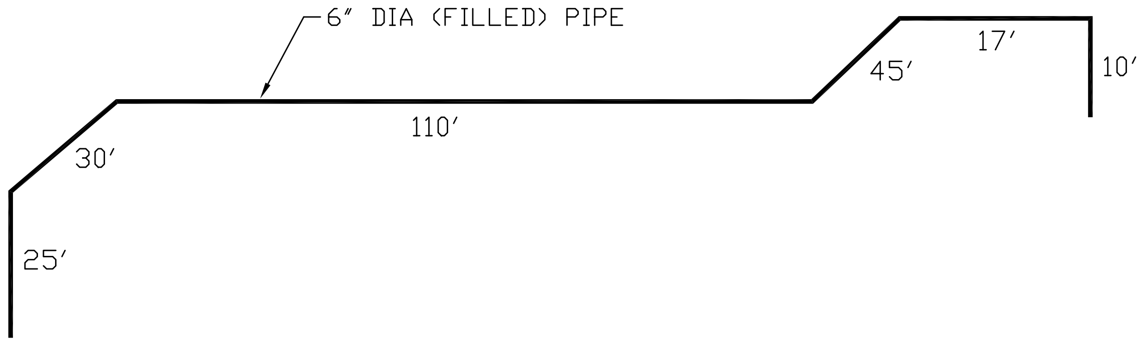
FORCE CLASS SAMPLE CALCULATIONS

All of the following examples are based on the use of the *Sample* Load Determination Tables 1 and 1A (D4.5). Note that the tables used are project specific and will change based on the Code, the Project Location and the Building Use classification. Project specific Tables 1 and 1A must be obtained from Kinetics Noise Control prior to reviewing any particular application.

This manual section applies only after it has been determined that restraint is required for a particular run of piping, ductwork or on a particular piece of equipment. More information is available to make this determination in section D2 (Codes) and D7 through D10 (Piping, Ducting, Conduit and Suspended Equipment)

PIPING EXAMPLE

For our example, assume we have a length of pipe as illustrated below.



Further, assume that the 30', 110', 45' and 17' long runs are supported by hanger rods that are 36" long and which are anchored at the top into the underside of the roof slab for the structure and are spaced 10' apart. We can look at both struts and cables for restraint. The 25' and 10' runs are vetical drops.

Determine Design Seismic Force

The first thing that we need to know is the design seismic force that we must apply. If we look near the top right corner of Table 1 or Table 1A (D4.5), there are listed the design accelerations in G's that are appropriate for various elevations in this structure. Since we are attaching the piping in our example to the underside of the roof, the value of interest to us is the acceleration at the roof, in this case .336 G.

Determine the Maximum Restraint Spacing

Before we can make effective use of the rest of the information on Table 1 or 1A, we need to determine a spacing for our restraints. Since we do not know yet, what that spacing is,

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we can refer to Table 2 (D4.6). The upper portion of this table refers to piping and conduit while the lower portion refers to ductwork. There is also a table for lateral and one for axial restraing spacing. Beginning with lateral we need to find a column in the table that meets or exceeds .336 G. The second column lists a value of .42 G. This fulfills our needs.

