the order.

The Minimum Hole Size

The smallest hole that is possible to perforate varies with the material type and thickness. A rule of thumb for carbon steel and aluminum is that the hole diameter should not be less than the thickness of the material. The closer the 1 -to- 1 relationship between hole diameter and material thickness is approached, the higher the probability for tool failure, and the greater the precautions necessary to protect against it. These factors all increase the cost of production. For stainless steel and other higher strength materials, it is best to drop at least one thickness gage thinner than hole diameter.

The Minimum Bar Width

The same 1 -to-l relationship to thickness is the limit for bar width as well as hole diameter; keep the bar width greater than the thickness of the material to avoid problems. As the l-to-l relationship is approached, the increasing number of punches required sharply escalates the press tonnage needed to perforate the pattern.

WELD REPAIRS

Weld repairs may be necessary. If perfect plates are necessary, consult your IPA supplier.

HEAT TREATED PLATE HARDNESS TOLERANCE: FULL THROUGH HARDNESS

Commercial Quality – ±20 Brinell total
Superior Quality – ±15 Brinell total
Custom Quality – To be determined mutually between customer and perforated supplier.

SURFACE FINISH

Slight surface damage resulting from the perforating process can not be prevented.

Hot rolled steel is the product reduced from slab to required thickness at elevated temperatures. This produces a scale or oxide on the metal surface. Cold rolled steel is the product that has been substantially cold reduced at room temperature. It is characterized by an improved clean surface, greater uniformity in thickness, and improved mechanical properties compared to hot rolled steel. Pickled steel is the product from which the scale or oxide has been removed from the surface by a dilute acid solution.

Polished sheets - even though we will take extreme care in the handling of the material, we will **not** be responsible for the surface finish after processing. If the polished sheets have to be roller leveled, surface protection must be removed beforehand and paper inter-leaved afterwards. Spot grinding of material will not exceed .0l” under the specified thickness to remove surface imperfections.

CLEANLINESS – PERMISSIBLE LUBRICATION

The perforating process requires the use of lubricants. The natural condition of perforated material may vary from a light to a heavy concentration of oils and are furnished that way as a commercial product.

Normal surface condition leaving the perforating equipment: Perforated sheets or plate may have an oily film. There may be some accumulation and/or seepage of the lubricant.

A. Wiped Sheets - Wiped perforated sheets or plates are produced by rotary brushing or wiping after leaving the machinery, or by applying absorbent products. A light film will remain with some traces of absorbent particles.

B. Degreased Sheets - If buyer specifies total removal of lubricants, seller is not liable for any surface corrosion resulting from the absence of lubricants.

The above cleanliness requirements are additional cost factors and must be discussed with the perforator prior to placement of order if they are so required.

OVER-RUNS AND UNDER-RUNS

When perforated material is ordered in pounds or footage, as in the case of material produced from coil (unless otherwise agreed upon) the quantity ordered will be subject to the following:

Permissible Mill Quantity Variation of Sheets Produced from Coil

80,000# and Over **-** 5% Over or 5% Under

40.000# Thru 79.999# **-** 10% Over or 5% Under

20,600# Thru 39,999# **-** 15% Over or 10% Under

10,000# Thru 19,999# **-** 25% Over or 15% Under

0# Thru 9,999# **-** 25% Over or 25% Under

If an exact quantity is required the quote and the purchase order must contain an explicit statement that the order is for an exact quantity, and that mill and industry standards for variation do not apply.

Possible Quantity Variation of Sheets as Produced From Sheets or Plate

Small Quantities:

1 – l0 Sheets or Plates (<10 SHOULD BE EXACT, NO VARIATION)

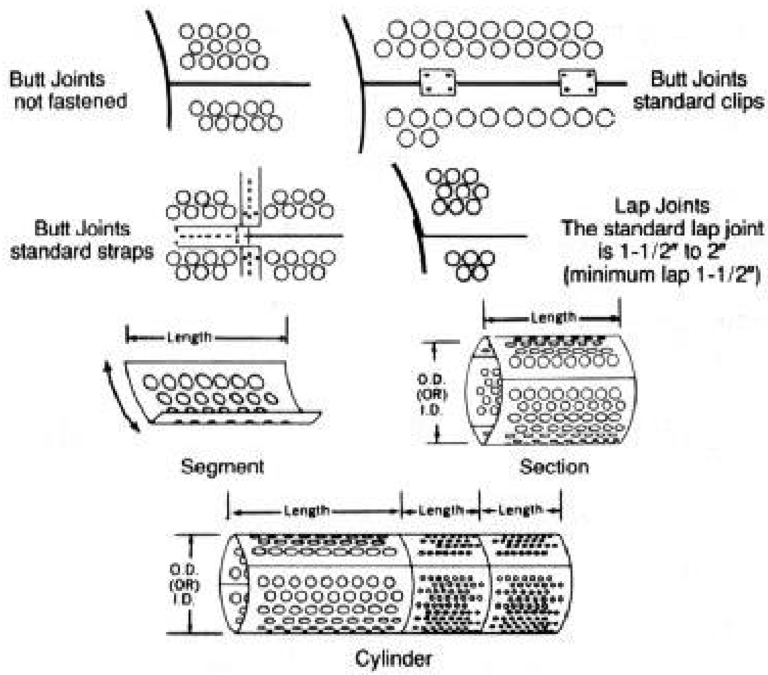
1 – 20 Sheets or Plates **-** (1 to 2 Sheet Variation)

21–50 Sheets or Plates **-** (2 to 5 Sheet Variation)

51 – l00 Sheets or Plates **-** (5 to 10 Sheet Variation)

>100 Sheets or Plates **-** (±10% Variation)

Revolving Screens



Crowned Screens

If a screen plate is to be "crowned" state the amount of the crown measured at the centerline. Unless otherwise specified, the standard crowns for screens 3/l 6" thick and heavier will be furnished as follows:

For 3' or 4' wide vibrating screens – l/2" crown
For 5' wide vibrating screens – 3/4" crown
For 6' wide vibrating screens and wider – 1" crown

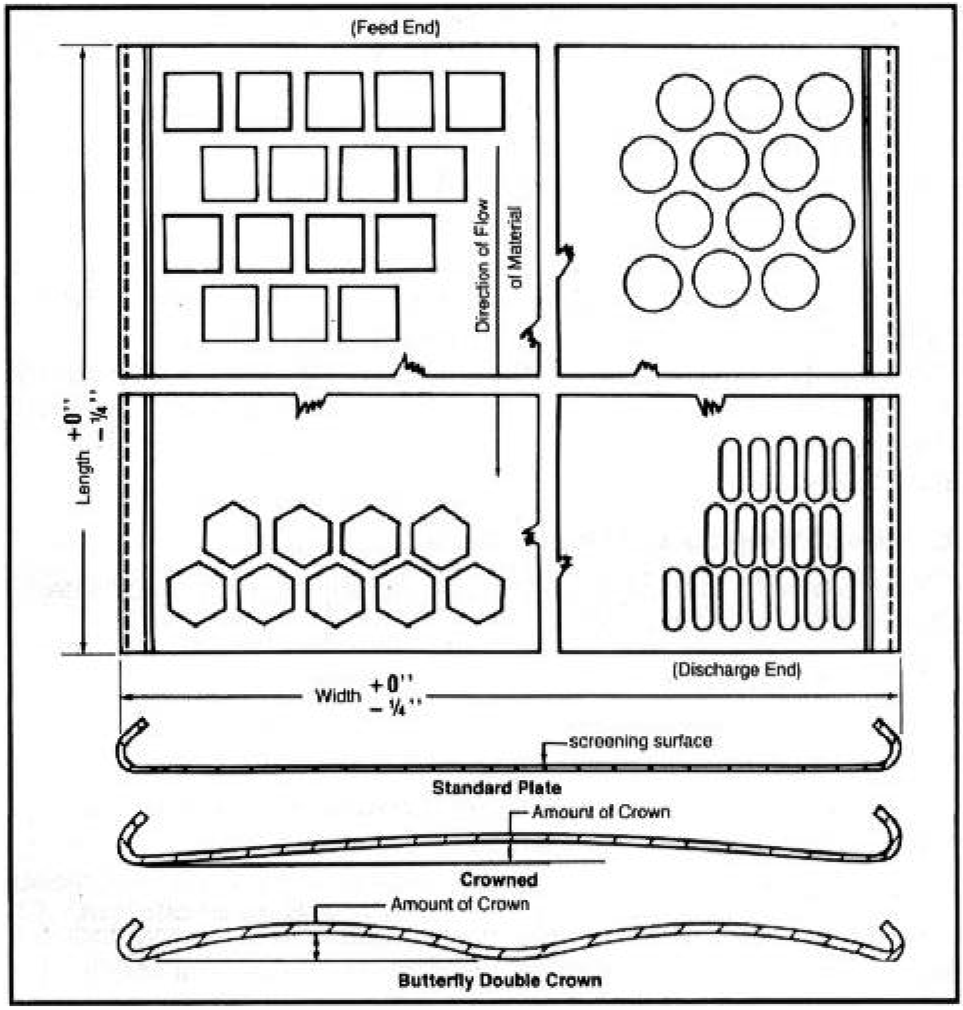
Width: The "width" is the dimension at right angles to the flow of material. Specify the overall width. If hook flanges are required, specify: "width (measured outside the hook flanges)."

