A SunCam online continuing education course

Pipe Support Failures

by

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1.0 INTRODUCTION

Pipe supports are engineered to

- Support the dead weight of the pipe, insulation, fluid and in-line components such as valves, flow meters, and instrumentation
- Restrain thermal pipe movement, as desired, from ambient to operating condition
- Restrain pipe movement created by surge, steam hammer, water hammer or other flow caused large dynamic loads
- Restrain pipe movement caused by operational flow induced vibrations such as vane passing pulsations, vortex shedding and other sources.
- Restrain pipe movements caused by outside sources, such as wind and seismic events.
- Provide stability to the pipe, particularly on long risers and long horizontal runs.
- Minimize sag to acceptable levels between supports, which may be limited to assure full drainage at all times.

This course is written to show the various types of supports, and the ways in which they may fail.

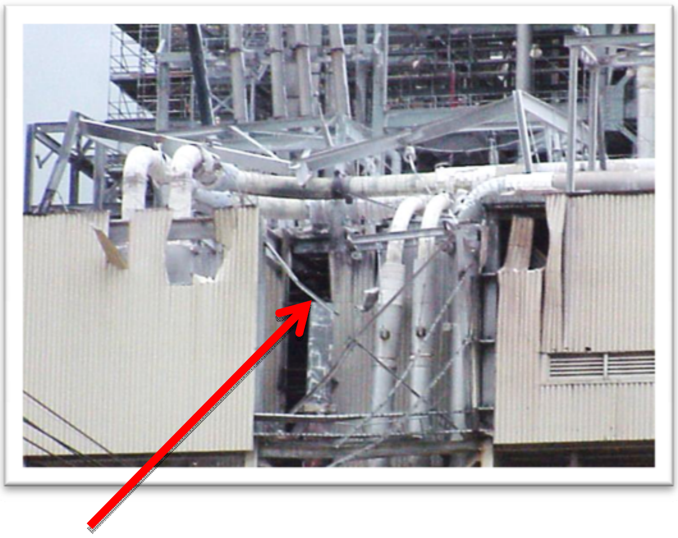
Shattered spring on constant support hanger can. Spring was not passivated properly after acid pickling, and failed due to hydrogen embrittlement.

There are three related courses that may be of use to the student.

- "Introduction to Piping Engineering" provides an overview of the loading conditions on pipe and basics of pipe stress analysis.
- "Building Mechanical Integrity Into the Plant Design" discusses the different design approach if Mechanical Integrity is considered during initial plant design.
- "Life Cycle Mechanical Integrity of Piping Systems" builds upon the information presented in these courses to show how to set up a long term visual inspection and monitoring program of piping systems at any time during plant life.

2.0 IMPORTANCE

A pipe support failure can cause catastrophic failure of pipe, collateral damage to the plant, fires, explosion, and injuries and death to personnel. Pictured below is the result of a seam welded pipe failure at a gulf coast area power plant. The final report attributed poorly functioning pipe supports as the primary cause of the excess stresses that failed the pipe.



Seam welded riser pipe failed and literally flew apart, causing collateral damage to nearby pipes and steel.

Part of the pipe landed on the ground near a walk area and roadway (lower left photo).
The internal desuperheater liner shot out of the failed pipe up over the administration building coming to rest in this pick-up truck. (photo below)
Luckily, no one was injured, but the potential for injury and death is obvious.

Beginning of missing pipe in riser

From this dramatic example, and other incidents that are shown in this course, pipe support damage is a real problem that can impact the availability of a plant, and potentially can create serious problems causing injuries and death. The goal of this course is to help engineers and designers recognize the potential problems and to avoid them before they become a catastrophic issue.

3.0 DESIGN PROCESS

To understand how pipe supports can fail, it is helpful to understand how they should be designed – and the short cuts that are sometimes taken.

Before routing a pipe, there should be a clear understanding of the process conditions; the expected loading conditions; acceptable areas for pipe per process safety and fire constraints; client expectations for access for maintenance, inspection and operations; an approximate layout of equipment; and a concept of the structural supports that will be available.

The initial plant layout approximately locates equipment, horizontal and vertical pipe chases, cable tray chases, walkways, crane access and other major considerations. General steel and concrete arrangement is based upon these layouts. Layout should be a team effort to attempt to foresee the detailed design requirements and avoid difficult or unworkable designs.

When a piping designer initially routes a pipe, it is a complex job of considering all of the above criteria, and leaving room for other equipment that will probably be added later, such as other pipes, cable trays and platforms. The designer should always consider how the pipe can be supported from steel or concrete. An approved pipe support spacing tables can be used for initial routing. The acceptable distance between pipe and steel is affected by the size and type of supports, along with the expected horizontal movements.

A review process with a piping engineer and structural engineer should be performed to assure the pipe can be supported efficiently. This review may include a preliminary pipe stress analysis to assure the pipe support spacing is appropriate, and the structural design will have capacity for all expected loading conditions. If significant detailed design problems are anticipated, the layout may need to be modified by a team effort.

There may be multiple design iterations as steel, pipe, platforms and other details are designed. At some point, the pipe support designs must be set based upon the "For Fabrication" pipe routing.

It is clear from this summary description, that proper planning and decision making early in the design process will make the final pipe support design drawings a relatively easy process. However, a poorly thought out and reviewed pipe support layout may result in extreme difficulties in making final steel design, and even in finding space to install the pipe supports. While some of the failures described in this course are the result of faulty fabrication, incorrect installation and unusual operating conditions – many failures are a direct result of faulty design practice.

4.0 RIGID PIPE SUPPORTS

There are many types of pipe supports with a large number of detail variations in how they are attached to the pipe and steel, and how they are arranged. A general grouping of types of rigid supports is shown with discussion of the types of damage that can be observed.

4.1 Rigid Rods

Rigid rods are probably the simplest and most reliable pipe supports available, but even these can fail.

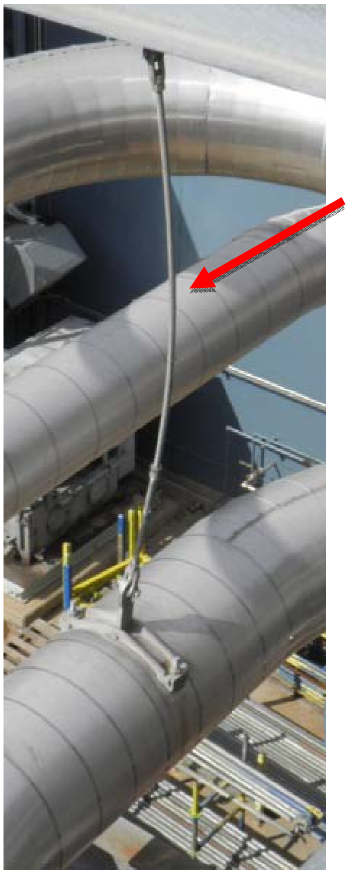
Standard trapeze rigid rod pipe support in good condition:

- The pins at the pipe trapeze and the steel are intentionally arranged orthogonally to allow horizontal movement of the pipe up to a 4^0 swing angle in any direction (red arrows). This 4^0 is an industry standard for most pipe support components. Exceeding this angle can create binding of the components, and also means that a significant horizontal load component may be transmitted to the steel.
- Lock nuts at clevises and at right hand threaded portion of rod are tightened to assure rod does not back out of components due to vibration (orange arrows).
- Pins with cotter pins are installed at steel and trapeze attachments to assure pins do not slip out.
- Turnbuckles are threaded right hand and left hand for easy adjustment. In this case, right hand thread is on top. Left hand threaded nuts are rarely installed (green arrow).