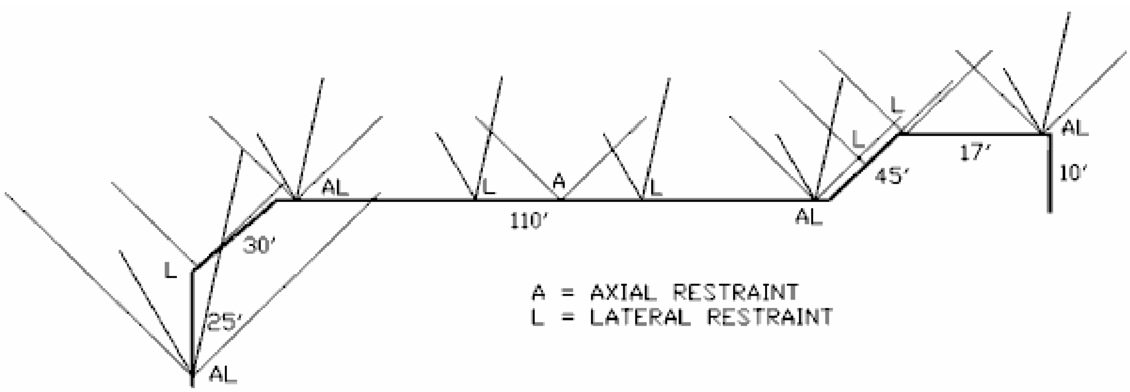
Reading down the column until we get to a 6" pipe, we get a maximum allowable lateral restraint spacing of 40 ft.

Likewise on the axial table we get a maximum allowable restraint spacing of 80 ft.

<u>Placing Restraints</u>
Using this information, along with the layout information available in section D7.4.1 (piping) or section 9.4.1(conduit), we can determine the we need the following restraints:

Run	Lateral Restraint	Axial Restraint
25'	2	1
30'	2	1
110'	4	2
45'	2	1
17'	1	1
10'	1	1

If we can locate some of these restraints within 2 ft of a corner, they can do "double duty" (act as a lateral restraint for one run and an axial restraint for the other). Consolidating these, we can come up with a layout that looks like this:



Note that for the vertical 25' and 10' drops, the hanger rods act as axial restraints.

<u>Determine the maximum length of pipe per restraint</u>
From the above picture, the maximum span between any two adjacent lateral restraints is 36' and the maximum span between any two adjacent axial restraints is 55'. For our

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purposes, we will use this “worst case” condition and size all restraints to this capacity.

Determine Restraint Hardware Capacity requirements

We can now apply the above information to Table 1 or 1A (D4.5) to determine a hardware “Force Class” or a design force requirment to size our restraint components.

Refering first to the weight per foot guide, we can see that a filled 6” pipe weighs 35 lb per foot. Using the Table 1 Force Class tables on the right side of the page and refering to the 40 ft OC spacing (for the 36’ case that we have), we see that for a roof application involving a pipe that weighs 50 lb per ft, we need a Force Class III rated hardware system.

Optional

If we would like to “fine tune” our selection, we can use Table 1A and perform the same exercise to determine the actual force requirement for the 50 lb per ft pipe restrained 40 ft OC to be 672 lb. If desired, the values on Table 1A can be pro-rated based on the weight and spacing. In this case we can multiply the 672 lb by the actual lb per ft divided by the tabulated lb per ft (35/50) and also by the actual restraint spacing divided by the tabulated spacing (36/40). After multiplying the 672 lb figure by these 2 factors, we find that the minimum component that we can select must withstand a design force of 423 lb.

Selecting restraint components

Table 5 and 5A (D4.8) list the capacity of various Kinetics Noise Control provided hardware and anchorage components. Table 5 indicates capacities in “Force Class” units while 5A indicates capacities in lb. The goal is to select components with capacities in excess of the design requirements.

If the cable or strut installation angle (as compared to the horizontal plane) is unknown, it should be assumed to be 60 degrees (worst case).

Cable ratings are listed at the top. Table 5 indicates that a .25” cable is adequate for any Force Class III requirement at 60 degrees.

Best practice using a strut is to limit the angle to 45 degrees. With a 36” long hanger rod and a 45 degree angle to the strut, the length of the strut would be 1.41 * 36 or 51”. This dimension is not important for cables, but is critical for struts (Use of struts for restraint of the bottom of the 25’ run is not recommended). Refering to Table 4c (D4.7), we need a strut that will be installed at 45 degrees, will be 51” long and will resist a Force Class III load. The minimum angle size that will accommodate this is a 2 x 2 x .25.

