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Paging Horn Spacing for the Integrator

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INTRODUCTION

In this paper, we will discuss the rule-of-thumb principals required for an integrator to successfully lay out paging horns for a typical paging system. Depending on the dispersion of the horn and the sound pressure level (SPL) produced by the horn, spot (isolated) sound coverage can be obtained from that paging horn to cover only specific locations. When blanket coverage is required over a large area, paging horns can be arranged in a specific layout pattern. This paper discusses some rule-of-thumb formulas that can be helpful in determining that pattern.

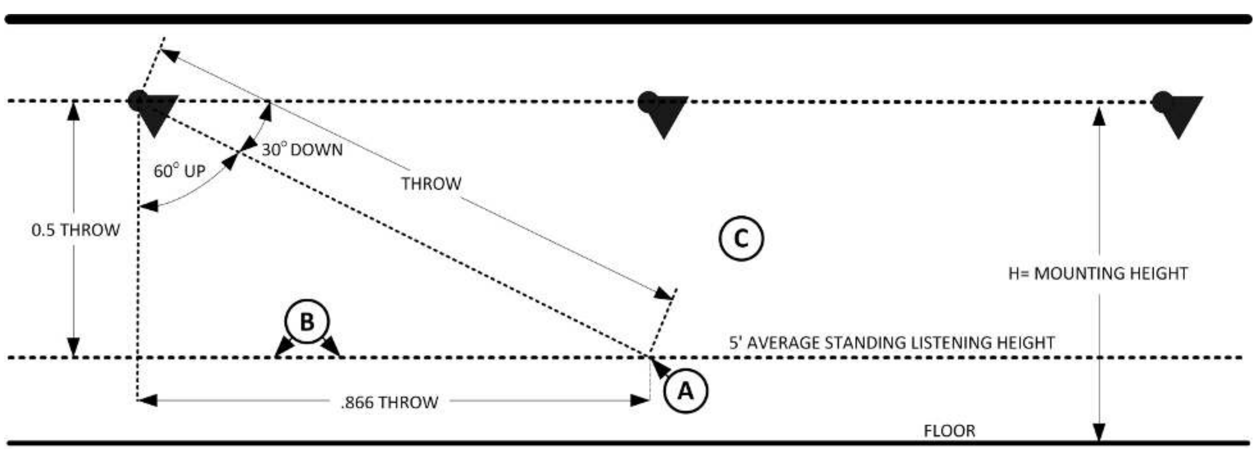
RULE-OF-THUMB for PAGING HORNS

It is generally recommended for a paging horn to be mounted 15’ to 20’ above the finished floor, aiming 30 degrees down from horizontal (60 degrees up from straight down) as shown in the drawing below. Note that a paging horn can be mounted higher than 20’, but where these horns are typically installed, the acoustics are so poor that mounting the horn higher than 20’ can excite reverberation that can result in poor speech articulation.

For seated listeners, we usually consider the average listening height to be at 4’ above the finished floor. Where paging horns are typically installed (factories, warehouses, shop areas), the listeners are often standing, so for the remainder of this paper, we will consider the average listening height to be at the 5’ (standing) average listening height. We will call the on-axis distance from the mouth of the horn to the listening height the “THROW.”

At the listening height (point “A” in the drawing), a certain sound pressure level is produced by the horn. At point "B," the SPL is off-axis (not directly on-line with the mouth of the horn) so the SPL will naturally be reduced, but since the distance from the horn to point B will be less than the distance to point A, the loss due to being off-axis will be offset by the gain due to being closer to the horn. The resultant SPL along the listening height will be very close to the SPL at point A.

Note that the SPL (due to the horn that is shown on the left) drops rapidly at point “C” because point C is both further from the first horn than point A and point C is also off-axis. The configuration shown where the horns are aimed down 30 degrees from the horizontal and the mounting height above the listening height is half of the THROW distance, is the ideal case that should be used if possible.



DESIGN STEPS

STEP 1: Determine the "Sound Pressure Level Design Goal"

In order for the sound from a paging horn to be heard and understood, the sound pressure level (SPL) that the horn must achieve is a **minimum of 10dBSPL over the average ambient noise level**. *Note: Many designers prefer to use 15dB over the ambient noise level so there is plenty of headroom in their sound system to handle changing conditions. For the purpose of this paper, we will use the 10dBSPL design criteria.* So how does the integrator who wants to design a paging horn sound system know what the ambient noise level is?