GUIDELINE 1: RIGID RODS WORK WELL IN TENSION BUT ARE USELESS IN COMPRESSION & BENDING

These photos show two variations of a commonly used steel attachment in which a hole is drilled through the steel and a washer and nuts are used to hold the rod in place.

- This arrangement on the left should only be used for low loads since eccentric loading of beams should be avoided,
- Use drilled holes only for very low horizontal movement. If the horizontal movement from thermal growth, wind or vibration is excessive then the rod is put in bending at the steel. Given enough cycles, the rod will break.
- At one plant, bending of the rod at the steel caused one pipe support to fail. The support was not repaired, and about 6 months later the next support upstream failed due to bending and the increased load from the first failure. The increased load on the next support caused an immediate domino effect – failing 10 supports and letting the 3” line sag 8’. Due to the criticality of the system, the plant was shut down for 3 days as the pipe was replaced.

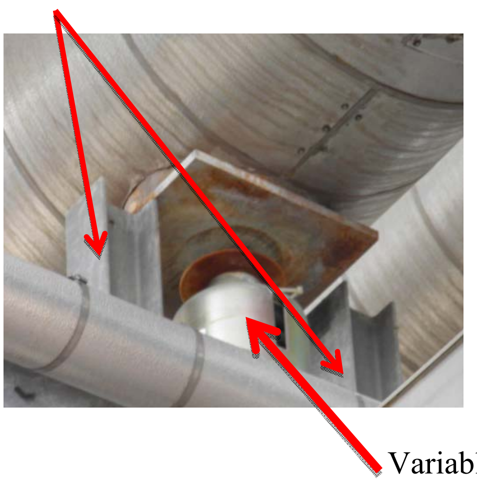


Obviously rod supports are designed only for tension load. When a rod is bowed and in compression like this, then the cause needs to be investigated.

In this case, a dynamic load had occurred, causing the line to "jump up" several inches. The end result is shown in the 2 photos below of the same variable spring hanger with guide. This support is downstream of the bowed rod about 40'. From the dynamic event, the trunnion completely lifted off the spring load flange and came to rest on top of the guide steel, instead of the variable spring load flange that it was originally resting upon. This raised the pipe elevation and bowed the rod.

This is an extreme example. More often rods are found unloaded but not in compression. Sometimes it is difficult to know if the rods are loaded from a visual exam, and grabbing the rod to test the tension is recommended if the rod is safely accessible.

Guide Steel　　　Trunnion w/ plate, resting on guide steel instead of load flange

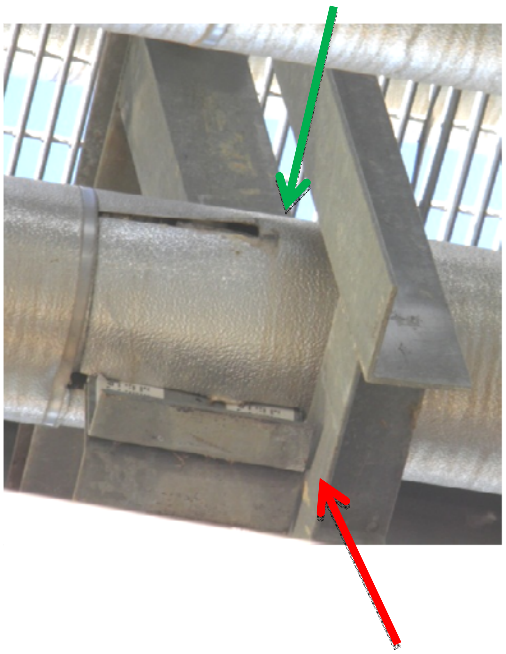


Variable Spring Can　　　Variable Spring Load Flange

The spring support was re-positioned properly, but the rigid rod had yielded and had a permanent bow. In this case, both the bowed rod and stanchion plate on top of the guide steel were symptoms of another problem, an unpredicted dynamic load.

4.2 Sliding Supports

There are a large number of different types of sliding supports. The most widely used are shown below and are the staple pipe support design on pipe racks, particularly in refinery and petrochemical plants.



A pipe shoe is attached to the pipe, by clamping it to the pipe. Shown here is one of the common problems, the shoe has worked its way off the steel due to thermal ratcheting or vibration (red arrow). This causes 2 immediate issues:

1. The pipe elevation is lowered locally, which not only causes increased pipe stress, but may cause drainage problems with an undrainable low point.
2. If the pipe needs to move axially, it is now restrained which will increase thermal stresses, and possibly damage to the steel. In this case the insulation is also damaged.

At the side of the pipe, visible through the insulation, is a stub intended as a lateral guide. Obviously it is inactive in this situation since it cannot contact the vertical steel (green arrow).

This is a typical example of a TEE welded to the bottom of the pipe as a shoe. This one is centered properly.

If this type of shoe falls off the steel, there is a risk of the weld to the pipe cracking and the crack penetrating into the pressure boundary of the pipe.

TEE welded to pipe, slides on I-Beam

GUIDELINE 2: OVERSIZE THE LENGTH OF THE SUPPORTS TO ASSURE THEY REMAIN ON THE STEEL.

In this case, the shoe is clamped over the insulation, but the clamp has slipped damaging the insulation and the shoe is on the verge of falling off the steel.

This design attempts to minimize heat loss by maintaining the insulation through the pipe support, but with the slippage and damaged insulation the heat loss is actually greater than if a shoe were welded to the pipe.

Here is another example of how sliding supports can bind up. The horizontal pipe moves about 4" horizontally from cold to hot conditions. There is no low friction slide plate.
The trunnion support sometimes slid and sometimes bound up and rotated the support stanchion - eventually leading to an overhang over the stanchion plate.
As shown in the picture, when the pipe moves to the right as it heats up, the plates do not slide and instead rotates the stanchion, and its support steel. While the picture may appear exaggerated due to the slope of the camera, it was estimated that the stanchion and support steel was being twisted up to 20^0.

This is one of a series of improperly sliding supports that led to a through wall failure of a high pressure steam line.