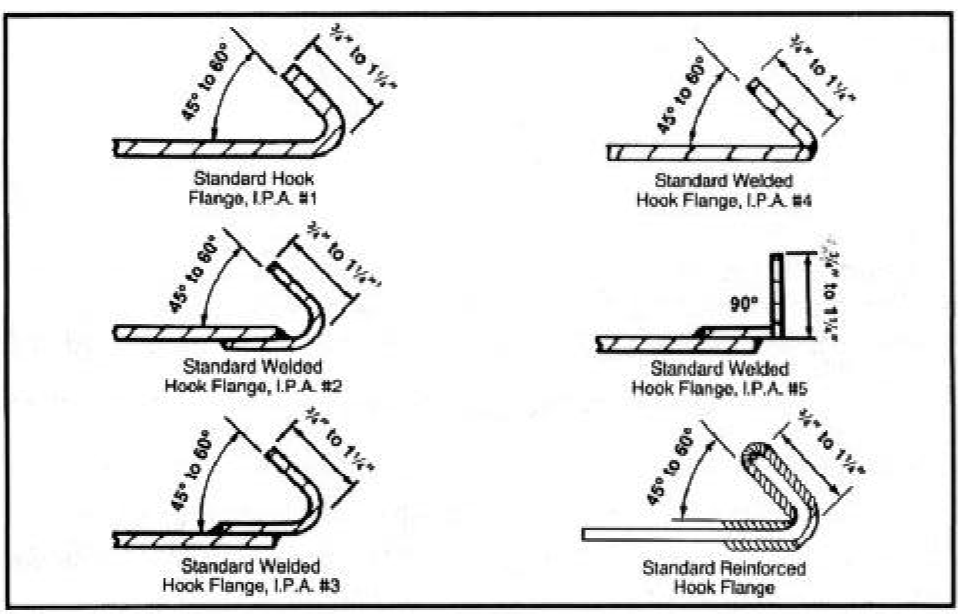
Tolerance of the screen width **-** Plus 0" minus l/4"

Length: The "length" is the dimension of the Perforated Screen Plate that is parallel to the flow of material being screened. Specify the overall length.

Tolerance of the screen length - Plus 0" minus 1/4"

Standard Plate for Vibrating Screens





IPA Trade Practices

Although each IPA member establishes their own terms and conditions, the following trade practices and terms of sale prevail generally throughout the industry.

1. Description of Goods Sold.

Perforated materials provided under this contract shall be in accordance with Seller' s quoted specifications and/or drawings (specifications). The industry Perforating Standards and Practices provided for in "Designers, Specifiers and Buyers Handbook for Perforated Metals" © 1978 shall prevail unless specifically excluded or modified.

No changes may be made in the specifications after the acceptance date unless agreed to by Seller in writing. In the event any such changes are made, Seller may revise its price and delivery schedule accordingly.

2. Units of Weights and Measure.

Any reference to units of weight or measure for perforated material shall apply after perforating.

3. Pre-Production Samples.

Prices stated shall not apply to any pre-production samples.

4. Inspection Procedures.

Seller' s prices are based on normal inspection and testing procedures as determined and performed by Seller.

5. Packing.

Seller will pack all shipments in accordance with normal industry standards. Upon request, Seller will provide special packaging, but reserves the right to change its price and delivery schedules if such packaging requires additional risk, expense or time.

6. Sales, Use and Other Taxes.

Buyer shall pay or reimburse Seller for any sales, use, excise, occupational, or other tax arising directly or indirectly from this sale transaction or the performance thereof, or from the use by any person of the perforated material sold, which Seller may be required to pay or collect, and any legal fees or other expenses incurred by Seller in connection therewith. Such taxes are not included in the quoted price.

7. Over-runs and Under-runs.

Where mill quantity is involved, the permissible mill quantity variation applies. In the case of coil, unless otherwise agreed upon, the quantity expressed in pounds or footage will be subject to published mill variations.

Where an exact quantity must be delivered, this agreement must contain an explicit statement that the order is for an exact quantity and that mill and industry standards for variation do not apply.

8. Transportation.

All prices and deliveries are F.O.B. Shipping Point and risk of loss shall pass to Buyer upon delivery to the carrier. Buyer shall specify type of carrier and routing. In the absence of such specifications, Seller will use its best judgment in selecting a carrier and shipping the goods, but shall not be liable for any delays or charges resulting from its selection.

9. Escalator.

The purchase price specified shall be adjusted to include any net increases in Seller's material and labor costs occurring between the date of acceptance of this contract and the date of shipment. Seller shall maintain records of the material and labor costs for manufacturing the perforated materials and shall compute such costs upon the date of acceptance of this contract and the date of shipment in order to arrive at such adjustment to the purchase price.

10. Payment Terms.

Terms for payment and discount are specified in the sale documents. Any discount allowed applies only to the invoiced value of the perforated material and not to any part of the transportation charges, taxes and/or other charges.

11. Quotations-Acceptances.

Quotations are valid for thirty days only from date of issuance and acceptance must be received by Seller in writing at its main office. No other acceptance, oral or written, will be binding on Seller. Acceptance of this quotation is expressly limited to the Terms and Conditions of this quotation and the rights of the parties shall be governed exclusively by the Terms and Conditions hereof. If the quotation is accepted and Buyer' s order form is used for the purpose, it is expressly understood and agreed that the Terms and conditions herein shall prevail insofar as the same may in any way conflict with the provisions set forth in such order forms of the Buyer, and the issuance of such order form by Buyer shall be deemed to be Buyer' s assent to the foregoing.

12. Quotations on Buyer' s Specifications.

If quotation, or any part thereof, is made pursuant to drawings or blueprints furnished by the Buyer, Seller reserves the right to recheck quotation before accepting order at the quoted prices and to adjust prices in the case of any error.

13. Buyer' s Credit on Default.

If, in the judgment of Seller, the financial condition of Buyer at any time does not justify initiation or continuance of production or shipment on the terms specified, Seller may require full or partial payment in advance.

14. Delays.

Seller shall not be liable for loss or damage due to delay in manufacture or delivery resulting from any cause beyond Seller' s reasonable control, including, but not limited to, compliance with any regulations, orders or instructions of any Federal, State or Municipal Government or any department or agency thereof, acts of God, acts or omissions of the Buyer, acts of civil or military authority, fires, strikes, factory shutdowns or alterations, embargoes, war, riot, delays in transportation or inability due to causes beyond the Seller' s reasonable control to obtain necessary labor, manufacturing facilities or materials from the Seller' s usual sources and any delays resulting from any such cause extends the delivery date accordingly. IN NO EVENT SHALL THE SELLER BE LIABLE FOR SPECIAL OR CONSEQUENTIAL DAMAGES FOR ANY DELAY FOR ANY CAUSE.

15. Errors in Weight or Number Delivered.

Seller shall have no liability for errors in weight or quantity delivered unless claim is made by Buyer within ten (10) days after receipt of shipment. If such timely claim is made by Buyer, Seller may either ship the quantity necessary to make good the deficiency or, at Seller' s option, credit Buyer with the invoice price of the deficiency. This shall be Buyer' s exclusive remedy for such errors.

16. Patent infringement.

Buyer shall save the Seller harmless from all loss, damage or liability, including attorneys' fees, arising out of the manufacture by Seller for the Buyer of any patented device or a part thereof or on account of the use of such articles by Buyer, the patents for which Seller does not own or control.

17. Government Price Controls.

Seller reserves the right to cancel orders in the event selling prices are established by government regulations which are lower than prices quoted.

16. Government Production Standards.

Seller hereby certifies that the perforated material was produced in compliance with all applicable requirements of Sections 6,7 and 12 of the Fair Labor Standards Act, as amended, and all regulations and orders of the U.S. Department of Labor issued under Section 14 thereof.

19. Correction or Errors.

Seller reserves the right to correct all typographical or clerical errors which may be present in the prices or specifications.

20. Warranty Matters.

(a) Consumer Products. Since the Seller is supplying perforated material for incorporation into another product by Buyer which may or may not be considered a "Consumer Product" as defined in the Magnuson-Moss Warranty Act, it is agreed that SELLER MAKES NO WARRANTY OF ANY NATURE WHATSOEVER, EXPRESS OR IMPLIED, WITH RESPECT TO MATERIAL WHICH MAY BECOME INCORPORATED INTO A CONSUMER PRODUCT. THERE ARE NO IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR USE WITH RESPECTTO SUCH GOODS

(b) Commercial Products. Seller warrants only to Buyer the perfo-
rated material sold against defects in material and workmanship for a period of thirty (30) days after Buyer' s receipt of shipment. THE' OBLIGATION OF SELLER UNDER THIS WARRANTY SHALL BE LIMITED TO REPAIRING OR REWORKING F.O.B. SELLER' S PLANT, OR ALLOWING CREDIT AT SELLER' S OPTION, ANY PERFORATED MATERIAL WHICH MAY PROVE TO BE THUS DEFECTIVE. PROVIDED THAT BUYER GIVES SELLER PROMPT NOTICE OF THE DEFECT OR DEFECTS DURING THE WARRANTY PERIOD AND INSPECTION, IF REQUIRED BY SELLER, CONFIRMS THE DEFECT OR DEFECTS. IT IS EXPRESSLY AGREED THAT THIS REMEDY OF REWORKING, REPLACEMENT, OR CREDIT,AT SELLER' S OPTION, IS THE EXCLUSIVE REMEDY UNDER THIS WARRANTY

Goods returned without prior notification to Seller will not be accepted and will be returned to Buyer F.O.B. Seller's Plant. Expenses incurred by Buyer in repairing or replacing any defective product will not be allowed except by written permission of Seller.

THIS SALE IS MADEONTHE EXPRESS UNDERSTANDINGTHAT THERE ARE NO EXPRESS WARRANTIES OTHER THAN THOSE CONTAINED IN THIS AGREEMENT, AND THAT THERE ARE NO IMPLIED WARRANTIES THAT THE GOODS SHALL BE MERCHANTABLE OR FIT FOR A PARTICULAR PURPOSE.

