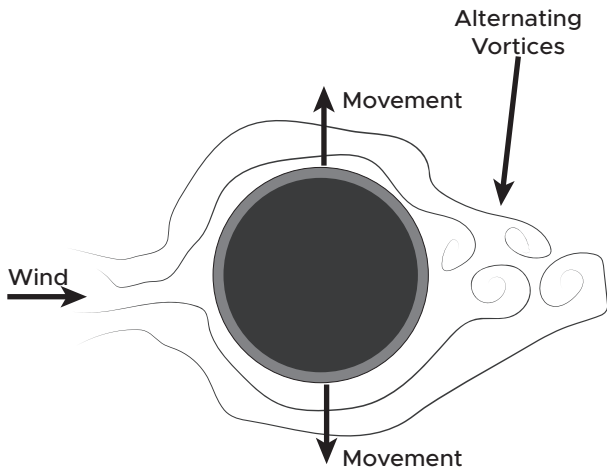


Wind Induced Vibration

For Stacks

Wind Induced Vibration

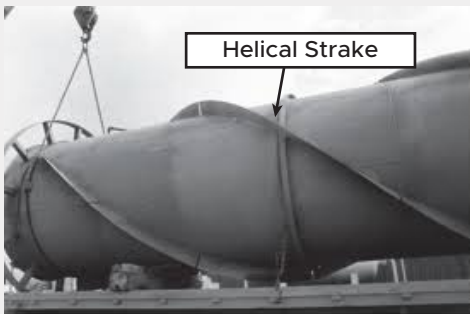
Every stack has a **critical wind speed** at which vortex shedding occurs. Vortex shedding is the instance where **alternating vortices** are generated on the down-wind side of the stack. These alternating vortices provide the driving force which causes the structure to **vibrate perpendicular** to the **direction of the wind**. When the critical wind speed of the stack is reached, these forces can cause the stack to **resonate** where **large forces** and deflections are experienced.



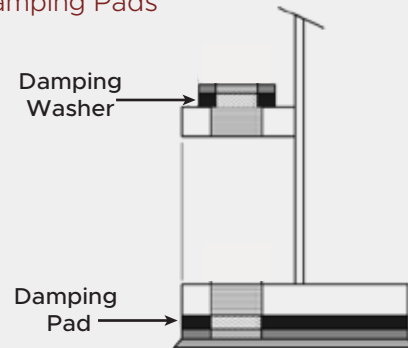
Typical Solutions

Typically wind induced vibration of steel stacks is addressed using one of these solutions:

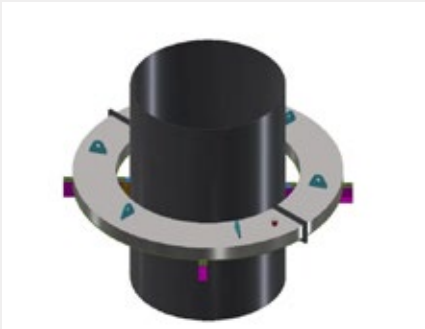
- Helical Strakes



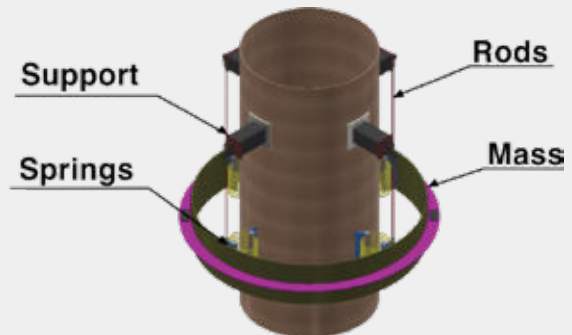
- Damping Pads



- Tuned Liquid Dampers (TLD)



- Tuned Mass Dampers (TMD)



Each of these solutions have their **advantages** and **disadvantages**, and so it takes a review of a specific design and situation in order to determine the best option for that stack.

Helical Strakes

For Stacks

Helical strakes are aerodynamic stabilizers which are sometimes used to reduce the forces and deflections of the stack experienced due to vortex shedding. Strakes consist of **three (3) vanes** which are wrapped in a helical pattern on the **upper 1/3 of the stack**.

When strakes are added the drag coefficient of the stack is increased greatly. A smooth cylinder will have a shape factor of 0.7, while the same stack with strakes will increase its shape factor to 1.4. Consequently, the load on the **top 1/3** of the stack is **doubled**. Since a stack is a large cantilever beam, increasing the forces at the top by a factor of 2 will increase the loads at the base by **approximately 1.5**. Similarly, the deflections will also increase significantly.

Advantages

1. Steel fabricators can build them
2. Sometimes provide the most economical solution
3. When stack is short and/or stiff, then the additional wind drag may not cause an increase in stack weight.