GUIDELINE 3: SLIDING SUPPORTS RARELY SLIDE TO THE LOCATIONS EXPECTED.

Guideline 3 may seem a little overly negative, but even when low friction slide pads are used, the frictional coefficient is difficult to predict. In most installations, there are many of these sliding supports in a row, and just one of them binding up or sliding at a higher friction factor can create inconsistencies. These types of supports are inexpensive, but if more than 1" to 2" of horizontal movement is expected, they are very difficult to maintain.

Lift-Off is a common problem with rigid stanchion supports. In this case the pipe stanchion is approximately 1" above the steel and supporting no load. Causes are often:

- Thermal growth of pipe not properly accounted for and support should be a spring. **
- Bowing of the pipe
- Pipe pivoting at a nearby support

** Inexperienced pipe stress analysts often look at the loads in a pipe stress run without paying attention to the plus or minus sign. Given normal convention of up +, down -; when a support load is +, the support is trying to lift off. If a + load is calculated, rather than re-analyze with modified supports, an analyst may report the positive load plus safety factor as the design load. This photo shows the result of such a mistake.

4.3 Guides And Restraints

Guides are usually intended to restrain the movement of the pipe in one or more directions, limiting or eliminating the movement completely. If no movement is allowed, they are called guides. If some movement is allowed they are called gapped guides or limit stops. If the guide is arranged to limit movement in line with the centerline of the pipe, it is an axial restraint, and if perpendicular to the centerline it is a lateral restraint.

Missing Guide Steel

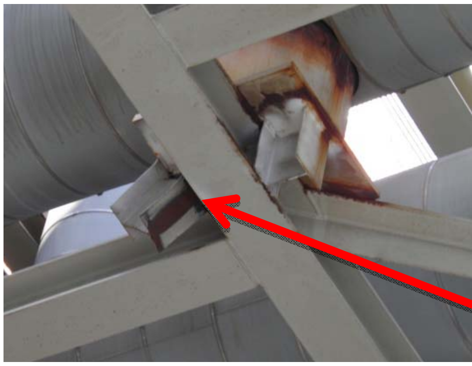
This is one common style guide in which angle steel is welded to a structural stanchion, to limit horizontal movement of a pipe trunnion.

Note that the angle steel is completely missing on the left and foreground sides. (Remnants of the welds are visible.) Was the load excessive for the design and ripped the angle off? Was the angle intentionally removed by maintenance? Is there some other explanation? In this case, the exact reason for the missing angle steel was never resolved.

Bent Spider Plate

This is one of many examples of riser guides that restrain the pipe horizontally, while allowing thermal movement vertically. There is a clamp under the insulation w/ 4 plates sticking out through the insulation to guide the pipe w/in the outside clamp. One plate is bent in this photo. The plate is also vertically shorter than the clamp, leading to potential to bind up as the pipe moves vertically.

This particular guide also has the problem of a double unbraced cantilever support. If the pipe pushes on the guide, the steel may twist and bind up the guide.



Trunnion support with wide flange steel straddling the support beam to act as an axial guide. The wide flange to the left has been overloaded and bent out to about a 45^0 angle.

Bent Guide Steel Welded to Trunnion Plate

There is one other common cause for inadequate guide design. The supports are not always engineered. Perhaps the loads are not calculated, or all possible loading conditions are not considered. Another common issue is that rigid supports and guides are often designed from standards. The standard size may be appropriate in a high percentage of cases, but occasionally this approach will undersize the components.

GUIDELINE 4: GUIDES AND LIMIT STOPS MUST BE DESIGNED FOR ALL POSSIBLE LOADING CONDITIONS, AND SHOULD BE CONSERVATIVELY ENGINEERED FOR UNEXPECTED EVENTS.

4.4 Sway Struts

Sway struts are engineered rigid components that are designed to resist load in tension or compression. They are length limited by buckling for a particular compressive load. While most other components are almost always arranged along the axis of the pipe or perpendicular to the axis, it is common that sway struts are installed at skewed angles and often in pairs. Multiple sway struts provide some stability in compression, where a single axis might rotate and not restrain the pipe as needed. Note that the connection pins are not loose as commonly seen in rod hangers, but are machined pins to bearings.

To Left: Vertical sway struts to support weight load. Functioning properly.

Below: Horizontal sway strut attached to riser pipe by a pipe clamp. Functioning properly.

4.5 Snubbers

Hydraulic snubbers are installed in locations where movement due to sudden dynamic loads need to be resisted, but the thermal movement of the pipe does not allow the installation of sway struts, guides or limit stops. Snubbers are provided with tight fitting pins and bearings at the pipe and steel attachments, similar to sway struts. There is a piston which has a specific stroke, and it must be set up to never fully compress or fully extend due to thermal movement in any operating condition.

Hydraulic snubbers are maintenance items, as the hydraulic fluid may leak from failed seals, the internal valve can clog, or there is other damage to the mechanism. If a hydraulic snubber is inoperable due to leaking hydraulic fluid, it typically will move freely and not restrain thermal growth unless the snubber is fully compressed or fully extended.

Snubbers should only be installed to resist short term occasional dynamic loads. Snubbers will not operate long if there is a high cycle vibration that it is expected to restrain. Because of their initial cost, maintenance cost and limited application, snubbers should be installed as a last resort when other types of guides and limit stops are not acceptable.

Shiny portion of piston indicates movement

Reservoir w/ leaking fluid

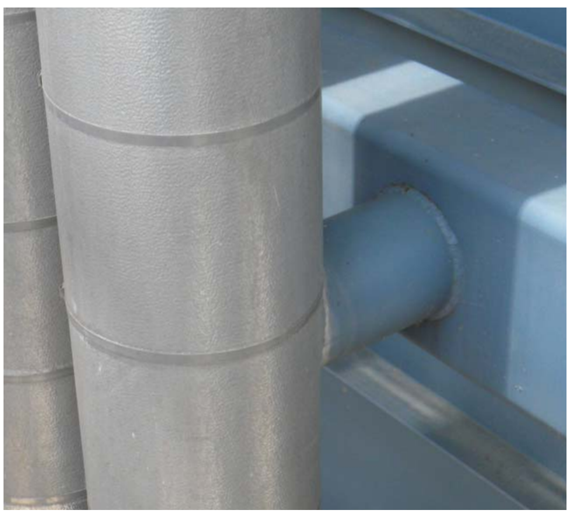
This is a hydraulic snubber installed in the horizontal position. Stroke is extended several inches. The shiny portion of the piston is usually a good indication of the actual movement. Always check to see if piston is fully extended or compressed. Evidence of fluid leakage and reservoir is probably empty, making it incapable of resisting dynamic loads.