THE SELLER SHALL NOT BE LIABLE FOR ANY SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES OR FOR LOSS, DAMAGE OR EXPENSE DIRECTLY OR INDIRECTLY ARISING FROM THE GOODS SOLD OR THE .USE THEREOF OR FROM ANY OTHER CAUSE WHETHER BASED ON BREACH OF THIS CONTRACT BY SELLER. OR WARRANTY (EXPRESS OR IMPLIED) OR TORT OR CONTRACT.

21. Products Liability Indemnity.

Buyer agrees at its own expense to defend and hold Seller harmless in the event any suits are instituted or claims are made against Seller, whether groundless or not, asserting any damages or liability relating to any product of Buyer which incorporates or utilizes perforated material sold to Buyer. Buyer' s indemnification shall include, but not be limited to, all Seller' s costs, damages, expenses, attorneys' fees and liabilities associated with any such suit or claim.

22. Tooling.

All tooling used by the Seller in the processing of the perforated material shall remain the property of Seller. Invoices for tooling charges may be rendered prior to commencing the processing of the perforated material.

23. Scrap.

Scrap material resulting from the processing of the perforated material shall be the property of the seller.

24. Customer' s Material.

Despite the best precautions taken by the Seller, material may be spoiled in processing due to operator' s oversight, failure of tool or equipment, or inherent characteristics of the material beyond the processor's control.

Where a customer chooses to supply the raw material, he assumes responsibility for any spoilage that takes place in the course of processing or during transportation to the Seller' s plant and while it is awaiting processing. The charge for perforating services covers only the labor involved and doesn't include replacement of material.

For these reasons, the Seller will provide credit for perforating services only and the replacement of the material is the Buyer' s obligation.

Material furnished by the buyer shall be shipped to the Seller freight prepaid and all risk of loss or damage to the material shall remain with the Buyer. Buyer hereby indemnifies and holds Seller harmless against any and all claims for loss, liability, injury or damage arising out of or in connection with the perforated material and/or workmanship applied to or used in connection with the Buyer' s material. In the event Buyer- supplied material is defective, Seller reserves the right to change its price and delivery schedules if such defects cause additional risk, expense or time in repairing the goods.

25. Use of Lubricants.

The perforating process requires the use of lubricants. The natural condition of perforated material may vary from a light to heavy concentration of oils. Quoted prices do not include degreasing, and if Buyer specifies that the material must be degreased, there will be an additional charge for degreasing. If Buyer specifies total removal of lubricants, Seller is not liable for any surface corrosion resulting from the absence of lubricants.

26. Cancellation, Changes or Alterations.

Orders placed cannot be cancelled or altered nor can referred deliveries of goods completed or in process be extended beyond original specified delivery dates, except with Seller' s express written consent and upon terms which will indemnify Seller against loss.

27. Limitation on Waiver of Breach.

The waiver by Seller of any breach of this contract shall be limited to the particular instance and shall not operate or be deemed to waive any future breach of the same provision or any other provision on the same or any other occasion, nor operate as a waiver of Seller' s right to enforce any rights by such remedies as may be appropriate.

28. Seller' s Remedies Cumulative.

The rights and remedies of Seller under this contract shall be cumulative and the exercise of any one of them shall not be exclusive of any other right or remedy provided by this contract or allowed by law.

29. Assignment of Contract.

This contract may not be assigned by Buyer without the prior written consent of Seller. Any assignment without such prior consent shall be void.

30. Entire Agreement.

This contract contains the entire agreement between the parties and is not subject to modifications except by written agreement signed by both parties.

31. Law Governing Contract.

This contract shall be governed by the internal laws of the State in which Seller's mail office is located.

Metric Conversion Table

Millimeters	x	0.03937	=	Inches
"	=	25.4	x	Inches
Meters	x	3.2809	=	Feet
"	=	0.3048	x	Feet
Kilometers	x	0.621377	=	Miles
"	=	1.6093	x	Miles
Square centimeters	x	0.155	=	Square inches
" "	=	6.4515	x	Square inches
Square meters	x	10.7641	=	Square feet
" "	=	0.0929	x	Square feet
Square kilometers	x	247.1098	=	Acres
" "	=	0.004047	x	Acres
Hectares	x	2.471	=	Acres
"	=	0.4047	x	Acres
Cubic centimeters	x	0.061025	=	Cubic inches
" "	=	16.3872	x	Cubic inches
Cubic meters	x	35.314	=	Cubic feet
" "	=	0.02832	x	Cubic feet
" "	x	1.308	=	Cubic yards
" "	=	0.765	x	Cubic yards
Liters	x	61.023	=	Cubic inches
"	=	0.01639	x	Cubic inches
"	x	0.26418	=	U.S. gallons
"	=	3.7854	x	U.S. gallons
Grams	x	15.4324	=	Grains
"	=	0.0648	x	Grains
"	x	0.03527	=	Ounces Avoirdupois
"	=	28.35	x	Ounces Avoirdupois
Kilograms	x	2.2046	=	Pounds
"	=	0.4536	x	Pounds
Kilograms per square centimeter	x	14.2231	=	Lbs. per sq. inch
" " " "	=	0.0703	x	Lbs. per sq. inch
Kilogram per cubic meter	x	0.06243	=	Lbs. per cubic foot
" " " "	=	16.0189	x	Lbs. per cubic foot
Metric Tons (1,000 kilograms)	x	1.1023	=	Tons (2,000 lbs.)
" "	=	0.9072	x	Tons (2,000 lbs.)
Kilowatts	x	0.3405	=	Horsepower
"	=	0.746	x	Horsepower

How to Cut the Cost of Steel Parts*

If flat-rolled steel is the basic material for your product, here are some suggestions from Armco Steel that may help you reduce manufacturing costs:

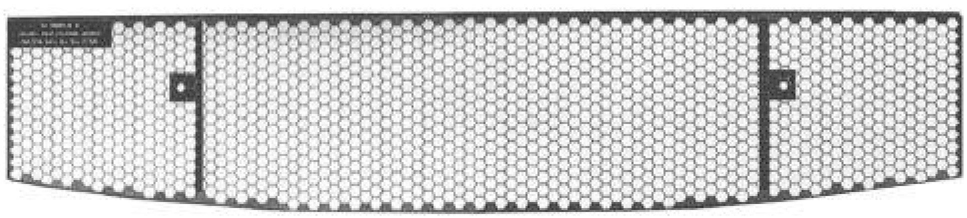
Coil vs. cut-to-length. Material cost per pound is lower for coil, and coils are easier, faster, and safer to handle than cut lengths. Total scrap tends to be less with coils.

Preproduction processing. Slitting and cutting to length are often done more economically by a nearby metal service center than by a mill supplier. Also, a service center can reduce your cost of possession, as well as reduce scrap handling. Don' t overlook coated stock.

Review "blanket' specs. Check the need for and the effect of "blanket" specifications, tolerances, and special ordering requirements in material cost and availability. Remember: Special ordering or design requirements are paid for many times; a design or tooling change is paid for only once.

Try a lower-cost grade. Experiment with a less expensive grade of steel for a given part to determine whether breakage is within acceptable limits and whether the surface is satisfactory. If, on the other hand, excessive breakage is pushing costs out of line, consider upgrading your specifications to a better drawing-quality steel.

Order to minimum thickness. When design code or industry custom dictates the use of a particular gage, make sure that you are buying these items at their "minimum" thickness for the required gage. All steel ordered to "minimum" thickness from a steel mill is priced by theoretical weight, not actual weight. Actual weight is about 2.5% greater than "minimum" weight at equal thickness and size.



*Source: American Machinist, May 1976.

Try higher-strength steel. In general, changing from a commercial-quality material to a high-strength material can yield weight reductions on the order of 20-30%.

Check "extra" costs. Examine decimal thickness and width of steel to be sure you are not paying for unnecessary size-extras. By a slight part redesign, one cabinet manufacturer reduced the required width of a blank to below 60 in., thereby saving $6 a ton.

Reducing trim. Check your shearing and blanking practices to obtain the most efficient use of steel by reducing the amount of side trim in slitting coil stock, and, in blanking operations, by nesting blanks or reducing edge trim.

Combining parts on a blank. Inventory and handling costs can be reduced by combining several individual parts in one piece. In switching from cut lengths to coils, a manufacturer of steel building products noted a near duplication in part thickness and width for two parts. Two 26-in. wide parts called for 0.034-in. and 0.036-in. material. Combining them reduced congestion in inventory and increased the order quantities for a material-cost saving of over $100.000/yr. Performance specs. Rewrite specifications so that they are performance oriented rather than defect oriented. For example, a spec that reads "unexposed part with 90-deg. maximum bend" communicates much more to a steel mill than "must be free from all injurious defects," even though both phrases may be describing the same need.

Reduce number of welds. Fabricating costs can be cut and productivity boosted by using the minimum number of spotwelds, in accordance with American Welding Society standard practice.

Sheet vs. strip. If you are buying strip to get the mill-rolled edge, consider an edge-coining operation during fabrication to eliminate the extra cost.

Evaluate current designs. Check your designs and make sure that you would order the same material grade if a given part were to be designed today. For example, if a part that was originally designed as an exposed part is now considered to be unexposed, a good surface may no longer be needed.

Materials availability. Evaluate all purchased materials for potential alternatives in case of short supply. Giving the purchasing department the freedom to compromise on such things as thickness and size or relaxing the need for a noncritical specification can improve supply possibilities, and often it may reduce materials costs.