Disadvantages

1. Double the wind load on the upper 1/3 of the stack, increasing stack weight significantly for tall stacks.
2. Nearly always more expensive than a vibration damper when the stack height is 150 ft [45 m] tall or greater.
3. Complex geometry make fabrication difficult
4. Can interfere with other attachments (i.e. ladders, platforms, etc.)
5. Foundation and Anchor Bolts usually increase in size
6. Does not work when other tall structures nearby.
7. Euro code does not allow their use for Scruton Number < 8 (which covers most stacks with vibration issues)

Do Helical Strakes always work?

No, Helical strakes are not always an acceptable solution. When there is **interference** effects from a nearby structure, then strakes can be ineffective due to **buffeting**. Also, if you are following the **Euro** standards they have specific **checks** for Helical strakes that must be met in order for strakes to be acceptable.

Can we use segmented strakes?

No, although it is easier to fabricate strakes that are **segmented** rather than continuous and helical; however, the testing that has been done is based upon continuous helical strakes, and so we **must** use **continuous helical**

Is it ok to break streaks at an obstruction?

Many times there is a flange, stiffening ring or some other **obstruction**. Without testing there is not any way to know how much you can break the helical strakes and they will still work; however, it is generally considered **acceptable** to **stop** a strake on one side of an obstruction (i.e. stiffening ring) and then start it again **immediately** on the other side of the obstruction.

Do I need to put Helical strakes on my flare tip?

This is very much a **grey** area. We have some guidance in standards about small obstructions; however, there is **nothing** in the standards that permit leaving helical strakes off of the top few feet of a stack. We can tell you that in our practice, helical strakes are **rarely** put on a flare tip and we are **unaware** of any major issues; however, this is definitely a grey area and it is generally recommended to **avoid** this situation when possible. One way to avoid is using a **damper** instead of helical strakes.

Damping Pad

For Stacks

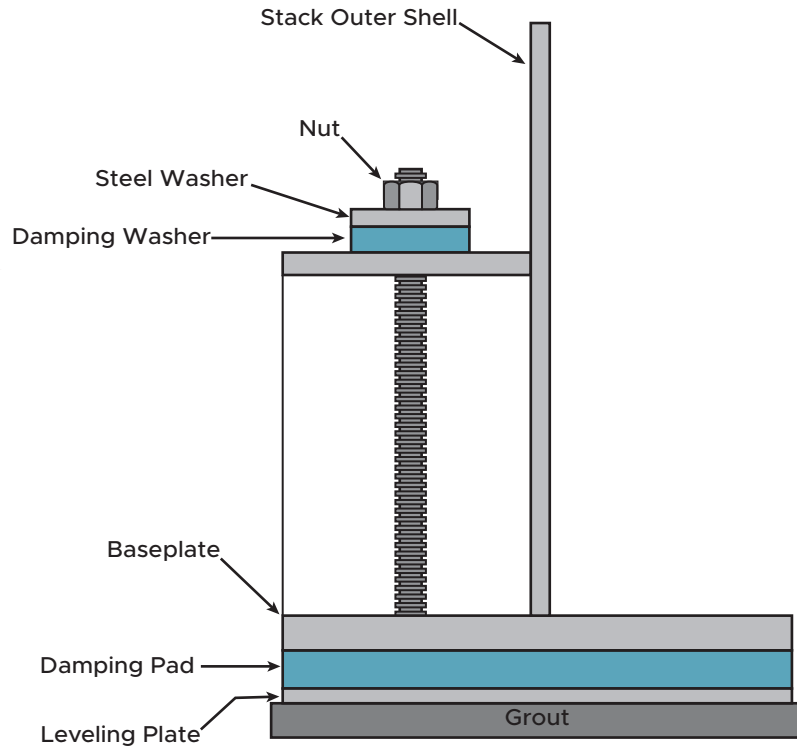
What is a damping pad?

A damping pad is a preformed **laminated fabric pad** of manufactured material composed of layers of tightly twisted, closely woven lightweight material. Each layer is made up of an elastomeric compound containing **mold and mildew** inhibiting agents.

What is it used for?

Because steel stacks have relatively **low inherent** structural damping, excessive top-of-stack deflection can result at critical wind speeds due to vortex shedding. To keep these deflections within acceptable limits, a damping pad is placed **between** the stack base plate and concrete foundation and conforms to the exact shape and size of the base plate.

The addition of the damping pad **increases** the inherent structural damping in the stack and foundation system, **reducing** deflection due to vortex shedding.



Advantages

1. Does **not** increase wind loads
2. **Compressive** strength 12,000 psi [82.7 MPa]
3. Impervious to most **oils and solvents**
4. **Resist** effects of steam, water, mildew and brine
5. Temperature range: **-40 °F [-40 °C] to 200 °F [93 °C]**

Disadvantages

1. Only withstand temperatures up to **200 °F [93 °C]**
2. Not always attractive to **retrofit existing** stacks
 - Requires extra **projection** of anchor bolts
 - Must **lift** stack for installation
3. Slight increase in **lateral deflection**

How do damping pads work?