Mechanical snubbers were a popular alternative to hydraulic snubbers for a period of time because they eliminated the maintenance issue of hydraulic fluid. Mechanical snubbers fell out of favor when failures were found. When a mechanical snubber fails, it typically has a broken internal part that cannot be seen. The failed part completely locks the snubber in place and will restrain thermal movement like a sway strut. The difficulty in knowing when a mechanical snubber has failed, and the fact it will lock up has made them rarely installed since the 1990's.

GUIDELINE 5: DUE TO HIGH COSTS & LIMITED APPLICABILITY SNUBBERS SHOULD BE AVOIDED IF THERE IS A REASONABLE ALTERNATIVE DESIGN.

4.6 Anchors

An anchor is a rigid restraint in which pipe displacements and rotations are nearly eliminated. Below to the left is a stanchion that is welded to a riser pipe, and welded to the steel. The length of the stanchion is limited, the stanchion weld to the pipe was engineered for the expected loads, and the steel was designed for the full load. All 3 displacements and all 3 rotations are limited by the stiffness of the stanchion and the structural steel. Properly engineered, installed and maintained for corrosion - anchors should virtually never fail.



Failed Weld

However, in the right photo is an example of an anchor that did fail. The stanchion is cantilevered from the structural steel and then cantilevered orthogonally to the riser pipe. (Vertical pipe not in photo.) No unusual loading conditions occurred, just a poorly engineered design creating bending moments in components that did not have the proper strength. This anchor was relatively flexible as originally designed, and did not provide the stiffness that was desired. The solution was to re-weld and brace the stanchion from near the pipe location back to the structural steel.

GUIDELINE 6: ANCHORS AND OTHER RESTRAINTS SHOULD BE DESIGNED FOR BOTH STRESS AND NECESSARY STIFFNESS.

5.0 SPRING SUPPORTS

There are two primary spring supports:

- Variable Springs for relatively low vertical thermal movements up to 2", although special designs can be made for greater movements
- Constant Supports for vertical movements greater than 2".

Both types are provided by many pipe support suppliers based upon each manufacturer's designs and testing. The spring can dimensions, spring rates, travel scales, travel stop design, structural attachments, adjoining rod sizes and other details vary between manufacturers. This can be an issue if a particular manufacturer was assumed to supply all spring supports, and the contract was awarded to a different supplier. While often the changes are relatively simple, it is possible that the size and type of spring selected will not fit in the available space with a different manufacturer's equipment.

5.1 Variable Spring Hangers

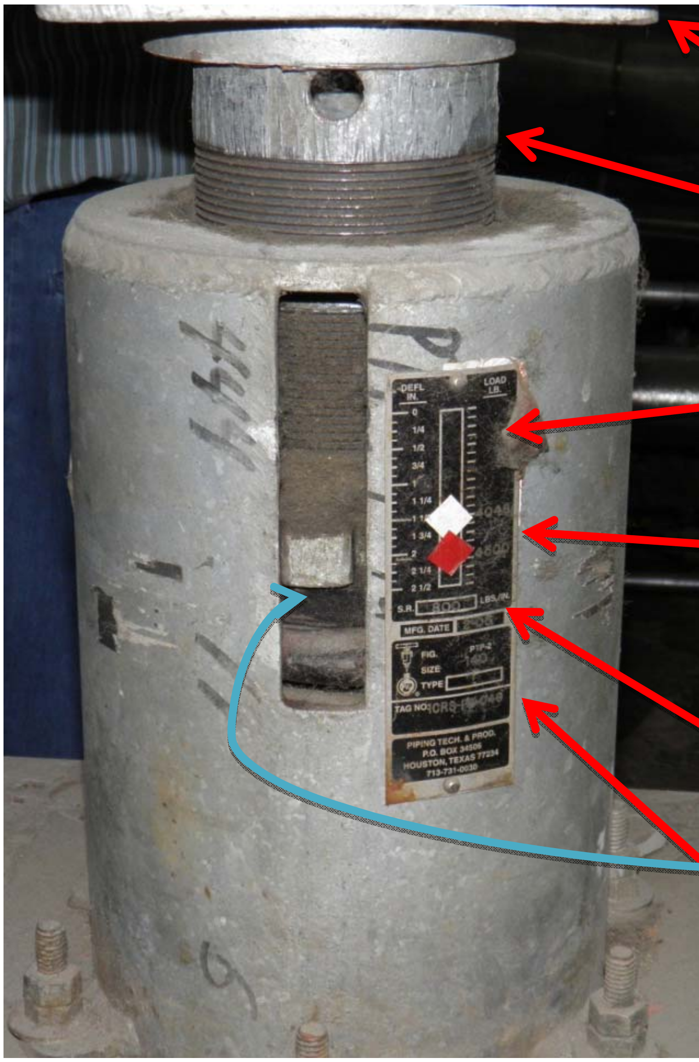
Variable spring hangers are helical coils that are designed to compress or expand as the pipe moves from ambient temperature to operating temperature. As the spring compresses, the load increases. This change in load from ambient to operating condition is called the load variability, and it must be limited to assure the pipe is properly supported in all operating conditions.

To accommodate the load variation limitation, hanger vendors typically make helical coils in at least 3 different lengths using the same strength coil. As the length of the coil doubles, the spring rate in lbs/in is halved. The space required for such springs also doubles, and in most installations there is a space limitation for long springs with low spring rates.

Design for a variable spring is based upon:

- Optimum load – usually set at operating or hot load
- Travel in inches – calculated vertical thermal movement from ambient to operating condition, or cold to hot movement (Convention is movement down cold to hot is negative, movement up is positive)
- Spring Rate – lbs/in
- Ambient (cold) load = Optimum load + (Spring Rate X Travel)
- Load variation Percent = ((Hot Load – Cold Load)/ Hot Load) X 100 or = ((Spring rate x travel)/Hot Load) X 100

Since the load changes as the helical coil expands and contracts, there is a limit to the amount of movement that a spring should be designed for. A typical maximum variation from ambient to operating load is 25% of the optimum load, which is usually set as the operating condition load. On critical systems, engineers will limit this load variation to 10% to 15% to assure the pipe is properly supported at all times.



F (floor support) Style Variable Spring

Load Flange

Adjustment Collar, Screws up and down to adjust height of load flange and compression of spring.

Travel and Load Scale: 0" to 2-1/2" on this size can.

Design cold position, white diamond, 1-1/2", 4046#. Design hot position, Red diamond, 2-1/16". 4500#. Thus design movement 0.56" down, cold to hot.

Spring rate 800 #/in.

Indicator Tab – Normally read at bottom. In this case 2-3/8".

Manufacturer: PTP-2 Size 140

GUIDELINE 7: THE VARIATION IN LOAD ON A VARIABLE SPRING HANGER SHOULD NEVER EXCEED 25%, AND IN MANY SITUATIONS SHOULD NOT EXCEED 10%.

On the next page is part of a typical vendor's variable spring hanger selection chart.