Fraction and Decimal Equivalents

1/64	0.015625	33/64	0.515625
1/32	0.031250	17/32	0.531250
3/64	0.046875	35/64	0.546875
1/16	0.062500	9/16	0.562500
5/64	0.078125	37/64	0.578125
3/32	0.093750	19/32	0.593750
7/64	0.109375	39/64	0.609375
1/8	0.125000	5/8	0.625000
9/64	0.140625	41/64	0.640625
5/32	0.156250	21/32	0.656250
11/64	0.171875	43/64	0.671875
3/16	0.187500	11/16	0.687500
13/64	0.203125	45/64	0.703125
7/32	0.218750	23/32	0.718750
15/64	0.234375	47/64	0.734375
1/4	0.250000	3/4	0.750000
17/64	0.265625	49/64	0.765625
9/32	0.281250	25/32	0.781250
19/64	0.296875	51/64	0.796875
5/16	0.312500	13/16	0.812500
21/64	0.328125	53/64	0.828125
11/32	0.343750	27/32	0.843750
23/64	0.359375	55/64	0.859375
3/8	0.375000	7/8	0.875000
25/64	0.390625	57/64	0.890625
13/32	0.406250	29/32	0.906250
27/64	0.421875	59/64	0.921875
7/16	0.437500	15/16	0.937500
29/64	0.453125	61/64	0.953125
15/32	0.468750	31/32	0.968750
31/64	0.484375	63/64	0.984375
1/2	0.500000	1	1.000000

Useful Information

Circumference of a circle = diameter x 3.1416.

Diameter of a circle = circumference x .31931.

Area of a circle = $diameter^2$ x .7854.

Doubling the diameter of a circle increases its area four times.

Area of a triangle = base x 1/2 of perpendicular height

Area of ellipse = product of both diameters x .7854.

Area of a parallelogram = base x altitude.

Side of inscribed square = diameter x .7071 or circumference divided by 4.4428.

Side of a square of equal area to a circle = diameter x .8862

A side of a square x 1.4142 = diameter of its circumscribing circle.

A side of a square x 4.443 = circumference of its circumscribing circle.

A side of a square x 1.128 = diameter of an equal circle.

A side of a square x 3.547 = circumference of an equal circle.

Cubic inches in a ball = cube diameter x .5236.

Cubic contents of a cone = area of base x 1/3 the altitude.

Surface of frustrum of cone or pyramid = sum of circumference of both ends x 1/2 slant height + area of both ends.

Contents of frustrum of cone or pyramid = multiply area of two ends and get square root; add the two areas and multiply by 1/3 altitude.

Doubling the diameter of a pipe increases its capacity four times.

A gallon of water (U.S. Standard) weighs 8 1/3 Ibs. And contains 231 cubic inches.

A cubic foot of water contains 7 1/2 gallons, 1728 cubic inches and weighs 62 1/2 Ibs.

Pressure in pounds per square inch of a column of water = height of the column in feet x .434.

The capacity of a cylindrical tank in U.S. gallons = $diameter^2$ (inches) x length (inches) x .0034.

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The Formability of Perforated Metals

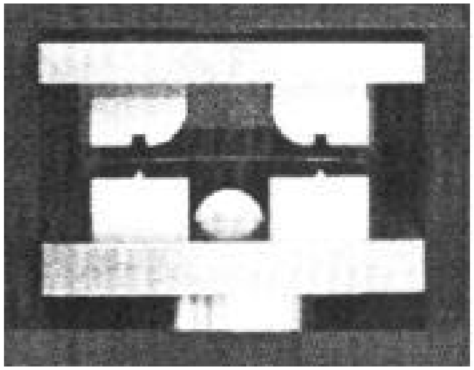
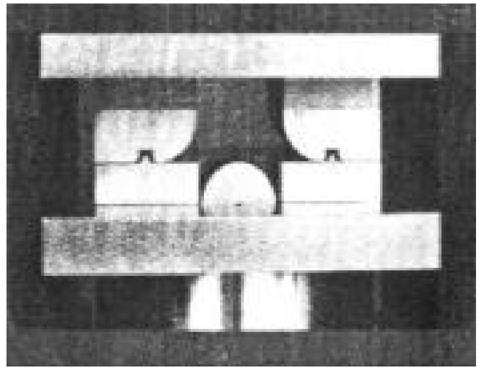
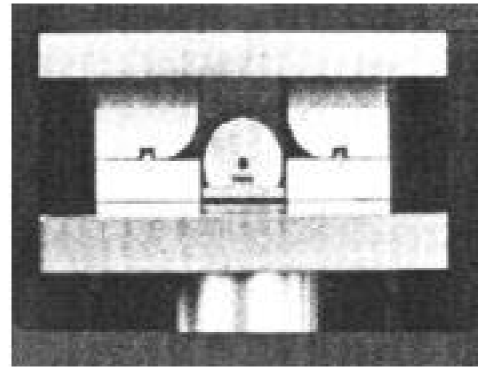
A Study Sponsored by the Industrial Perforators Association and conducted by the Department of Materials Science and Engineering at Ohio State University using methods, tooling and a testing machine of their design generally defined as the OSU Formability Test

The OSU Formability Test

The forming processes are among the most frequently used in the fabrication of perforated metals. formability is the term used to evaluate the capability of a material to withstand the stretch/draw stresses of forming before splitting occurs. Ohio State University's Materials Science and Engineering Department has had a long-standing interest in testing for formability ecause the standard mechanical tests for evaluating strength in metal materials, such as the tensile tests, had not correlated well with what actually occurs in forming operations. In pursuit of this interest, they developed a machine and method for testing Formability, (the LDH test) but the machine was not only very expensive, (upwards of $200,000) but lacked the ability to give consistently accurate results.

Dissatisfied, they set out, again, to design an inexpensive formability testing machine and a more accurate formability test. Following the lead of a study conducted by General Motors Corporation that found that 80% of the failures occurring in automotive stampings were the result of splitting under plain/strain conditions, this is where they focused their formability testing design. After several years working in conjunction with Interlaken Technology Corporation, they succeeded in designing and refining both machine and tooling for measuring Formability to yield testing results that had on tenth the variation found in the old LDH tests, and a testing machine design that old for $20,000 complete with tooling and power supply, affordable for any small shop.

Formability Test

The OSU/lnterlaken testing machine, shown here in three steps of the tests: 1. The punching tool with 1” radius, is withdrawn and the test sample is in place above it. 2. The test sample is clamped in position. 3. The punch is advanced, (pushed in) at a rate of 1 mm per second until failure occurs. At this point the Punch Height is measured. Each test sample specification was evaluated three times and the Maximum Punch Heights recorded for each were averaged and shown in the table of Test Results on pages 123 and 124 of this report.

Our Goals

Determine how cold rolled perforated steel reacts to drawing operations and develop the following relationships:

1. Effect of open area on Formability.
2. Effect of hole size on Formability.
3. Differences between commercial quality and drawing quality cold rolled steel in their Formability.
4. Differences in Formability according to the orientation of the work piece with respect to the punching tool, i.e. when applying drawing forces perpendicular to a straight row of holes or parallel to a straight row of holes.

Procedure

Each sample was first cleaned with acetone followed by methanol and dried. Then the sample was lubricated with Parco 404 Prelube in the region of punch contact. The sample was placed in the OSU Formability tooling and clamped. The punch was then advanced at a rate of 1mm per second until failure occurred. For each test the measure of formability was the punch height at which a maximum load was obtained from the recorded load versus punch displacement data. Three tests were performed on each of the 94 test conditions requested and the Punch Heights recorded for each were averaged. The Average Punch Height was the recorded Test Result.

Test Results

A Table of Formability Test Results for all perforated test pieces included in the study is available on the back page of this report. There were 76 configurations of test pieces with varying perforation hole sizes and patterns from which 100 test results were obtained including those with A and B Orientation. These test piece configurations are numbered and described in the columns reading from left to right.

Notice that the first eight configurations had no perforations. There were four gage sizes of cold rolled steel sheet included in both Commercial Quality and Draw Quality. The hole sizes are provided in decimals, the Open Area for each perforated pattern in percent. The thickness of the sheets were measured and it is interesting to note that for the same gage, the thickness of the Draw Quality Steel was slightly different than the Commercial Quality Steel.

The Test Results, expressed as Average Punch Height, (the average of the three tests conducted for each test specification), are shown according to Orientation: B Orientation having the straight row of holes running parallel with the orientation of the punch and A Orientation were the straight row of holes are perpendicular to the orientation of the
punch.

The charts and their explanations that follow illustrate the effects of each of the variables referred to OUR GOALS, above.

The effect of percent open area

This can be seen in the first four plots (Charts l-4). There is a chart for each of four thicknesses of Commercial Quality steel: 22 GA, 20 GA, 18 GA and 16 GA. There is a plotted curve for three different hole sizes in perforated patterns with open areas ranging from zero to forty percent. The results show an initial sharp drop in formability from the zero percent open area (plain stock) with the introduction of holes. After this there is a more moderate decline in formability with increasing open area.