Returning to Table 5, below the cable data on the left are ratings for various hardware components that are anchored to concrete. On the right are ratings for hardware components that are through bolted. These tables list capacities for the clips mounted in either of the orientations indicated by figure at the top of the page. If the restraint that we are using is attached to concrete, in order to achieve a Force Class III connection, the 1

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bolt anchor table on the left indicates that a CCA clip with a single .75 anchor mounted to a vertical surface is needed. As an option, at the bottom of the page on the 2 bolt anchor chart, either a KSCA or CCA clip mounted with (2) .38 anchors could be used.

If the restraint is through bolted (or welded), data from the Grade 2 Bolt table on the right can be used. It indicates that with through bolts, a .5" bolt is adequate, no matter what the orientation.

Optional

As with the load determination table, it is also possible to "fine tune" our hardware selection. This can often verify the acceptability of a smaller hardware component than that selected based on Force Class. To do this, we use Table 5A in the same manner as we did above, but we apply the 423 lb figure that we determined earlier as our force requirement. Using this, we can verify that a either a 5mm or .18 cable with gripple connectors would be adequate at 60 degrees.

We can also confirm the acceptability of a single .5 anchor with a KSCA clip in any orientation.

If through bolted, we can use a KSCA clip with a .38 bolt in any orientation.

Thus it can be seen that with a little more effort, smaller hardware can often be justified.

This addresses the lateral restraints. The axial restraints can be addressed in the identical manner with the following result.

Force Determination

Force Class Method.
  Design Requirement (60 ft span, 50 lb/ft pipe) – Force Class = IV
Optional Method
  Design Requirement (55 ft span, 35 lb/ft pipe) – Design Force = 647 lb

Cable / Strut Size Determination

Force Class Method.
  Cable size for Force Class IV at 60 degrees = .38"
  Size for 51" long strut at Force Class IV at 45 degrees = 2.5 x 2.5 x .25"
Optional Method
  Cable size for 647 lb at 60 degrees = .18" (U-clip connection)

Attachment Hardware Determination

Force Class Method.
  Concrete Connection for Force Class IV at 60 degrees
    CCA clip with (4) .375 anchors at any orientation

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Through-Bolt Connection

CCA clip with .75 bolt works for any orientation

Optional Method

Concrete Connection for 647 lb at 60 degrees

CCA clip with.875 anchor at any orientation

Through Bolt Connection

KSCA clip with .38 bolt at any orientation

Minimum Hanger Rod Size and Anchor Determination

The supported weight per hanger rod based on 10 ft spacing and 35 lb/ft piping is 350 lb.

Refer to Table 4a (D4.7) and note that all cables behave the same as a strut that is oriented horizontally. For supported weights up to 500 lb, the use of a cable restraint and a Force Class III (Lateral) seismic load, the minimum acceptable hanger rod size is .50". If a strut is used in place of the cable and the angle of the strut is 45 degrees to the horizontal, the minimum hanger rod size permissible is .75"

Below this is the anchor capacity table. If the hangers are anchored to concrete rather than through-bolted, this table indicates the size requirments for the anchor. In a similar fashion to the above, the anchor size for the cable restrained system can be found to be .88", while that for the strut restrained system jumps to 1.25"

When the above table is applied to the axial restraint which needs a Force Class IV rating based on the 55 ft spacing, supporting from concrete becomes impractical. To resolve this issue, the piping must be either hung from steel or the spacing between restraints decreased to reduce the Force Class Requirement.

Evaluating Rod Stiffeners

Using only the lateral restraint example from above and assuming that we are using cable restraints and the minimum size hanger rods (.50") we can use Table 4b to evaluate the need for rod stiffeners.

Looking up Force Class III and a cable angle of 60 degrees (worst case) in the upper table, we find that the maximum unstiffened length that we can have for a .50" hanger rod is 10". Since our hanger rod is 36", a rod stiffener is required.