Example: From a stress analysis report, the optimum load is 1,000 lbs, and the pipe is expected to move up 1.5" from ambient to operating condition.

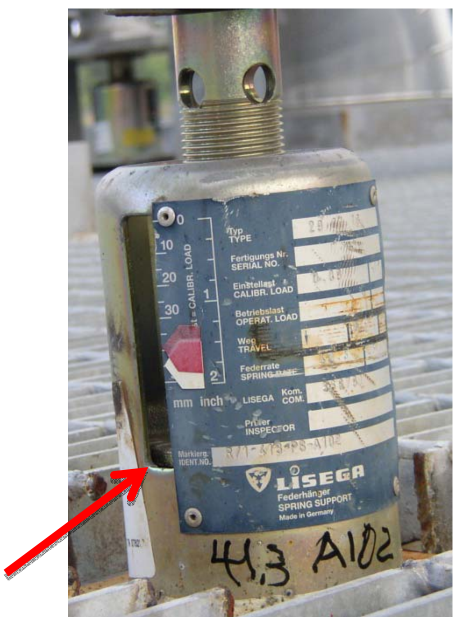
- Look for the 1,000 lbs and set that as the spring's operating load.
- There are 2 choices, a size 9 or size 10. Try a size 9
- There are 5 different spring ranges, BE 399 through BE 403, each with a different spring rate as shown at the bottom of the table, 400 lbs/in to 50 lbs /in.
- At 1.5" movement x 400 lbs/in the load variation would be 600 lbs or 60%. To be less than 25% variability, select BE 403 at 100 lbs/in. (1.5 x 100 /1000) x100 = 15%. Design ambient load is thus 1000 lbs + 150 lbs = 1150 lbs. which is within range of this spring. Per the table, design settings would be 4.5" ambient and 3" operating condition.
- If the initial attempt were to assume a size 10, a BE400 would have to be selected to obtain load variability less than 25%. In general, the larger the spring in length and size number, the more expensive the spring is. Thus, unless there are some additional criteria, the size 9 BE 403 would be the optimum size.
- Most pipe stress computer programs will perform this calculation for the engineer, and then re-analyze the pipe using the selected spring rate to re-calculate the expected vertical movement. The engineer should always check to make sure the computer generated spring size and spring rate are the desired selection for the spring hanger.

EXAMPLE VARIABLE SPRING HANGER SELECTION TABLE

WORKING RANGE, IN.			HANGER SIZE												
BE403	**BE402**	**BE401**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
		-	46	60	82	108	144	190	252	336	450	600	802	1068	1426
		-	47	63	85	113	150	197	263	350	469	625	835	1113	1485
		-----	49	65	88	117	156	205	273	364	488	650	868	1157	1544
		-	51	68	92	122	162	213	284	378	506	675	902	1202	1604
0	0	0	53	70	95	126	168	221	294	392	525	700	935	1246	1663
		-	55	73	98	131	174	229	305	406	544	725	968	1291	1722
		-----	57	75	102	135	180	237	315	420	563	750	**1002**	1335	1782
		-	59	78	105	140	186	245	326	434	581	775	1035	1380	1841
1	0.5	0.25	61	80	109	144	192	253	336	448	600	800	1069	1424	1901
		-	62	83	112	149	198	260	347	462	619	825	1102	1469	1960
		-----	64	85	115	153	204	268	357	476	638	850	1135	1513	2019
		-	66	88	119	158	210	276	368	490	656	875	1169	1558	2079
2	1	0.5	68	90	122	162	216	284	378	504	675	900	1202	1602	2138
		-	70	93	125	167	222	292	389	518	694	925	1235	1647	2197
		-----	72	95	129	171	228	300	399	532	713	950	1269	1691	2257
		-	74	98	132	176	234	308	410	546	731	975	1302	1736	2316
3	1.5	0.75	76	100	136	180	240	316	420	560	750	**1000**	1336	1780	2376
		-	77	103	139	185	246	323	431	574	769	1025	1369	1825	2435
		-----	79	105	142	189	252	331	441	588	788	1050	1402	1869	2494
		-	81	108	146	194	258	339	452	602	806	1075	1436	1914	2554
4	2	1	83	110	149	198	264	347	462	616	825	1100	1469	1958	2613
		-	85	113	152	203	270	355	473	630	844	1125	1502	2003	2672
		-----	87	115	156	207	276	363	483	644	863	1150	1536	2047	2732
		-	89	118	159	212	282	371	494	658	881	1175	1569	2092	2791
5	2.5	1.25	91	120	163	216	288	379	504	672	900	1200	1603	2136	2851
		-	92	123	166	221	294	386	515	686	919	1225	1636	2181	2910
		-----	94	125	169	225	300	394	525	700	938	1250	1669	2225	2969
			SPRING RATE - LBS/INCH												
			30	40	54	72	96	126	168	224	300	400	534	712	950
			15	20	27	36	48	63	84	112	150	200	267	356	475
			7.5	10	13.5	18	24	31.5	42	56	75	100	133.5	178	237.5

Problems with variable springs can be the same as rigid rods, with bowed rods, swing angle greater than 4^0 or corroded components. The other common issues are

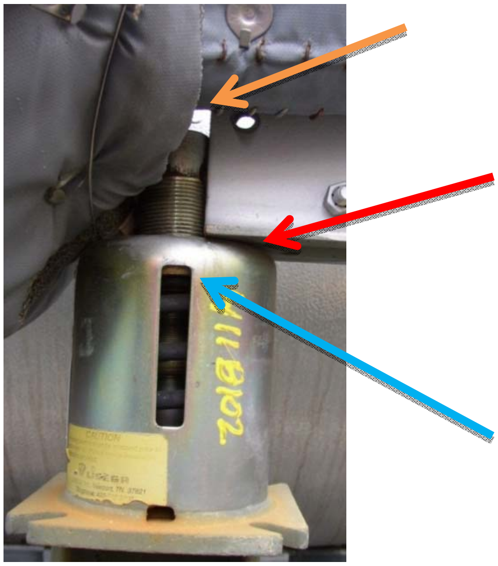
- Pipe and spring do not move as expected.
- If a spring is below the pipe, F style, then 4^0 is not applicable. Manufacturers typically recommend 0.25" maximum horizontal movement so that the load collar does not bind against the can.
- Spring is bottomed out – once the spring is fully compressed it acts as if it is rigid.
- Spring is topped out – the spring is fully extended against the top of the can. Since the spring is pre-loaded, the load in the spring decreases from the pre-load until it eventually equals 0 lbs. It is possible for the spring to appear topped out, and the spring is still supporting some load.