Method A: Simply stated, if the sound system is being designed for an existing building where the acoustic environment and background noise conditions already exist, take a sound pressure meter to the site and take multiple readings at the average listening height (4' for seated listeners or 5' for standing listeners) during a typical day and use the average of those readings as your average ambient noise level. *Note: Your sound pressure meter should be set on the A-Weighted scale. Your chosen SPL Design Goal will assure that your paging horn system will be able to achieve a minimum of 10dBSPL above the ambient noise level.*

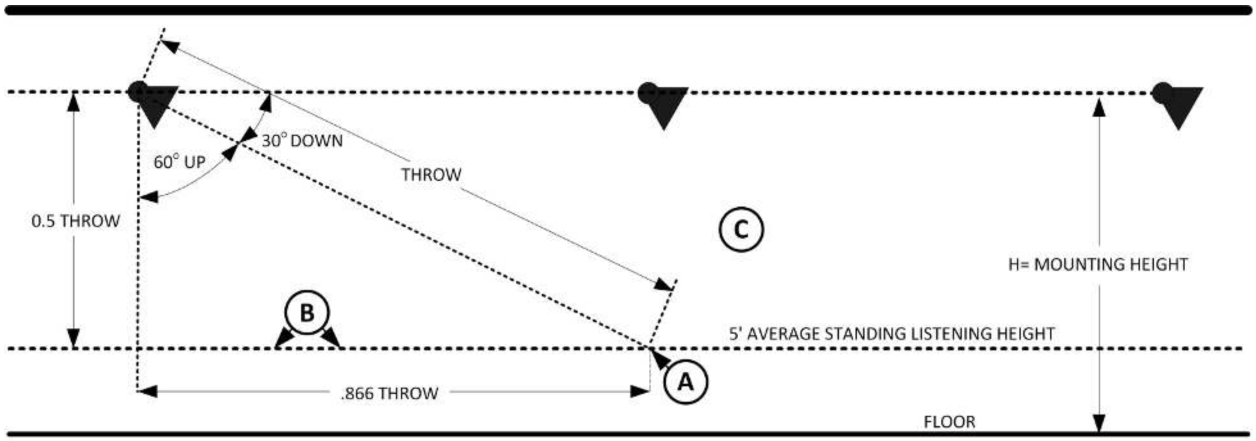
Method B: If SPL readings can't be taken because the building is under construction, or the inhabitants have not moved in yet, then an educated guess is required. The chart below gives design guidelines for "Maximum Sound Pressure Levels Required for Adequate Sound System Performance". Note that the values in the table include the required 10dBSPL above average ambient noise level. Some judgement on your part will be required to adjust your SPL Design Goal depending upon your particular application, so SPL ranges are given in the table.

Rule of Thumb Maximum SPL Level Required for Adequate Sound System Performance (in selected venues assuming typical background noise levels)

Venue	Application Type	SPL in dB
Office	Quiet office – no sound masking.	55-60
	Quiet office – with sound masking.	60-65
	Noisy office – with high levels of background noise.	65-75
Warehouse	Quiet warehouse – storage only.	65-75
	Loud warehouse – storage but constant forklift noise.	75-85
Factory	Quiet factory – light manufacturing.	80-90
	Loud factory – heavy manufacturing (Note: Osha may limit SPL).	90-105
Gymnasium Arena or Stadium	Cheering sports crowd. SPL depends on the size of the crowd (and the score in the game). Loud crowd cheer may exceed the capability of any sound system.	100-110

EXAMPLE 1: For examples 1-5 in this paper, my application is a fairly quiet factory that is under construction. I'm not sure exactly how quiet it will be so I choose my SPL Design Goal to be 90dB (the higher end of the range for a quiet factory) in the table.

STEP 2: Determine the "THROW"



"0.5 times the Throw," is the distance from the horn mounting height to the average listening height. For many warehouse and factory paging horn systems, the system will be configured for a standing listener, so we will design for a 5' average standing listening height.