The second table indicates multipliers that can be used to evaluate the additional length that can be achieved with the addition of various rod stiffening materials. We would like to increase our length from 10" to 36", thus we need a multiplier of 3.6 (36/10). If we look at the line in the table for .50" hanger rod, we can see that a .75" diameter pipe or a 1.5 x 1.5 x .25 angle will both offer multipliers in excess of the 3.6 that we need and would be acceptable as rod stiffeners.

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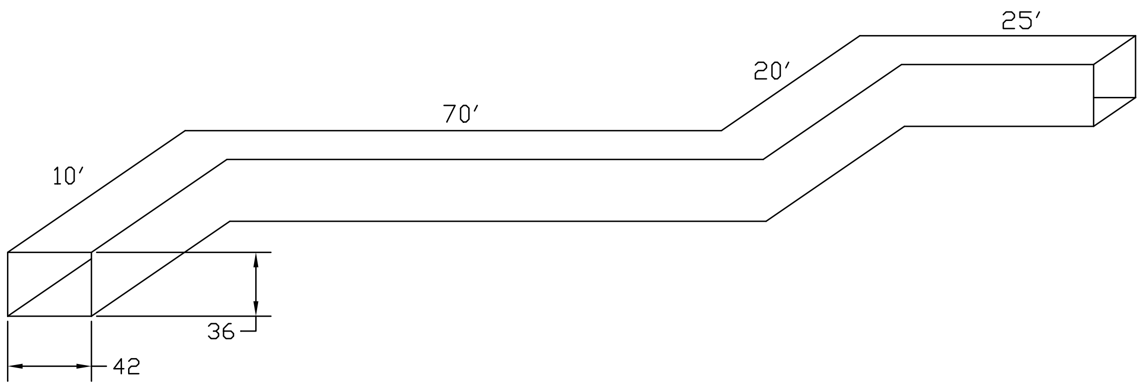
The maximum spacing between clamps cannot exceed the maximum unstiffened rod length, so a minimum of 3 clamps are needed to clamp the hanger rod to the rod stiffener.

DUCTWORK EXAMPLE

For our example, assume we have a length of duct as illustrated below.



Further, assume that the entire system is supported by hanger rods that are 54" long and which are anchored at the top into the underside of the roof slab for the structure and are spaced 10' apart. We can look at both struts and cables for restraint.

Determine Design Seismic Force

The first thing that we need to know is the design seismic force that we must apply. If we look near the top right corner of Table 1 or Table 1A (D4.5), there are listed the design accelerations in G's that are appropriate for various elevations in this structure. Since we are attaching the ductwork in our example to the underside of the roof, the value of interest to us is the acceleration at the roof, in this case .336 G.

Determine the Maximum Restraint Spacing

Before we can make effective use of the rest of the information on Table 1 or 1A, we need to determine a spacing for our restraints. Since we do not know yet, what that spacing is, we can refer to Table 2 (D4.6). The upper portion of this table refers to piping and conduit while the lower portion refers to ductwork. There is also a table for lateral and one for axial restraint spacing. Beginning with lateral we need to find a column in the table that meets or exceeds .336 G. The second column lists a value of .42 G. This will meet our requirement.

Reading down the column until we get to a 42" x 42" duct, we get a maximum allowable lateral restraint spacing of 40 ft.

Likewise on the axial table we get a maximum allowable restraint spacing of 80 ft.