Chart 1: Effect of Open Area and Hole Size on Formability
Commercial Quality, 22 Gage Steel, B Orientation

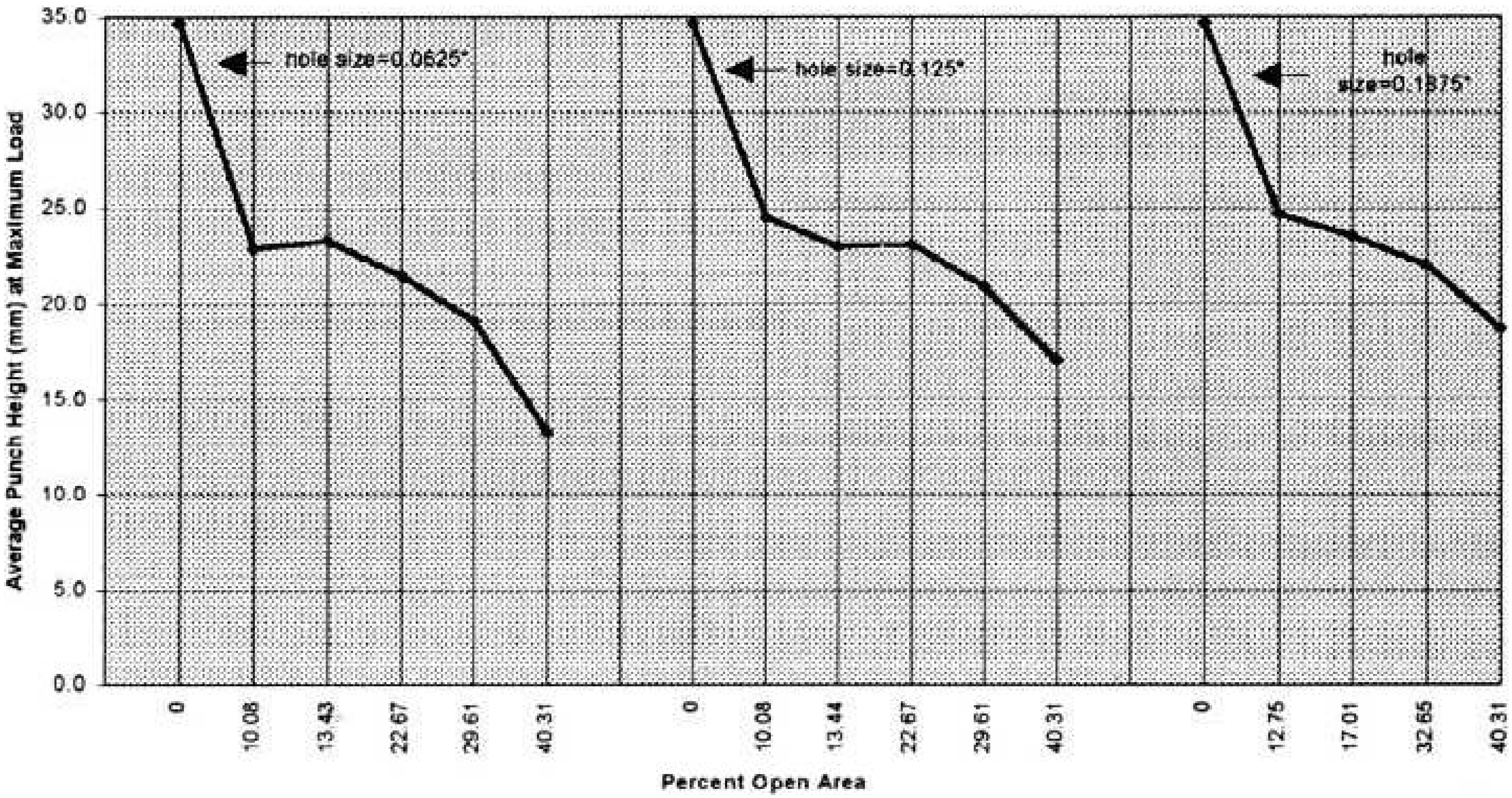


Chart 2: Effect of Open Area and Hole Size on Formability
Commercial Quality, 20 Gage Steel, B Orientation

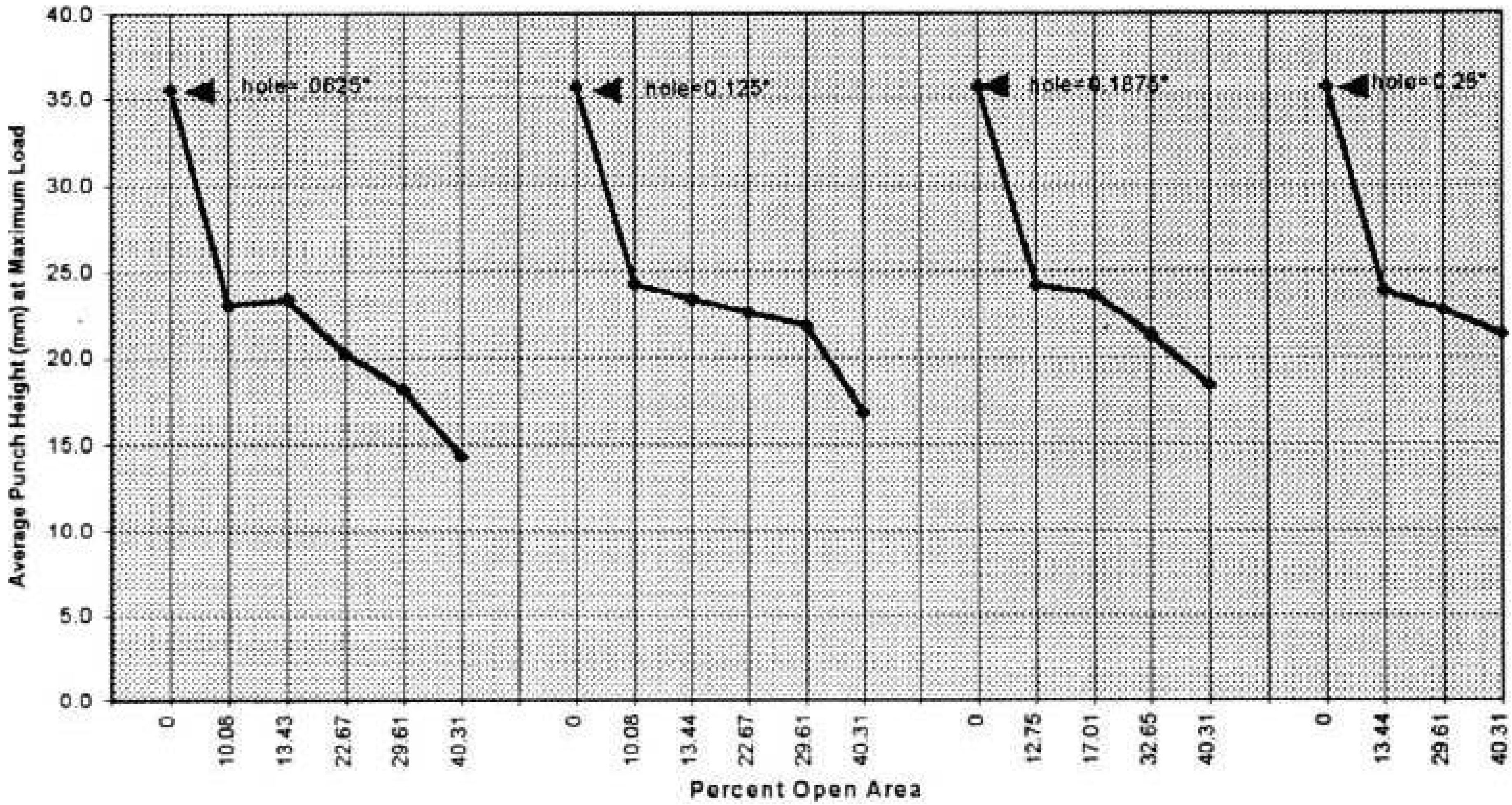


Chart 3: Effect of Open Area and Hole Size on Formability
Commercial Quality, 18 Gage, B Orientation