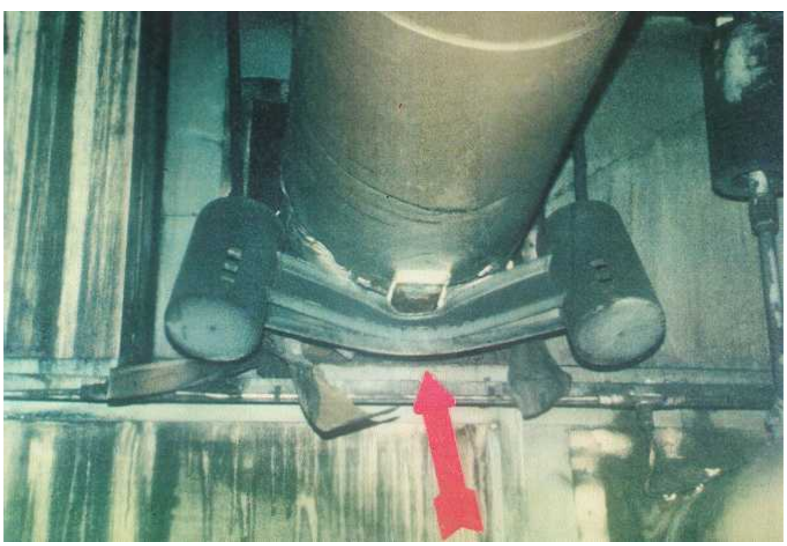
Lisega F style variable spring hanger: For this manufacturer, the indicator is read from the top of the load plate inside the can. In this case the load plate is well below scale, arrow point. Assume the hanger is bottomed out, although without being able to see the spring, it is not possible to tell if the spring is fully compressed.

Topped out variable spring hanger: Support point from the pipe is not on top of can (orange arrow), but to the right (red arrow). This problem is the same as the shoe "falling off" the steel described in the rigid section.

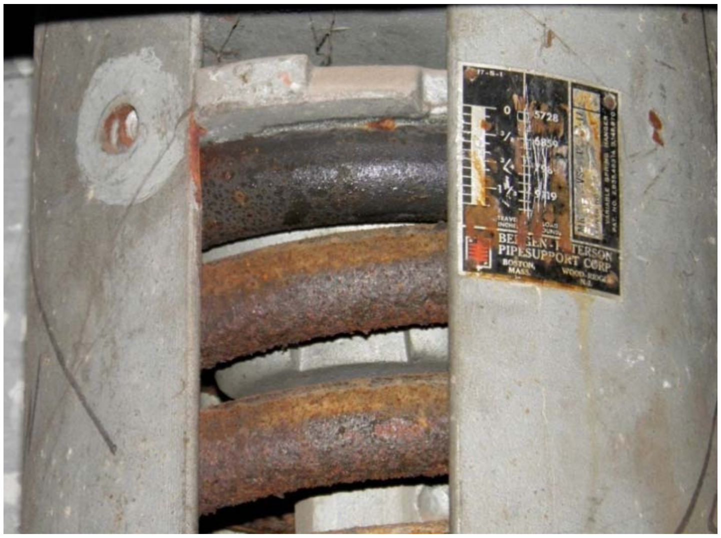
Spring is fully extended with the load plate partially visible at the top of the can (blue arrow). Scale is not visible.



GUIDELINE 8: HORIZONTAL MOVEMENT SHOULD BE MAINTAINED AT LESS THAN 4^0 FOR VARIABLE SPRING HANGERS, AND LESS THAN 0.25" FOR FLOOR SUPPORT VARIABLE SPRINGS.



A large dynamic load damaged this trapeze variable spring rod hanger. Not only is the steel damaged, but the rods are bent, and the spring cans are topped out. Complete replacement was necessary.



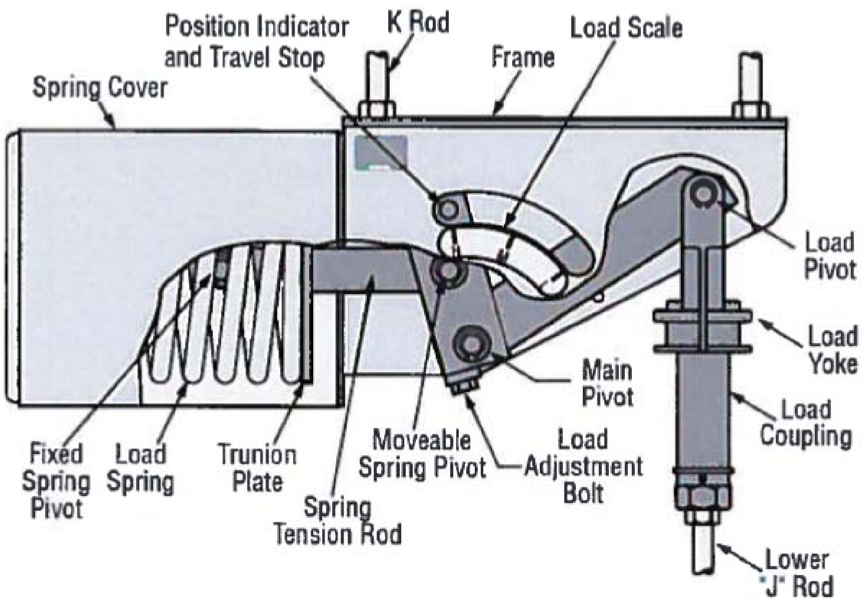
Spring coating has deteriorated and the spring is starting to corrode. While the spring is not near failure, the spring capacity is being affected and replacement should be considered.

Variable spring hangers are shipped with travel stops installed to set the hanger at its design ambient load. In this case, the red travel stop below the indicator bar was left in place while the travel stop above the indicator was properly removed. All travel stops should always be removed prior to operation. Otherwise, the spring may be effectively topped out or bottomed out in certain conditions.