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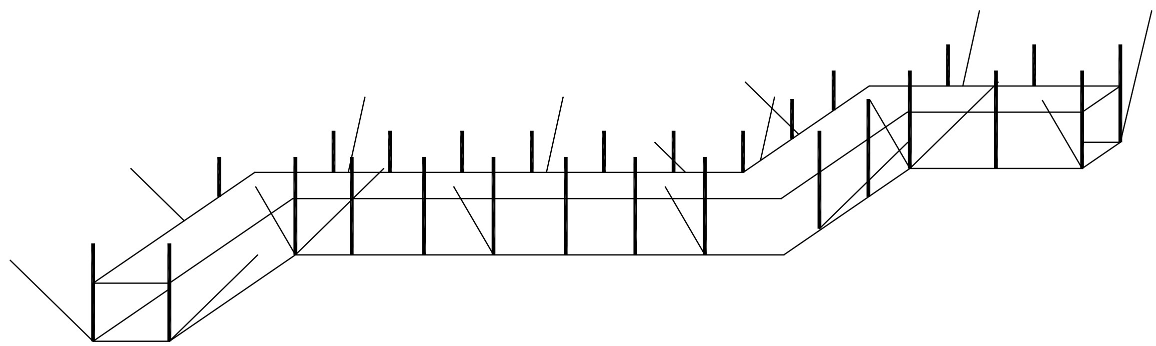
Placing Restraints

Using this information, along with the layout information available in section D7.4.1 (piping) or section 9.4.1(conduit), we can determine the we need the following restraints:

Run	Lateral Restraint	Axial Restraint
10’	1	1
70’	3	1
20’	2	1
25’	1	1

If we can locate some of these restraints within 2 ft of a corner, they can do “double duty” (act as a lateral restraint for one run and an axial restraint for the other. Consolidating these, we can come up with a layout that looks like this:



Determine the maximum length of duct per restraint

From the above picture, the maximum span between any two adjacent lateral restraints is 34’ and the maximum span between any two adjacent axial restraints is 67’. For our purposes, we will use this “worst case” condition and size all restraints to this capacity.

Determine Restraint Hardware Capacity requirements

We can now apply the above information to Table 1 or 1A (D4.5) to determine a hardware “Force Class” or a design force requirement to size our restraint components.

Refering first to the weight per foot guide, we can see that a 42 x 42 duct weighs 29 lb per foot. Using the Table 1 Force Class tables on the right side of the page and refering to the 40 ft OC spacing (for the 34’ case that we have), we see that for a roof application involving a duct that weighs 50 lb per ft, we need a Force Class III rated hardware system.

Optional

If we would like to “fine tune” our selection, we can use Table 1A and perform the same exercise to determine the actual force requirement for the 50 lb per ft pipe restrained 40 ft OC to be 672 lb. If desired, the values on Table 1A can be pro-rated based on the weight and spacing. In this case we can multiply the 672 lb by the actual lb per ft divided by the tabulated lb per ft (29/50) and also be the actual restraint spacing divided by the tabulated

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spacing (34/40). After multiplying the 672 lb figure by these 2 factors, we find that the minimum component that we can select must withstand a design force of 332 lb.

<u>Selecting restraint components</u>
Table 5 and 5A (D4.8) list the capacity of various Kinetics Noise Control provided hardware and anchorage components. Table 5 indicates capacities in “Force Class” units while 5A indicates capacities in lb. The goal is to select components with capacities in excess of the design requirements.

If the cable or strut installation angle (as compared to the horizontal plane) is unknown, it should be assumed to be 60 degrees (worst case).

Cable ratings are listed at the top. Table 5 indicates that a .25” cable is adequate for any Force Class III requirement at 60 degrees.

Good design practice is to limit the strut angle to 45 degrees. With a 54” long hanger rod and a 45 degree angle to the strut, the length of the strut would be 1.41 * 54 or 77”. This dimension is not important for cables, but is critcal for struts. Refering to Table 4c (D4.7), we need a strut that will be installed at 45 degrees, will be 77” long and will resist a Force Class III load. The minimum angle size that will accommodate this is a 2.5 x 2.5 x .38.

Returning to Table 5, below the cable data on the left are ratings for various hardware components that are anchored to concrete. On the right are ratings for hardware components that are through bolted. These tables list capacities for the clips mounted in either of the orientations indicated by figure at the top of the page. If the restraint that we are using is attached to concrete, in order to achieve a Force Class III connection, the 1 Bolt anchor table on the left indicates that a CCA clip with a single .75 anchor mounted to a vertical surface is needed. As an option, at the bottom of the page on the 2 Bolt anchor chart, either a KSCA or CCA clip mounted with (2) .38 anchors could be used as well.