H = Proposed mounting height
L = Average listening height (5' for standing listener)
.5 THROW = H–L so **THROW = 2 (H–L)**

EXAMPLE 2: From my knowledge of the building I'm proposing to mount my paging horns at 20' above the finished floor. The application is a quiet factory so I'll choose my average standing listening height at 5'.
THROW = 2 (20'– 5') = 30' or 9.144 meters.

Note: For any sound designer, a metric conversion calculator and a scientific calculator are "must have" tools as you will see in the following steps.

STEP 3: Determine the Paging Horn Power Input Required

At this point I know my SPL Design Goal, and I know the THROW of my paging horns. I need to choose a paging horn for this application and determine the transformer power tap that I need to use. I can do that by using handy tables (as described in Alternate Step 3), or I can do that by using the generic SPL formula given below:

SPL = S + 10LOG(P) – 20LOG(D)

- SPL is the resulting SPL at the listening level (our SPL Design Goal).
- S is the manufacturer's specified average sensitivity at 1 watt 1 meter.
- P is the input power to the speaker.
- D is the distance (in meters) on-axis from the speaker to the listening level (THROW)

EXAMPLE 3: I choose to use the Lowell LH-15TA paging horn. The sensitivity is given on the spec sheet as 112.2dB (1W1M). Recall that my SPL Design Goal is 90dB and my throw is 30' (9.144M). I'll start off figuring that I'll tap the horn at the maximum 15W.

SPL = S + 10LOG(P) – 20LOG(D)
SPL = 112.2dB + 10LOG(15) – 20LOG(9.144M) = 104.74dB
That tells me I have plenty of SPL for this relatively quiet factory.

My SPL Design Goal is only 90dB, I'll try again using the 3.8W tap.
SPL = 112.2dB + 10LOG(3.8) – 20LOG(9.144M) = 98.22dB

Don't forget that I'll only get that SPL when my amplifier is turned all the way up to 70.7 volts. I want to have at least 6dB of headroom in my amplifier, so I'm happy with my maximum 98.22dB result.

Sound Guy Rule-of-Thumb:
You may have heard sound guys using the rule-of-thumb:
Doubling the input power adds 3dB to the SPL.
Doubling the distance from the speaker loses (subtract) 6dB from the SPL.

Let's see if that rule of thumb works out in example 3.
Recall that my SPL Design Goal is 90dBSPL and my THROW is 30' (9.144M).
I have chosen to use the Lowell LH-15TA paging horn tapped at 3.8W.
The sensitivity is given on the spec sheet as 112.2dB (1W1M).
112.2dB(**1W**1M), 115.2dB(**2W**1M), 118.2dB(**4W**1M), 112.2(4W**2M**), 106.2(4W**4M**), 100.2(4W**8M**), 94.2(4W**16M**).

I can't get to the exact numbers using the rule of thumb, (I only have 3.8W not 4W, and I'm at 9.144M not 16M) but I can see that I'm close enough to meet my SPL Design Goal of 90dB.

Sometimes the rule of thumb can be faster, but most of the time I find it much easier to do an exact calculation using the formula.

ALTERNATE STEP 3:

Once you know your SPL Design Goal (Step 1) and your THROW (Step 2), if you are using a Lowell horn, you can simply plug the distance into the charts below to determine the power tap to use.

Note: The charts below give maximum SPL at a given distance and at a given power tap on the horn with the amplifier driving at a full 70.7V output. It is not desirable to drive the amplifier that hard at all times, so it is advisable to choose a value from the tables that will allow a given amount of headroom in the amplifier. In other words, if your design target SPL is 80dB, choosing a power tap and distance from the table for 86dB would guarantee a minimum of 6dB of headroom in the power amplifier. Note also that even if a horn can be tapped at 30 watts and will achieve the target SPL at 128', that requires that the horn be mounted 64' above the average listening level to result in even sound pressure level between horns. Mounting the horn lower than that (at less than the desired 30 degree down angle) would make the SPL extremely loud to a listener near the horn. A better choice would be to choose a reasonable mounting height, tap the power tap lower, and add more horns to keep the sound pressure even throughout the listening area. *Note: In very reverberant rooms the distances will need to be reduced because of speech articulation lost due to the reverberation.*