5.2 Constant Support Hangers

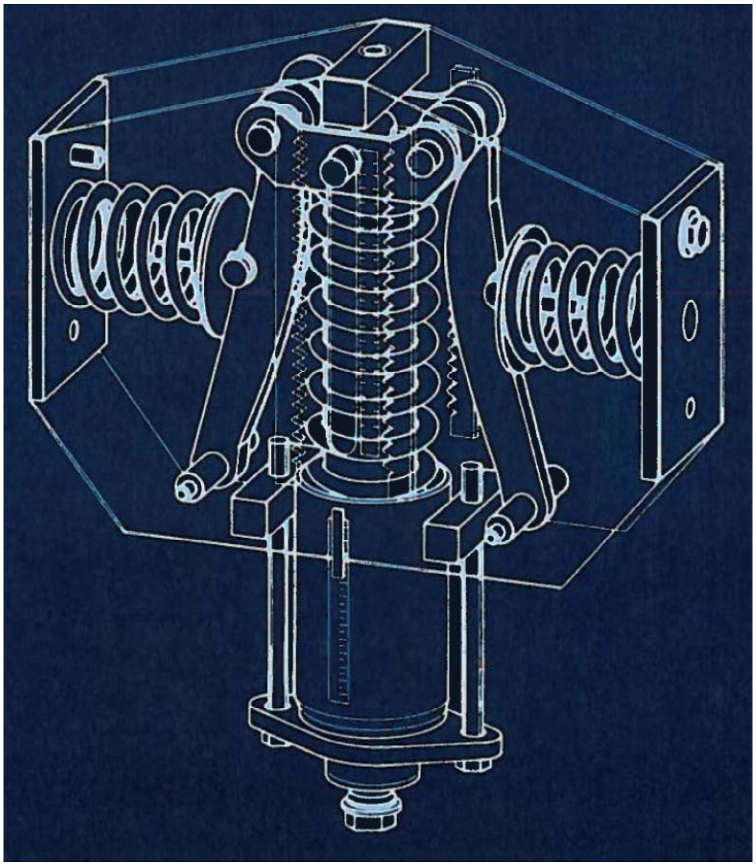
For cases where the vertical movement is too great to use a variable spring hanger, pipe support vendors have developed constant support hangers. The name implies that the load is the same over the entire movement range of the hanger. However, that is a misnomer as per MSS-SP-58, the load can vary by plus – minus 6% over the full range and still be within specification. After the cans have aged, even larger variations than 12% have been documented.

Most constant supports have a helical coil, (perhaps multiple nested helical coils), that act like a typical variable spring hanger. Traditionally, to reduce the load variation through the range, lever arms and pivot pins transfer the load from the rod to the steel. Lisega supplies a different design using compensating springs to maintain a consistent load through the travel range. See the sketches below.

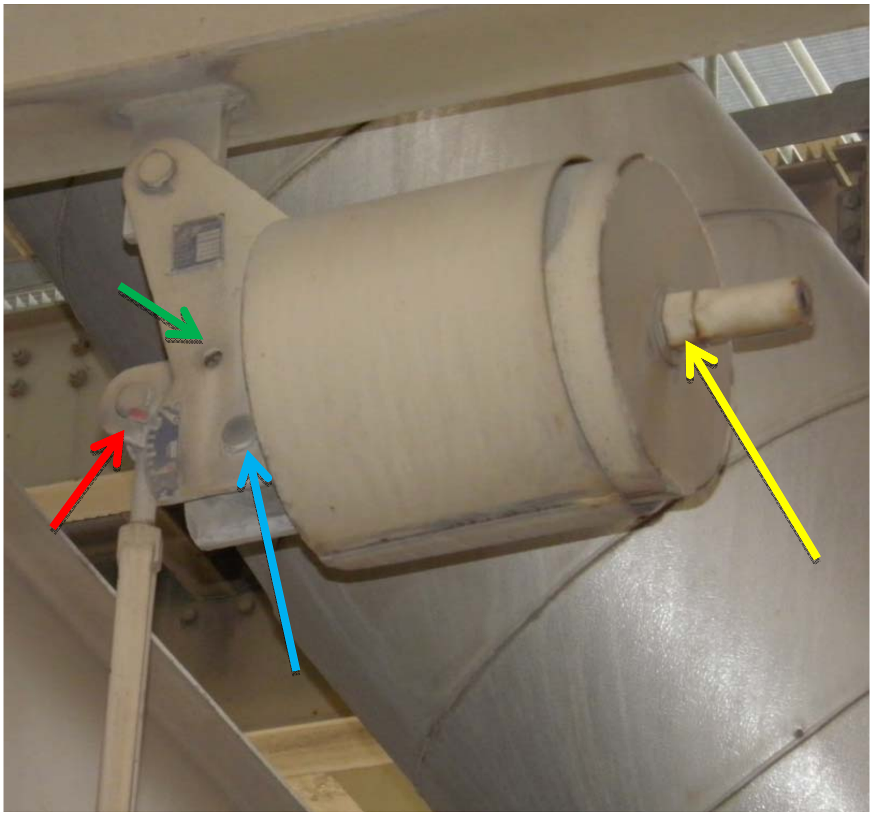


This is an Anvil constant support can. The cans may look quite different depending on the orientation and manufacturer, but the operation principal is the same except for Lisega.

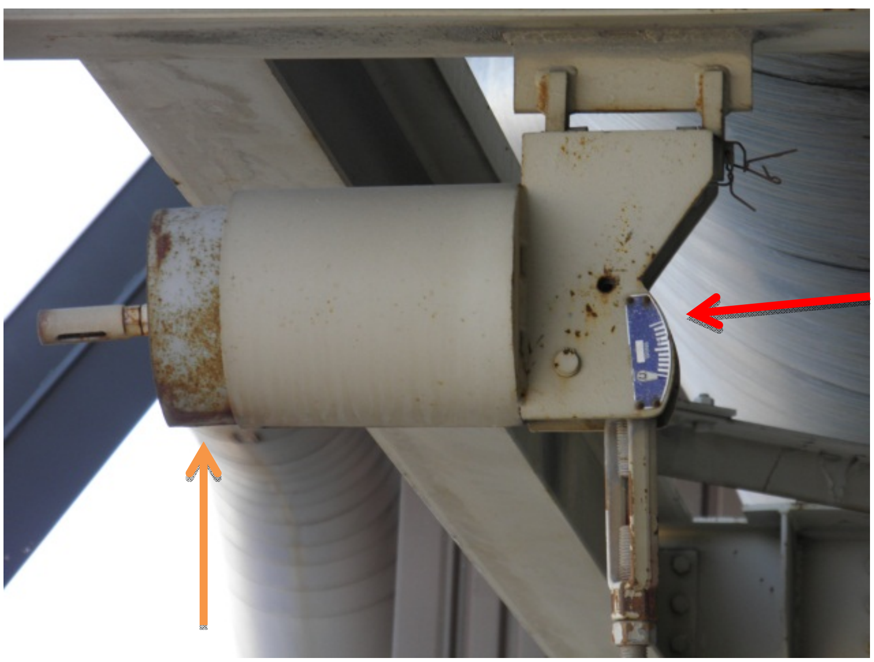
- As the pipe moves down, it pulls the load pivot pin down.
- The Main Pivot rotates but does not move.
- The internal arms from the pivot pin to the end of the spring compresses the spring.
- The load is adjusted by changing the distance from the Main Pivot to the Moveable Spring Pivot with the Load Adjustment Bolt.