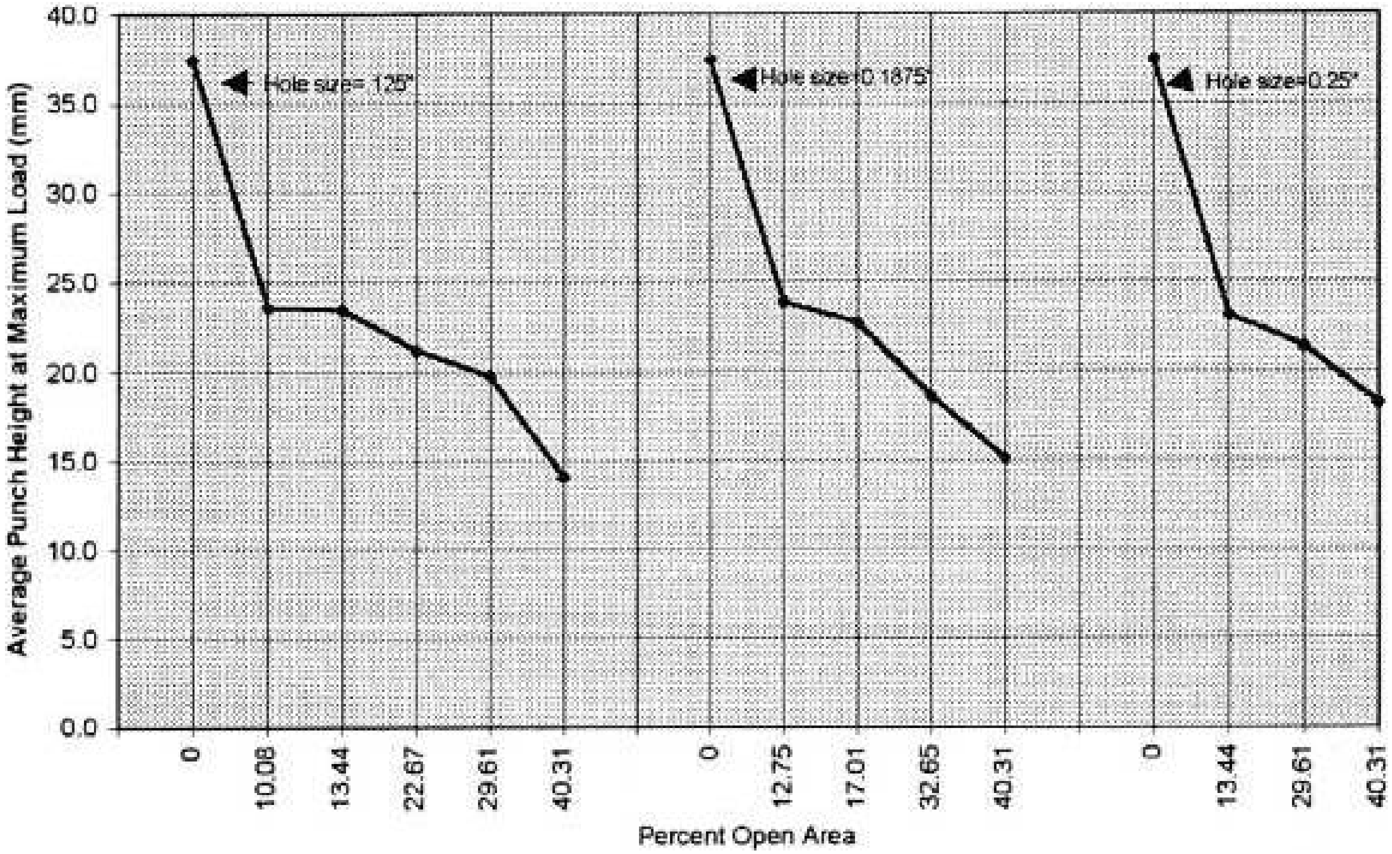
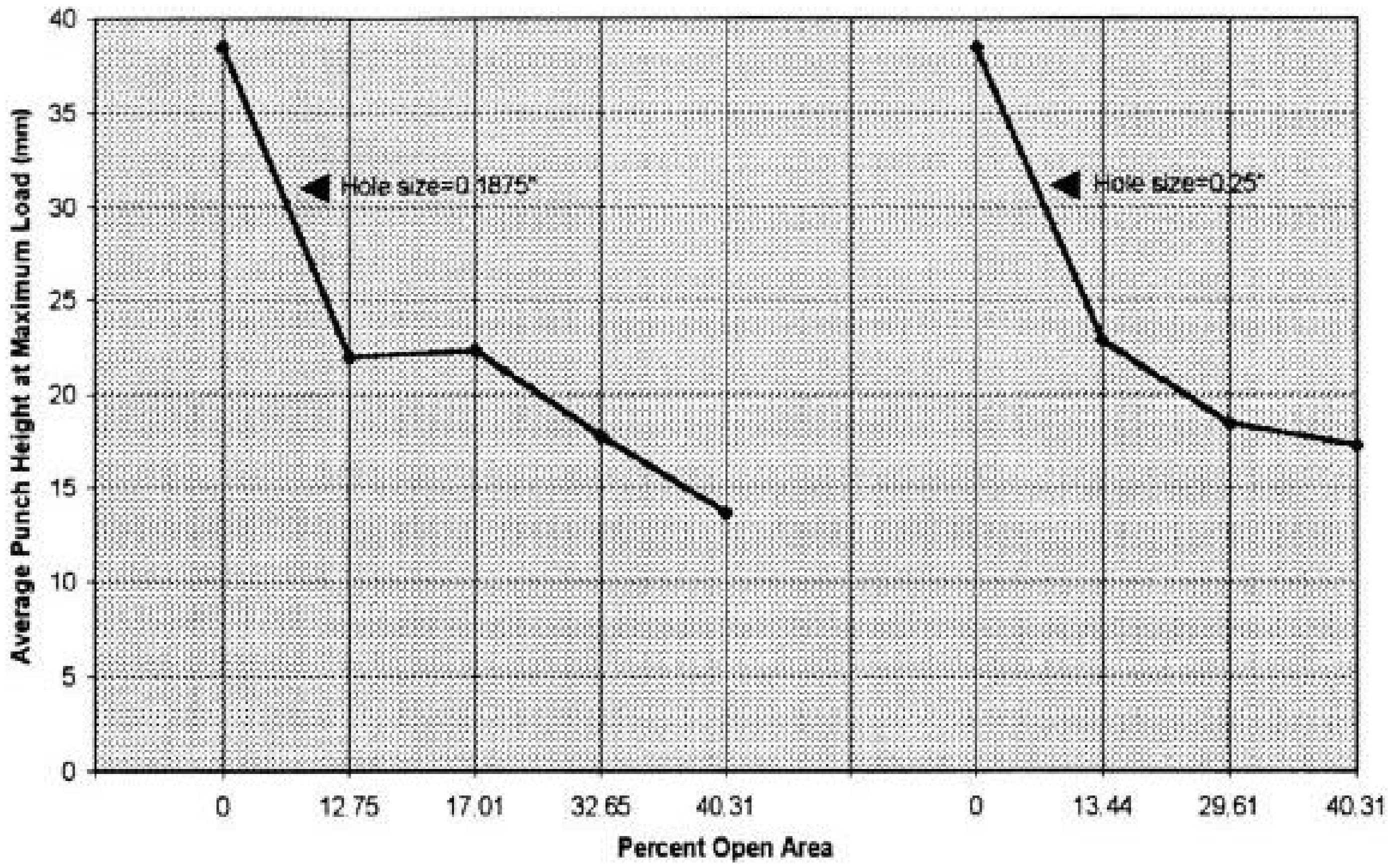


Chart 4: Effect of Open Area and Hole Size on Formability
Commercial Quality, 16 Gage, B Orientation



The effect of hole size and sheet thickness

In Charts 1 through 4, it can be seen that increasing the hole size has very little effect in the 10 to 20 percent open area range. Looking at Chart 5, in the 30 to 40 percent range increasing the hole size could slightly increase the formability for the same percent open area. For a particular hole size and percent open area, the formability actually decreases slightly with increasing thickness. This can be seen in figure 6.

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Chart 5: Effect of Hole Size on Formability
Commercial Quality,20 Gage Steel, B Orientation

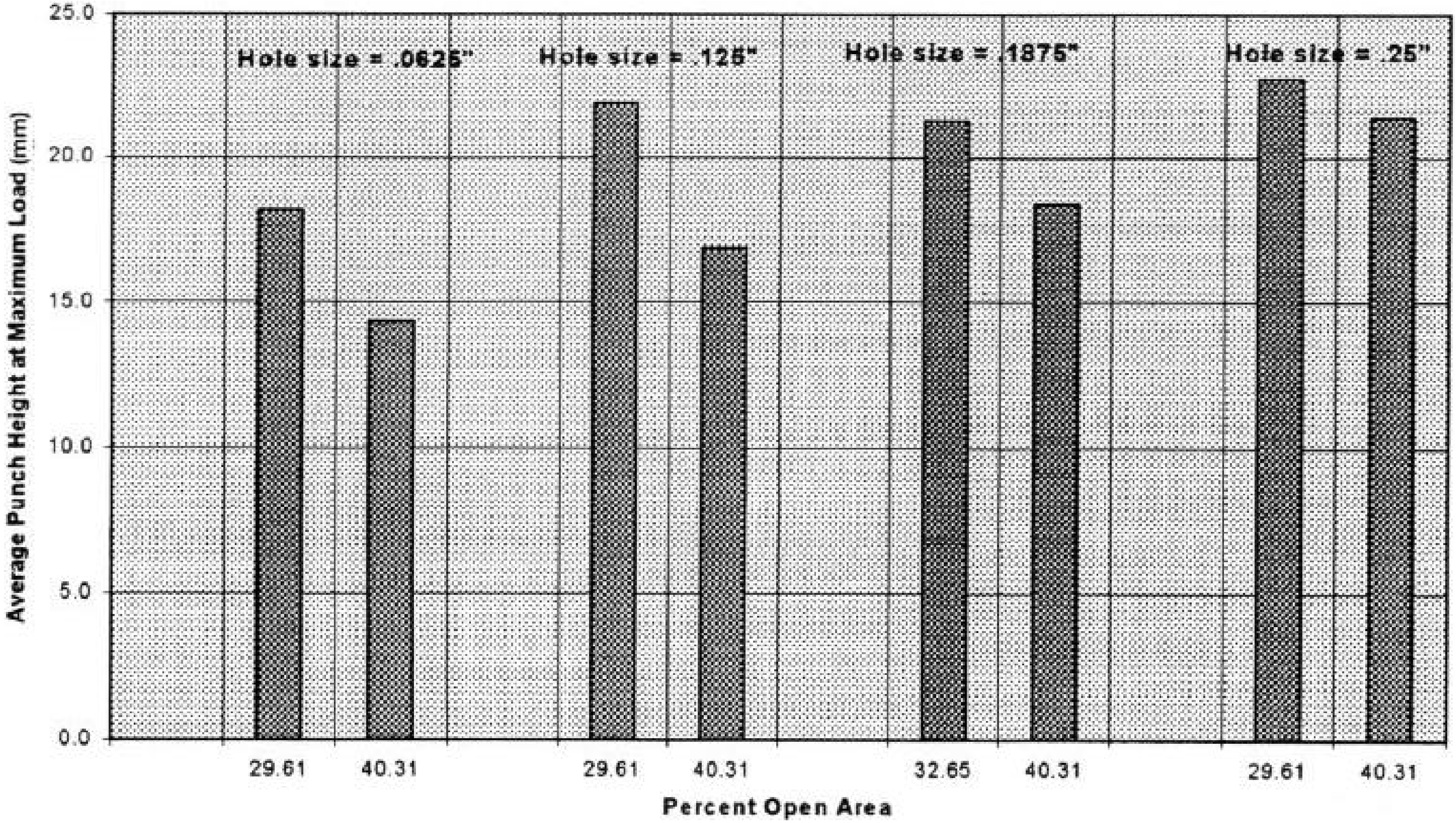
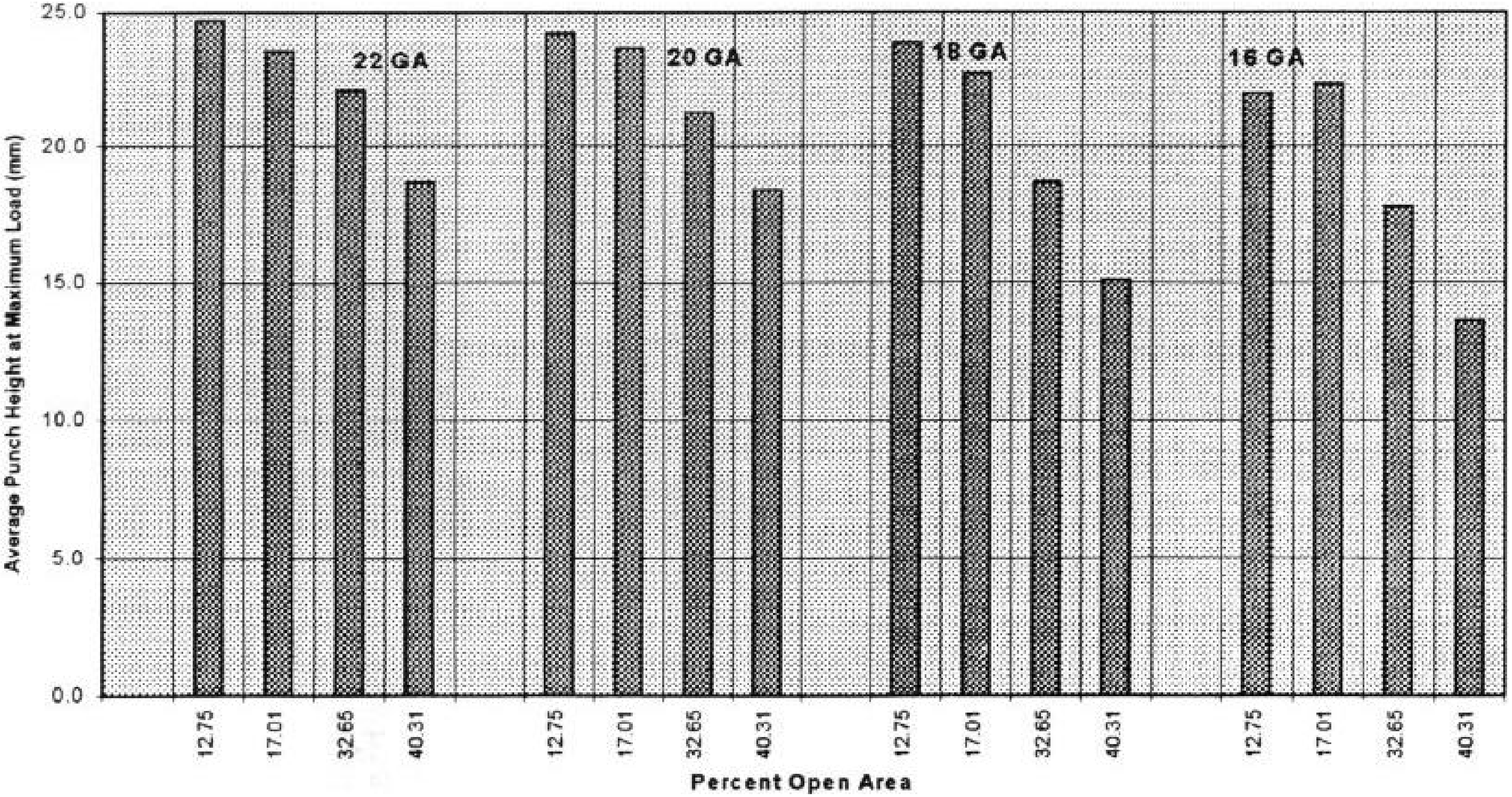