		DISTANCE →	4'	8'	16'	32'	64'	128'	256'
LH-30T 30W @ 4' SPL=125dB	POWER TAP (AT FULL 70V AMP DRIVE) →	30W	125dB	119dB	113dB	107dB	101dB	95dB	89dB
		15W	122dB	116dB	110dB	104dB	98dB	92dB	86dB
		7.5W	119dB	113dB	107dB	101dB	95dB	89dB	83dB
		3.8W	116dB	110dB	104dB	98dB	92dB	86dB	80dB
		1.8W	113dB	107dB	101dB	95dB	89dB	83dB	77dB

		DISTANCE →	4'	8'	16'	32'	64'	128'	256'
LH-15T 15W @ 4' SPL=121dB	POWER TAP (AT FULL 70V AMP DRIVE) →	15W	121dB	115dB	109dB	103dB	97dB	91dB	85dB
		7.5W	118dB	112dB	106dB	100dB	94dB	88dB	82dB
		3.8W	115dB	109dB	103dB	97dB	91dB	85dB	79dB
		1.8W	112dB	106dB	100dB	94dB	88dB	82dB	76dB
		0.9W	109dB	103dB	97dB	91dB	85dB	79dB	73dB

		DISTANCE →	4'	8'	16'	32'	64'	128'	256'
LUH-15TA 1W @ 1M SPL=105dB 15W @ 4' SPL 115dB	POWER TAP (AT FULL 70V AMP DRIVE) →	15W	115dB	109dB	103dB	97dB	91dB	85dB	79dB
		7.5W	112dB	106dB	100dB	94dB	88dB	82dB	76dB
		3.8W	109dB	103dB	97dB	91dB	85dB	79dB	73dB
		1.8W	106dB	100dB	94dB	88dB	82dB	76dB	70dB
		0.9W	103dB	97dB	91dB	85dB	79dB	73dB	67dB

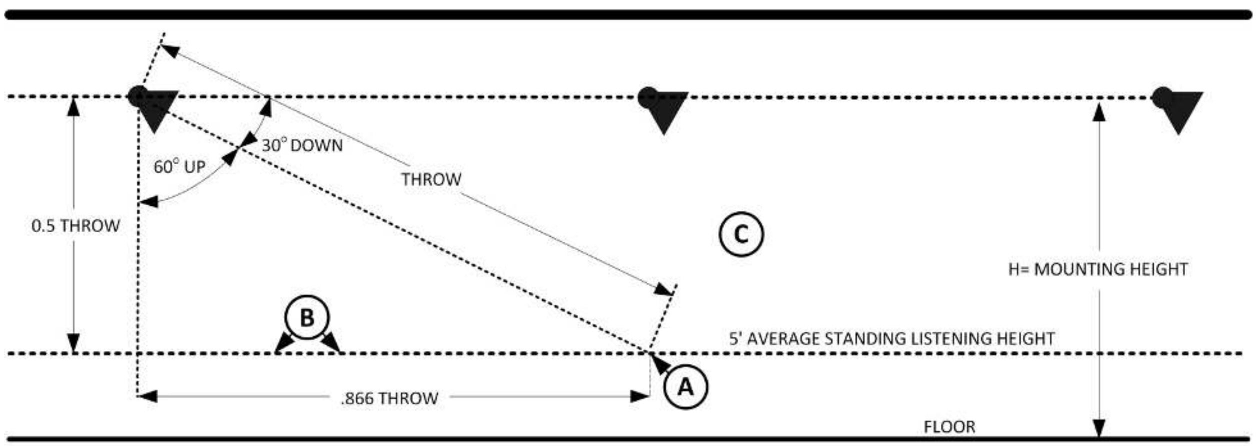
EXAMPLE 4: Recall that our SPL Design Goal is 90dB and my THROW is 30' (9.144M). I'll start with the LH-15TA because it's a smaller and less expensive horn. There isn't a 30' column in the table so I'll look at the 32' column. I'd like to have some extra headroom in my system, so I like the 3.8W tap on the LH-15TA because that gives me 98dB at 32' (with the amplifier turned all the way up to 70.7 volts). That gives my amplifier some headroom and I know I'll easily get 90dB, which is my SPL Design Goal, so that's a good choice.

STEP 4: Determine the Pattern for the Paging Horns

So at this point in the design process, I know which horn I'm going to use and which transformer tap I'm going to use to get my SPL Design Goal. I also know that by mounting the horns on a 30 degree down angle, I will have a certain THROW which I have already calculated based on the horn mounting height. Now what I need to determine is the pattern for the horn spacing. To determine the pattern spacing, I need to know the dispersion of the paging horns at the 2kHz Octave (critical for speech articulation).