A stack foundation can be **very rigid** and offer little inherent structural damping. A damping pad is **not as stiff** as steel and concrete. Adding a damping pad **increases** the structural damping of the system and **reduces** the vibration amplitudes that occur due to resonant structural vibration.

How Much Damping Can Be Achieved?

Damping can **vary greatly**. We recommend **sending** us your MecaStack input file and we can give you an **estimate** based upon your specific situation. If that is not feasible, a conservative estimate is to use a structural damping of **0.003**.

Will This Cause the Stack to See Larger Lateral Deflections Due to Along Wind Loads?

The damping pads do introduce some elasticity into the base, but they are also very stiff. There will be **minimal** impact on the lateral deflection due to along wind loads.

Do the Pads Hold up Over Time?

These pads have been in service for up to **30 years**, with no reported problems.

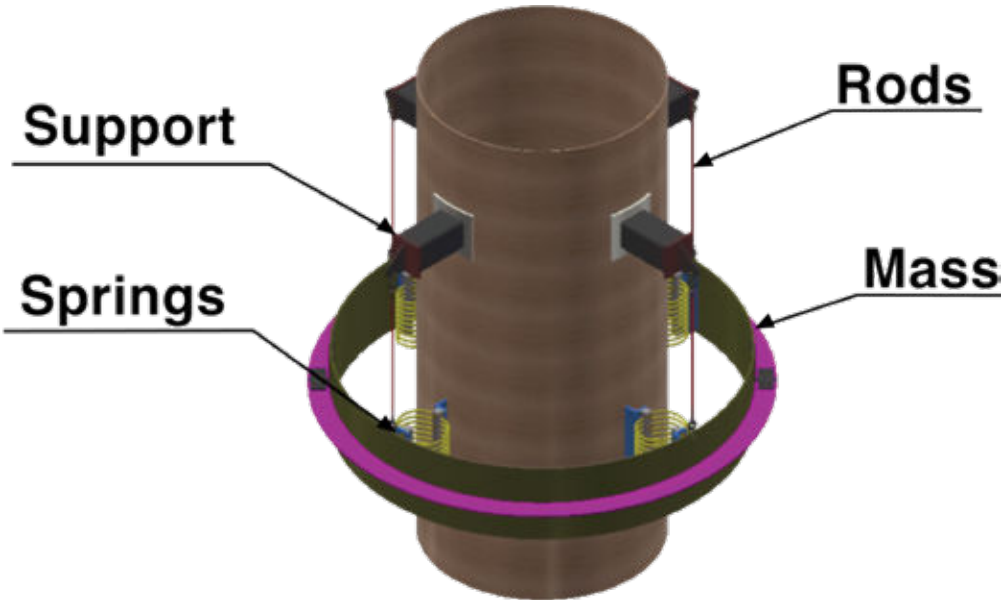
Can Pads be Used on Existing Stacks?

It is possible to use pads on existing stacks, but the stack must be **raised** in order to insert a pad under the baseplate. Typically pads are **1 in [25.4 mm]** thick, so it must also be considered that stack connections will be raised approximately **1 in [25.4 mm]**. Typically a damping pad is **not used** to retrofit an existing stack because there are generally better options available for this situation.

Tuned Mass Damper

For Stacks

The Tuned Mass Dampers (**TMD's**) utilize mass to provide the damping. The dampers are “**tuned**” to the natural frequency of the stack so that they are most effective at or near the natural frequency of the stack. The Tuned Mass Damper consists of a cylindrical ring of steel mass, which is suspended by cables. The ring is larger than the diameter of the stack and is separated from the stack with wire rope coil springs.



Advantages

- 1) All **Mechanical** Parts
- 2) No problem with **high temperatures**
- 3) Inspected from grade with **Binoculars**
- 4) Provides **large** structural damping

Disadvantages

- 1) Ideally will be full **360 Degrees**
- 2) Needs to be **near top** of stack
- 3) Cannot serve **dual** purpose (i.e. platform)
- 4) Sometimes **interferes** with ladders, platforms and piping

Can we place it lower on the stack for easier access?

The Tuned Mass Damper (TMD) is most effective if it is placed where the mode shape is highest, and for a typical stack that is going to be at the **very top** of the stack. The lower on the stack the TMD is placed the **less efficient** it becomes, and it is required to be a **larger** mass as a result. At some point the mode shape will just be too low and the TMD becomes ineffective.

Does the TMD require maintenance?

The TMD is made from **stainless** parts that are robust and provide good resistance to corrosion; however, the most likely component to fail are the wire rope springs which do flex and can fatigue over time. It's difficult to estimate with any accuracy how long the spring will last, but some TMD's have been in service for **decades** without any issues.