Chart 6: Effect of Perforated Sheet Thickness on Formability
Commercial Quality, Hole Size = 0.1875", B Orientation



The effect of draw quality versus commercial quality steel

A comparison of the formability of draw quality versus commercial quality steel is shown in Chart 7. Generally draw quality has higher formability. Chart 7 compares four thicknesses of steel with a perforated pattern with a hole size of .01875” and 17.01% Open Area.

The effect of orientation

The effect of orientation changes the formability by about 30%. A perforated pattern that has the straight row of holes parallel to the punch (B orientation) **has less Formability** than having the straight row of holes perpendicular to the punch (A orientation).

Chart 7: Formability Difference in Commercial Quality and Draw Quality Steel
3/16 x 0.4325, Hole Size =0.1875”, Percent Open Area = 17.01 %

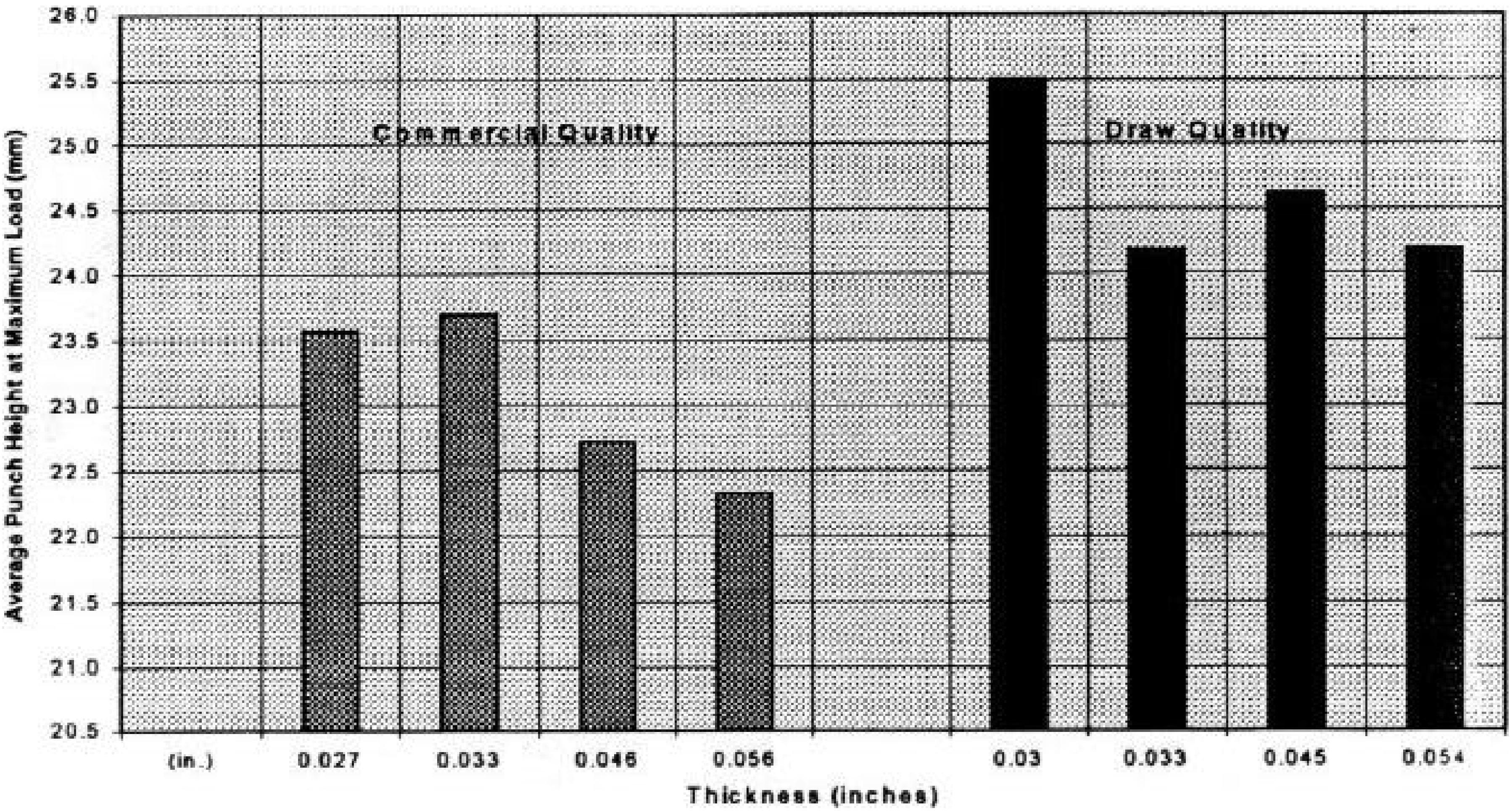
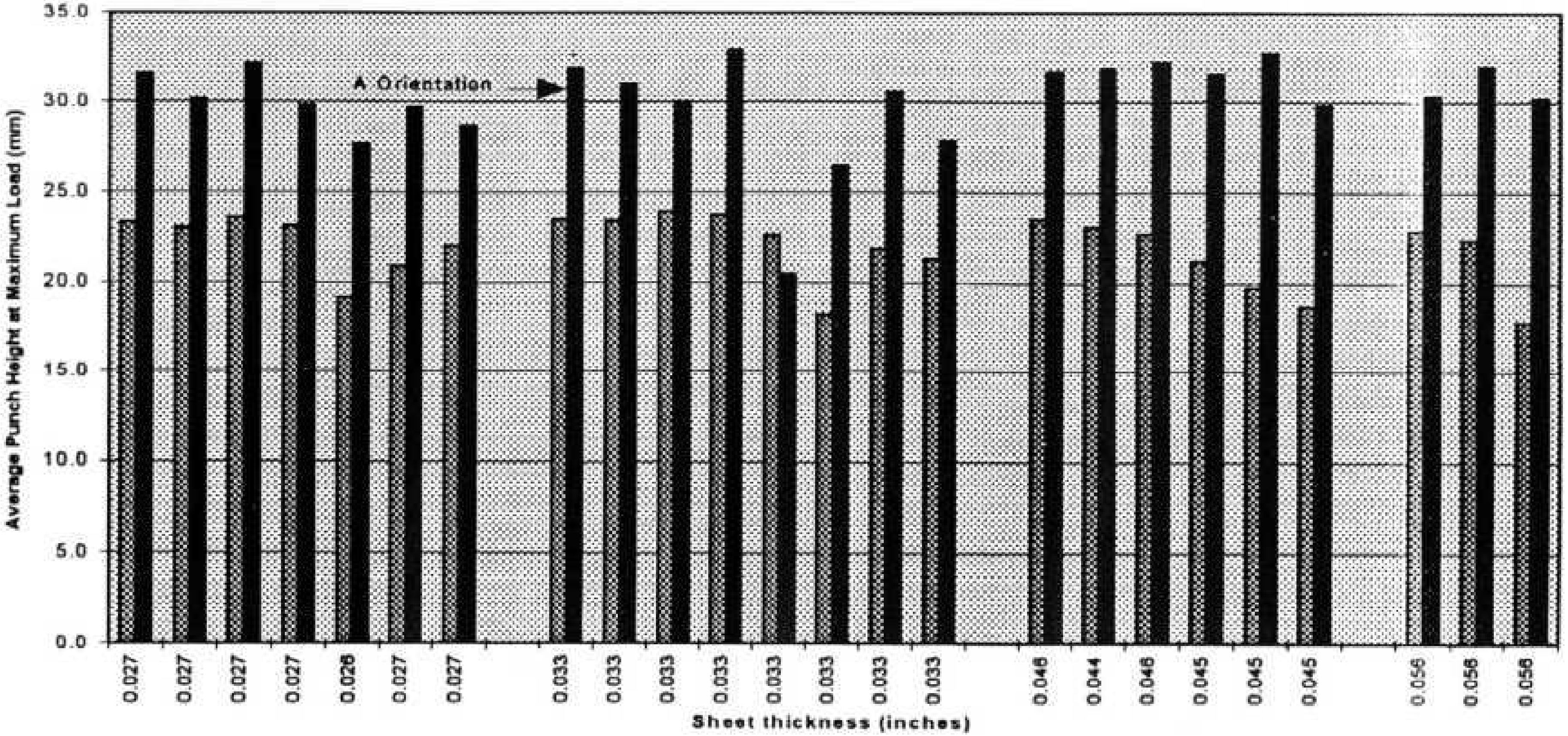