D = Conical Dispersion Angle

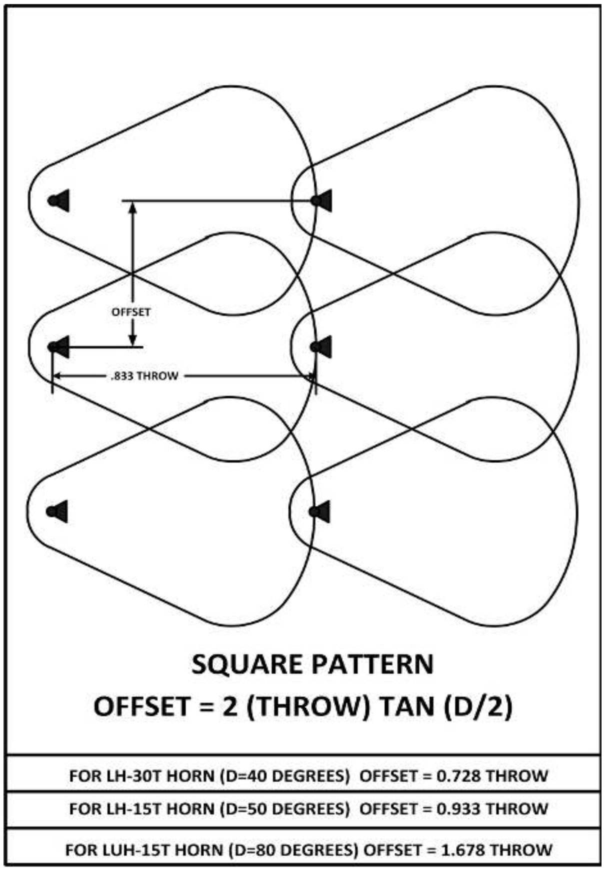
Note: A Linear Dispersion specification is not used in this case because the horns are not used in a distributed system with the horns shooting straight down at the floor.

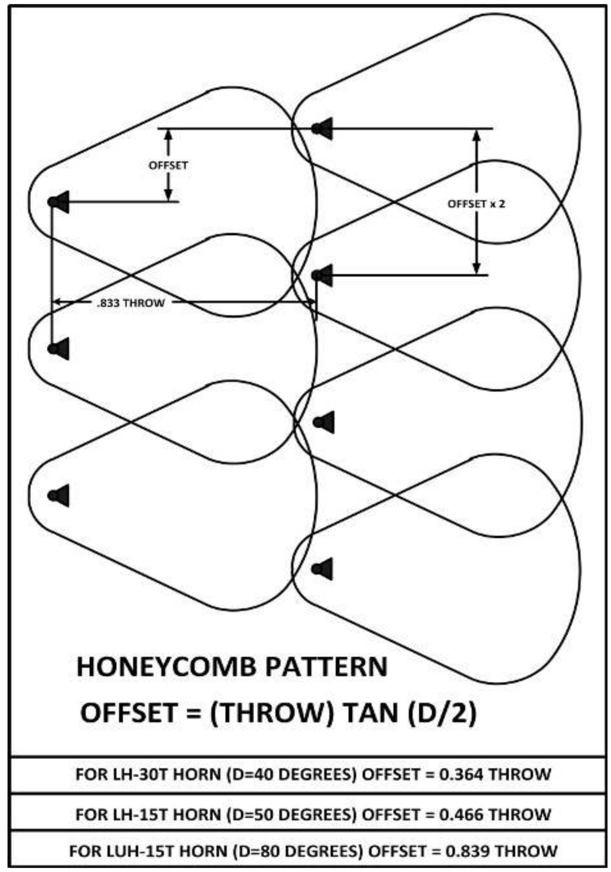


As shown above:

Row to Row Spacing = .866 THROW

The *maximum* "OFFSET" spacing (sideways spacing) is given in the following tables for two different spacing patterns. Note: The "Honeycomb Pattern" produces the best coverage, but this pattern is not always practical in real-world situations since the horns will typically mount to posts or beams which run in straight rows.