How can the TMD be inspected?

The most likely problem would be with the wire rope springs. These might be visible from grade using **binoculars** or they can be viewed more closely with a **drone**.

Can the Stack be lifted with the TMD in place?

It is possible to **lift** the stack with the TMD **installed**, if provisions have been made to block the springs and protect them during lifting. Once the stack is vertical, then the blocking needs to be removed to allow the springs to function. This is explained in more detail in our installation manual.

What if we have a Ladder or Piping on outside of stack?

In the case of piping, depending upon the size and quantity it may be possible to route the piping on the **inside** of the **annular gap** between the stack shell and TMD mass. If this is not feasible, another option is to **notch** the mass to allow a ladder and/or piping to pass through the TMD.

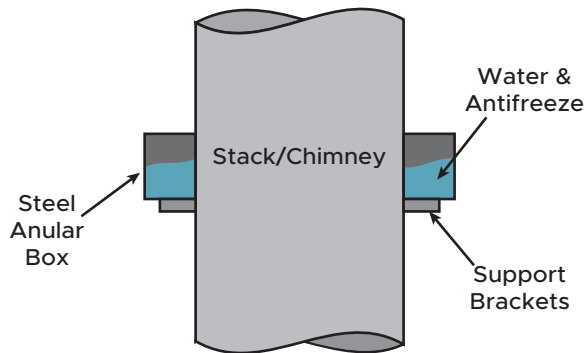


Tuned Liquid Damper

For Stacks

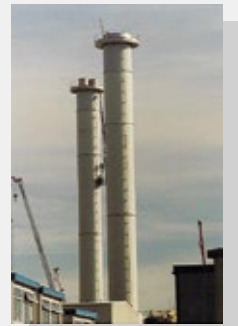
How does it work?

Tuned Liquid Damper (**TLD**) consists of an annular sealed chamber that contains a **liquid**, which is typically a combination of water and **ethylene glycol (anti-freeze)** to prevent freezing. The chamber consists of internal baffles to control **sloshing** of the liquid, which will provide damping to the structure.



TLD used as Platform

In some special circumstances a TLD can be designed to also serve as a **platform**. This can facilitate access to the TLD to perform **inspection** also. In other situations, the damper can be placed directly **below** the platform, and the fill nozzle extended up to be accessible from the platform.



TLD used as Platform

Advantages:

1. Can take different **shapes** and sizes
2. Accommodates **Ladders, Platforms and Piping**
3. Cost effective: Buy design only, and build it **locally**
4. No **moving** parts

Disadvantages:

1. Special precautions required when stack is **hot**
2. **Radiation shields** needed on Flare Stacks
3. Can't visually see **lost liquid** from grade
4. **Corrosion** concern due to presence of liquid, although since it's a **sealed** chamber this isn't usually a problem.



Gangway for Multiple Stacks



Guyed Tower



Damper



Damper under Platform

Will the water freeze?

A mixture of water combined with **ethylene glycol (antifreeze)** is recommended with each design. Combining water with antifreeze will allow the damper to work well in very **low** ambient temperatures.

Is the Damper shipped full of fluid?

Typically, the damper is shipped empty. The customer is then responsible for **filling the damper** with the recommended mixture of water and antifreeze.

How will I know if the Damper is leaking fluid?

During fabrication a **pressure test** is performed to ensure that the damper will hold product under atmospheric conditions. To date, Meca is unaware of any TLD leaking.

Will the fluid cause corrosion?

Some **corrosion** will be experienced, as is expected with all carbon steel. However, only **modest** corrosion rates have been witnessed on damper installations. The chamber is sealed much as a radiator on a car, and so without air circulating the corrosion is minimal. The only required maintenance on a damper is to check fluid level every **3 to 5 years**.

What damping ratio should I expect with a damper?

The exact damping is **dependent** upon the design of the stack and TLD, and so it must be **estimated** on each project; however, generally you can conservatively achieve a structural damping of **0.006** and often much higher.

What if I have a hot stack?

In the case where the stack shell is hot, > **180 °F [80 °C]**, some special precautions must be taken. The damper will be designed so that there is a **gap** between the shell and the damper, to essentially break the thermal bridge. We do not want the damper to exceed the **boiling point** of water, which would cause the damper to experience internal pressure. By breaking the **thermal bridges**, we ensure that the temperature will stay below the boiling point.

Can a damper decrease my along wind loads?

Most along-wind codes account for structural damping in their wind load calculations, so as **damping increases**, the calculated wind loads generally **decrease**. Some codes, such as the **Euro** standard, appear to be more sensitive to changes in damping. By contrast, the **American** code provides only **minimal load reduction** as damping increases, so the resulting improvement is usually not significant.