Chart 8: Difference in Formability Found in A Orientation and B Orientation
Sorted by 22, 20, 18 and 16 Gage Steel and by % Open Area



Test Piece	Perf Description	Gage	Hole Size (in)	Open Area %	Meas'd Thick. (in)	Quality	Ave. Pch. Hgt. Orientation	
							B (mm)	A (mm)
1	0	22	0	0	0.027	Commercial	34.7	
2	0	20	0	0	0.032	Commercial	35.7	
3	0	18	0	0	0.045	Commercial	37.4	
4	0	16	0	0	0.056	Commercial	38.5	
5	0	22	0	0	0.03	Draw	37.5	
6	0	20	0	0	0.033	Draw	38	
7	0	18	0	0	0.044	Draw	38.5	
8	0	16	0	0	0.054	Draw	39.7	
9	1/16x3/16	22	0.0625	10.08	0.027	Commercial	22.9	
10	1/1 6 x 3/16	20	0.0625	10.08	0.032	Commercial	23.1	
11	1/16 x 0.1615	22	0.0625	13.43	0.027	Commercial	23.3	31.7
12	1/16 x 0.1615	20	0.0625	13.43	0.033	Commercial	23.5	31.9
13	11/16 x 0.1615	22	0.0625	13.43	0.03	Draw	25.2	
14	1/16 x 0.1615	20	0.0625	13.43	0.034	Draw	23.9	
15	1/1 6 x 3/32	22	0.0625	40.31	0.027	Commercial	13.3	
16	1/1 6 x 3/32	20	0.0625	40.31	0.033	Commercial	14.4	
17	1/1 6 x 3/8	22	0.125	10.08	0.027	Commercial	24.5	
18	1/8 x 3/8	20	0.125	10.08	0.033	Commercial	24.3	
19	1/8 x 3/8	18	0.125	10.08	0.045	Commercial	23	
20	1/8 x 0.324	22	0.125	13.44	0.027	Commercial	23	30.1
21	1/8 x 0.324	20	0.125	13.44	0.033	Commercial	23.4	31.1
22	1/8 x 0.324	18	0.125	13.44	0.046	Commercial	23.5	31.8
23	1/8 x 0.324	22	0.125	13.44	0.03	Draw	25.3	
24	1/8 x 0.324	20	0.125	13.44	0.032	Draw	24.5	
25	1/8 x 0.324	18	0.125	13.44	0.045	Draw	24.1	
26	1/8 x 3/16	22	0.125	40.31	0.027	Commercial	17.1	
27	1/8 x 3/16	20	0.125	40.31	0.033	Commercial	16.9	
28	1/8 x 3/16	18	0.125	40.31	0.045	Commercial	14.1	
29	3/16 x 1/2	22	0.1875	12.75	0.027	Commercial	24.7	
30	3/16 x 1/2	20	0.1875	12.75	0.033	Commercial	24.2	
31	3/16 x 1/2	18	0.1875	12.75	0.045	Commercial	23.9	
32	3/16 x 1/2	16	0.1875	12.75	0.056	Commercial	22	
33	3/16 x 0.4325	22	0.1875	17.01	0.027	Commercial	23.6	32.1
34	3/16 x 0.4325	20	0.1875	17.01	0.033	Commercial	23.7	32.9
35	3/16 x 0.4325	18	0.1875	17.01	0.046	Commercial	22.7	32.2
36	3/16 x 0.4325	16	0.1875	17.01	0.056	Commercial	23.3	32
37	3/16 x 0.4325	22	0.1875	17.01	0.03	Draw	25.5	
38	3/16 x 0.4325	20	0.1875	17.01	0.033	Draw	24.2	

Test Piece	Perf. Description	Gage	Hole Size (in)	Open Area %	Meas'd Thick. (in)	Ouality	Ave. Pch. Hgt. Orientation	
							B (mm)	A (mm)
39	3/16 x 0.4325	18	0.1875	17.01	0.045	Draw	24.6	
40	3/16 x 0.4325	16	0.1875	17.01	0.054	Draw	24.2	
41	1/4 x 1.3	20	0.25	13.44	0.033	Commercial	23.9	30
42	1/4 x 1.3	18	0.25	13.44	0.044	Commercial	23.1	31.9
43	1/4 x 1.3	16	0.25	13.44	0.056	Commercial	22.9	30.3
44	1/4 x 3/8	20	0.25	40.31	0.033	Commercial	21.4	
45	1/4 x 3/8	18	0.25	40.31	0.046	Commercial	18.3	
46	1/4 x 3/8	16	0.25	40.31	0.056	Commercial	17.3	
47	1/4 x 7/16	20	0.25	29.61	0.033	Commercial	22.8	
48	1/4 x 7/16	18	0.25	29.61	0.045	Commercial	21.4	
49	1/4 x 7/16	16	0.25	29.61	0.056	Commercial	18.5	
50	3/16 x 9/32	22	0.1875	40.31	0.027	Commercial	18.7	
51	3/16 x 9/32	*20*	0.1875	40.31	0.033	Commercial	18.4	
52	3/16 x 9/32	18	0.1875	40.31	0.045	Commercial	15.1	
53	3/16 x 9/32	16	10.18751	40.31	0.056	Commercial	13.6	
54	3/16 x 5/16	22	0.1875	32.65	0.027	Commercial	22.1	28.7
55	3/16 x 5/16	20	0.1875	32.65	0.033	Commercial	21.3	27.8
56	3/16 x 5/16	18	0.1875	32.65	0.045	Commercial	18.7	29.8
57	3/16 x 5/16	16	0.1875	32.65	0.056	Commercial	17.8	30.2
58	3/16 x 5/16	22	0.1875	32.65	0.03	Draw	22.8	
59	3/16 x 5/16	20	0.1875	32.65	0.033	Draw	21.3	
60	3/16 x 5/16	18	0.1875	32.65	0.044	Draw	21.6	
61	3/16 x 5/16	16	0.1875	32.65	0.053	Draw	20.4	
62	1/8 x 7/32	22	0.125	29.61	0.027	Commercial	20.9	29.7
63	1/8 x 7/32	20	0.125	29.61	0.033	Commercial	21.9	30.6
64	1/8 x 7/32	18	0.125	29.61	0.045	Commercial	19.8	32.8
65	1/8 x 7/32	22	0.125	29.61	0.03	Draw	23.1	
66	1/8 x 7/32	20	0.125	29.61	0.33	Draw	21.9	
67	1/8 x 7/32	18	0.125	29.61	0.045	Draw	21.5	
68	1/16 x 0.109	22	0.0625	29.61	0.026	Commercial	19.1	27.6
69	1/16 x 0.109	20	0.0625	29.61	0.033	Commercial	18.2	26.5
70	1/16 x 0.109	22	0.0625	29.61	0.03	Draw	20.5	
71	1/16 x 0.109	20	0.0625	29.61	0.033	Draw	19.2	
72	1/16 x 1/8	22	0.0625	22.67	0.027	Commercial	21.5	
73	1/1 6 x 1/8	20	0.0625	22.67	0.033	Commercial	20.3	
74	1/8 x 0.250	22	0.125	22.67	0.027	Commercial	23.1	29.8
75	1/8 x 0.250	20	0.125	22.67	0.033	Commercial	22.6	20.5
76	1/8 x 0.250	18	0.125	22.67	0.045	Commercial	21.2	31.6