If the restraint is through-bolted (or welded), data from the Grade 2 Bolt table on the right can be used. It indicates that with through-bolts, a .5” bolt is adequate, no matter what the orientation.

Optional

As with the load determination table, it is also possible to “fine tune” our hardware selection. This can often verify the acceptability of a smaller hardware component than that selected based on Force Class. To do this, we use Table 5A in the same manner as we did above, but we apply the 332 lb figure that we determined earlier as our force requirement. Using this, we can verify that a either a 5mm or .18 cable with gripple connectors would be adequate at 60 degrees.

We can also confirm the acceptability of a single .5 anchor with a KSCA clip in any orientation.

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If through bolted, we can use a KSCA clip with a .25 bolt in any orientation.

Thus it can be seen that with a little more effort, smaller hardware can often be justified.

This addresses the lateral restraints. The axial restraints can be addressed in the identical manner with the following result.

Force Determination

Force Class Method.

Design Requirement (80 ft span, 50 lb/ft duct) – Force Class = IV

Optional Method

Design Requirement (67 ft span, 29 lb/ft duct) – Design Force = 653 lb

Cable / Strut Size Determination

Force Class Method.

Cable size for Force Class IV at 60 degrees = .38”

Size for 77” long strut at Force Class IV at 45 degrees = 3 x 3 x .38”

Optional Method

Cable size for 653 lb at 60 degrees = .18” (U-clip connection)

Attachment Hardware Determination

Force Class Method.

Concrete Connection for Force Class IV at 60 degrees

CCA clip with (4) .375 anchors at any orientation

Through Bolt Connection

CCA clip with .75 bolt works for any orientation

Optional Method

Concrete Connection for 653 lb at 60 degrees

CCA clip with.875 anchor at any orientation

Through Bolt Connection

KSCA clip with .38 bolt at any orientation

Minimum Hanger Rod Size and Anchor Determination

The supported weight per hanger rod based on 10 ft spacing and 29 lb/ft duct is 145 lb (Note that there are (2) hanger rods splitting the total 290 lb at each support location).

Refer to Table 4a (D4.7) and note that all cables behave the same as a strut that is oriented horizontally. For supported weights up to 250 lb, the use of a cable restraint and a Force Class III (Lateral) seismic load, the minimum acceptable hanger rod size is .38”. If a strut is used in place of the cable and the angle of the strut is 45 degrees to the horizontal, the minimum hanger rod size permissible is .63”

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Below this is the anchor capacity table. If the hangers are anchored to concrete rather than through-bolted, this table indicates the size requirements for the anchor. In a similar fashion to the above, the anchor size for the cable restrained system can be found to be .63”, while that for the strut restrained system jumps to 1.25”

When the above table is applied to the axial restraint which needs a Force Class IV rating based on the 67 ft spacing, supporting from concrete becomes impractical. To resolve this issue, the ductwork must be either hung from steel or the spacing between restraints decreased to reduce the Force Class Requirement.

Evaluating Rod Stiffeners

Using only the lateral restraint example from above and assuming that we are using cable restraints and the minimum size hanger rods (.50”) we can use Table 4b to evaluate the need for rod stiffeners.

Looking up Force Class III and a cable angle of 60 degrees (worst case) in the upper table, we find that the maximum unstiffened length that we can have for a .38” hanger rod is 6”. Since our hanger rod is 54”, a rod stiffener is required.

The second table indicates multipliers that can be used to evaluate the additional length that can be achieved with the addition of various rod stiffening materials. We would like to increase our length from 6” to 54”, thus we need a multiplier of 9 (54/6). If we look at the line in the table for the .38” hanger rod, we can see that a 1” diameter pipe or a 2 x 2 x .12 angle will both offer multipliers in excess of the 9 that we need and would be acceptable as rod stiffeners.