EXAMPLE 5: Now we can complete the example we've been working on throughout this paper.

In Step 1, Example 1, we determined that the application is a fairly quiet factory that is under construction. At that point, we chose our SPL Design Goal to be 90dB (the higher end of the range for a quiet factory) in the table.

In Step 2, Example 2, based on a 30 degree down angle with a horn mounting height of 20', we determined that the THROW of the horn will be 30'.

In Step 3, Example 3, we chose the Lowell LH-15TA horn and decided to tap it on the 3.8W tap to achieve our target 90dB SPL at the 5' listening height.

Now in Step 4 we decide to design for a square pattern. Row-to-Row Spacing = .833 THROW = .833 (30') = 24.99' or roughly 25'.

Obviously if the beams that I'm mounting the horns to don't line up with the 25' I'll have to move the Row-to-Row Spacing a little closer together or a little farther apart. If the change is significant, I may need to adjust my power tap calculations to compensate for that.

I'm using square spacing so my side to side offset (the distance between speakers in the same row) for the LH-15TA with a square pattern will be: OFFSET = 0.933 THROW = 0.933 (30') = 27.99' or roughly 28'.

Just like with the Row-to-Row Spacing, if the beams that I'm mounting the horns to don't line up with the 28' I'll have to move the offset spacing a little closer together or a little farther apart. If the change is significant, I may need to adjust my power tap calculations to compensate for that.

It's not rare that it takes two or three times through these calculations to determine a design that creates the SPL Design Goal that can be installed in the building.

TAKING THINGS FROM THE OTHER DIRECTION

Very often in the real world, a contractor is given information that makes him work with these formulas in a different direction. For example, what if the location of the speakers is given?

EXAMPLE 6: It is given that a quiet factory has posts in a square pattern on 40' centers, and after a site survey, I determine that's the perfect place to put the horns.

Row to Row Spacing = .866 THROW so THROW = 1.155 (Row to Row Spacing)
THROW = 1.155 (40') = 46.2'

So to keep my 30 degree down angle my speakers should be mounted at 5' + 0.5 THROW = 5' 0.5 (46.2') = 28.1'. So I'll mount my paging horns at 28.1' above the finished floor.

For a quiet factory my SPL Design Goal (from the earlier example) is still 90dB. I'll choose the Lowell LH-15TA so for 46.2' I'll look in the 64' column. If I tap my horn at 7.5W I'll have more than 94dB at the 5' listening height (because I'm not all the way out at 64', only 46.2'). By choosing the 7.5W tap, I'll still have headroom for my amplifier.

If we use the formula method:
SPL = S + 10LOG(P) – 20LOG(D)
46.2' = 14.08 meters
SPL = 112.2dB + 10LOG(7.5W) – 20LOG(14.08M) = 97.95dB.

That's a good choice because I'll have plenty of headroom.

SPOT COVERAGE

As I touched on in the introduction to this paper, blanket coverage where paging horns are installed in a set pattern, is not necessarily required. Very often paging coverage is only required at specific locations like in the shipping department, at specific assembly areas, or where specific machine operators are located. Often in a warehouse application, it doesn't make sense to provide blanket coverage because storage shelves take up most of the square footage of the building. The practical approach is always to provide paging coverage in the areas where listeners are expected to be. The same formulas that have been discussed in this paper to space paging horns in patterns for blanket coverage, can be used to determine the paging horn requirements to cover specific "spot coverage" locations or to space paging horns in a row covering the aisles between the shelving where listeners are likely to be.

SUMMARY

In this paper, we have discussed the rule-of-thumb principals required for an integrator to successfully lay out paging horns for a typical paging system. Paging horn layout can be challenging because, unlike ceiling speakers, paging horns can't be mounted just anywhere. Paging horns typically are mounted to posts, beams, or trusses so their locations can be limited by the building structure. Following these rule-of-thumb principals can give the designer a method to verify that the paging horn coverage is sufficient for the application. Care should be taken to include enough headroom to deal with background noise conditions that are worse than the designer anticipated or may change over time. No matter what direction the designer has to take to lay out the speakers, whether physical restrictions are involved because of mounting locations, or even if only spot coverage is required to cover specific locations in a building, the formulas given always allow the designer to be confident that the system can produce the sound pressure level required for the application.