The maximum spacing between clamps cannot exceed the maximum unstiffened rod length, so a minimum of 8 clamps are needed to clamp the hanger rod to the rod stiffener. Because of the large number of clamps needed, in this case it might be preferable to increase the size of the hanger rod and decrease the number of clamps and the size of the required rod stiffener.

SUSPENDED EQUIPMENT EXAMPLE

For our example, assume we have a piece of suspended equipment as illustrated below.

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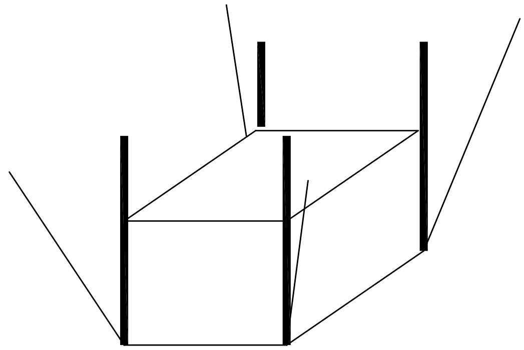

Further, assume that the equipment is supported by hanger rods that are 54” long and which are anchored at the top into the underside of the roof slab for the structure. In addition, assume that the equipment weights 900 lb. We can look at both struts and cables for restraint.

Determine Design Seismic Force

The first thing that we need to know is the design seismic force that must be applied. If we look near the top right corner of Table 1 or Table 1A (D4.5), there are listed the design accelerations in G’s that are appropriate for various elevations in this structure. Since we are attaching the equipment in our example to the underside of the roof, the value of interest to us is the acceleration at the roof, in this case .336 G.

Caution should be used here as the specific data in the Table 1 and 1A relative to A_c and R_p that are used for ductwork or piping may not be appropriate for use on equipment. If there is a question about the applicability of the tablulated values to equipment, contact Kinetics Noise Control for confirmation.

Use of the Force Class Tables to size restraints for equipment should be limited to smaller equipment requiring not more than 4 supports and 4 restraints (one in each corner oriented at 45 degrees to the equipment as shown above).

Determine the weight of the equipment that is being restrained

This should be “given” data received from the equipment supplier. It should be the operating weight of the equipment as installed.

Determine Restraint Hardware Capacity requirements

We can now apply the above information to Table 1 or 1A (D4.5) to determine a hardware “Force Class” or a design force requirment to size our restraint components.

Since we are working with something that has a known weight, the tabulated data in the tables needs to be tailored to offer a direct comparison. Use the table that indicates 10 ft OC spacing. Multiply all of the weights in the weight per foot column by 10. Compare these updated weights to the actual equipment weight to then determine the appropriate Force Class from the 10 ft OC table.

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Thus, the weight per ft values change from 10 lb/Ft to 100 lb, from 25 lb/ft to 250 lb, etc. Our equipment at 900 lb would than match the row on the table that originally read 100 lb/ft and now reads 1000 lb.

Reading the output from this table, the required Force Class for a roof level application would be Force Class II.

Optional

If we would like to "fine tune" our selection, we can use Table 1A and perform the same exercise to determine the actual force requirement for a 1000 lb piece of equipment to be 336 lb. If desired, the values on Table 1A can be pro-rated based on the actual weight. In this case we can multiply the 336 lb by the actual lb divided by the tabulated lb (900/1000). After multiplying the 336 lb figure by this factor, we find that the minimum component that we can select must withstand a design force of 302 lb.

Selecting restraint components

Table 5 and 5A (D4.8) list the capacity of various Kinetics Noise Control provided hardware and anchorage components. Table 5 indicates capacities in "Force Class" units while 5A indicates capacities in lb. The goal is to select components with capacities in excess of the design requirements.

If the cable or strut installation angle (as compared to the horizontal plane) is unknown, it should be assumed to be 60 degrees (worst case).

Cable ratings are listed at the top. Table 5 indicates that a .5mm or a .18" cable with Gripples is adequate for any Force Class II requirement at 60 degrees.

If we are using a strut, the angle should be limited to 45 degrees. With a 54" long hanger rod and a 45 degree angle to the strut, the length of the strut would be 1.41 * 54 or 77". This dimension is not important for cables, but is critcal for struts. Refering to Table 4c (D4.7), we need a strut that will be installed at 45 degrees, will be 77" long and will resist a Force Class II load. The minimum angle size that will accommodate this is a 2.5 x 2.5 x .25.

Returning to Table 5, below the cable data on the left are ratings for various hardware components that are anchored to concrete. On the right are ratings for hardware components that are through bolted. These tables list capacities for the clips mounted in either of the orientations indicated by figure at the top of the page. If the restraint that we are using is attached to concrete, in order to achieve a Force Class II connection, the 1 Bolt anchor table on the left indicates that a CCA clip with a single .75 anchor is needed. As an option, at the bottom of the page on the 2 Bolt anchor chart, either a KSCA or CCA clip mounted with (2) .25 anchors could be used as well.

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If the restraint is through-bolted (or welded), data from the Grade 2 Bolt table on the right can be used. It indicates that with through-bolts, a .38" bolt is adequate, no matter what the orientation.

Optional

As with the load determination table, it is also possible to "fine tune" our hardware selection. This can often verify the acceptability of a smaller hardware component than that selected based on Force Class. To do this, we use Table 5A in the same manner as we did above, but we apply the 302 lb figure that we determined earlier as our force requirement. Usng this, we can verify that a either a 5mm or .18 cable with gripple connectors would be adequate at 60 degrees, but that there is not enough of a difference to allow a reduction in cable size from the Force Class evaluation.

We can confirm the acceptability of a single .38 anchor with a KSCA clip in any orientation.

If through-bolted, we can use a KSCA clip with a .25 bolt in any orientation.

<u>Minimum Hanger Rod Size and Anchor Determination</u>

The supported weight at the most highly loaded hanger rod should be assumed to be approx 35% of the equipment weight unless there is some good reason to assume otherwise. In our case, 35% of 900 lb is 315 lb.

Refer to Table 4a (D4.7) and note that all cables behave the same as a strut that is oriented horizontally. For supported weights up to 500 lb, the use of a cable restraint and a Force Class II (Lateral) seismic load, The minimum acceptable hanger rod size is .50". If a strut is used in place of the cable and the angle of the strut is 45 degrees to the horizontal, the minimum hanger rod size permissible is .63"

Below this is the anchor capacity table. If the hangers are anchored to concrete rather than through bolted, this table indicates the size requirments for the anchor. In a similar fashion to the above, the anchor size for the cable restrained system can be found to be .88", while that for the strut restrained system jumps to 1.25"

<u>Evaluating Rod Stiffeners</u>

Using the minimum size hanger rods (.50") we can use Table 4b to evaluate the need for rod stiffeners.

Looking up Force Class II and a cable angle of 60 degrees (worst case) in the upper table, we find that the maximum unstiffened length that we can have for a .50" hanger rod is 14". Since our hanger rod is 54", a rod stiffener is required.

The second table indicates multipliers that can be used to evaluate the additional length that can be achieved with the addition of various rod stiffening materials. We would like to

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increase our length from 14” to 54”, thus we need a multiplier of 3.9 (54/14). If we look at the line in the table for the .50” hanger rod, we can see that a .75” diameter pipe or a 1.5 x 1.5 x .25 angle will both offer multipliers in excess of the 3.9 that we need and would be acceptable as rod stiffeners.

The maximum spacing between clamps cannot exceed the maximum unstiffened rod length, so a minimum of 3 clamps are needed to clamp the hanger rod to the rod stiffener.

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