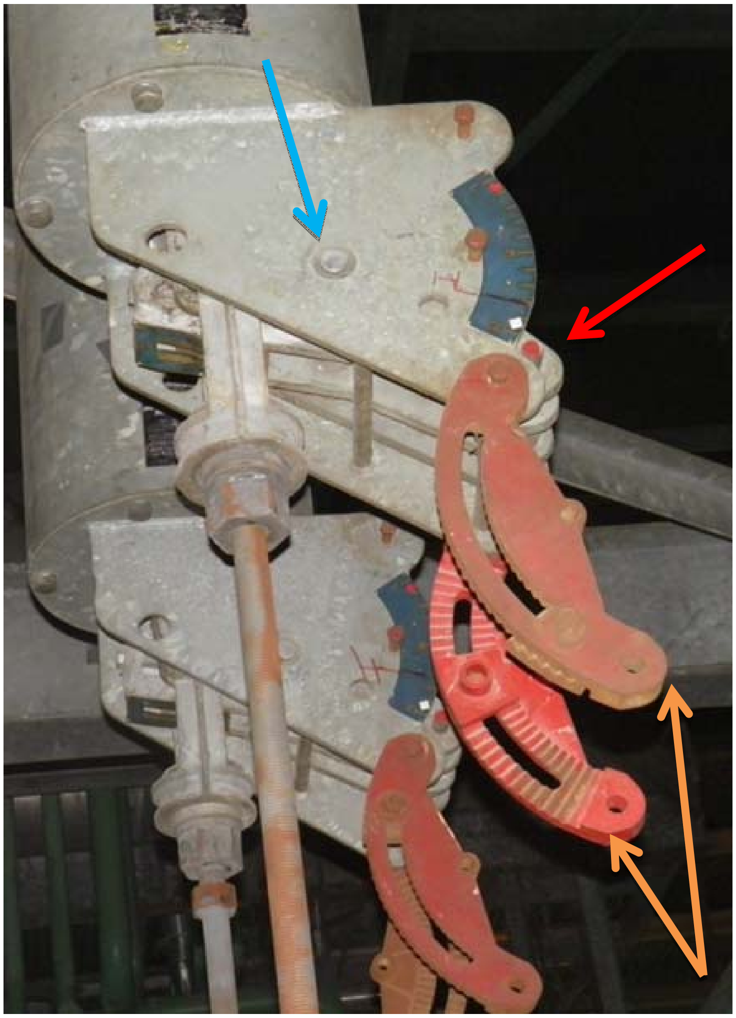
Sketch of Lisega Style Constant Support. As the pipe moves down, it compresses the center spring. This movement pulls the top portion of the side cams down, changing the angle of the compensating ”horizontal” springs. The compensating springs and cam angles are engineered to compensate the change in vertical load in the center spring.



A typical constant support hanger with a horizontal spring inside the large round cover: The travel indicator is at 1.5 out of 10 in this photo based upon red indicator (red arrow). The lever arm is from the top of the rod to the pivot pin that is visible (blue arrow). The open hole is where the travel stop would be installed during shipping (green arrow). The load adjustment bolt is at the far right, yellow arrow.



Travel indicator is missing (red arrow). The only way to estimate travel is from the extension of the can to the left (orange arrow).



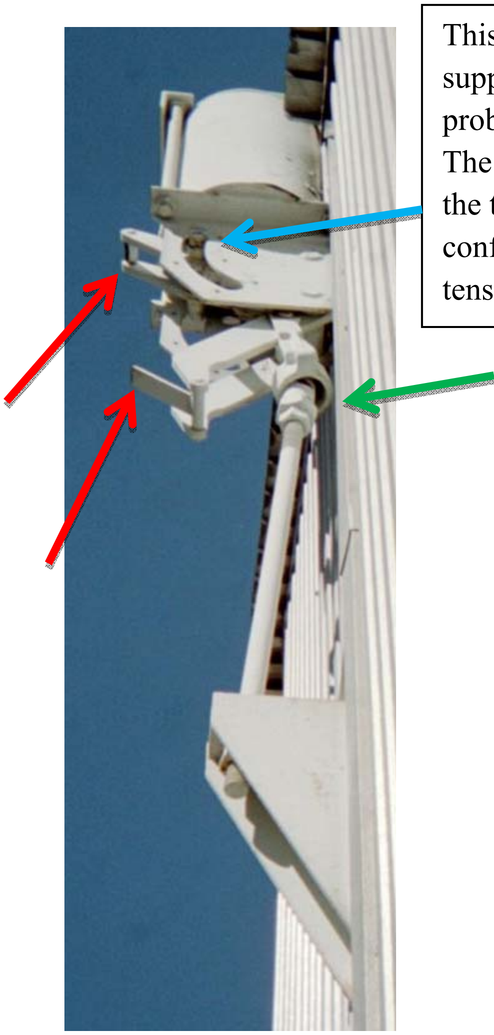
As with the variable spring hangers, a topped out hanger may still be carrying some load between the set load and 0 lbs.

Pivot pins should be designed as bearings (blue arrow). However, inexpensive constant support cans often have carbon steel pins which will flatten and not rotate properly with age.

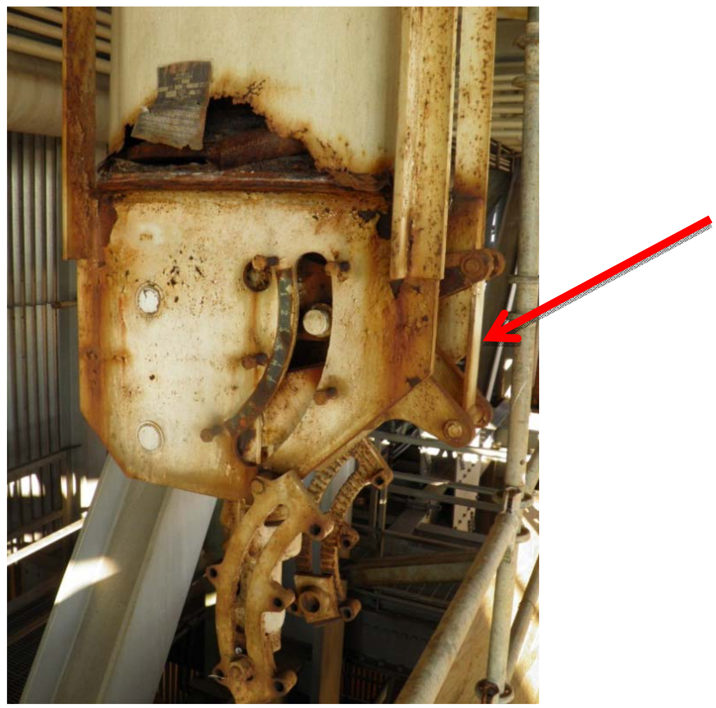
A vertical style constant support hanger that is topped out: With Anvil manufacturer, the travel indicator is the pin painted red, and it is hard against the frame (red arrow). (There are 2 pins, one on either side of the can.) With the position of the rod and pivot pin, as the pipe moves down, the indicator moves up. Thus, when the pin is hard against the bottom of the frame, the hanger is topped out.

The red and white diamonds on the travel scale are the design hot and cold travel settings, respectively. The difference between the two diamonds represents the calculated or actual travel. The distance from the 0 to the maximum travel is called the total travel. Typically the total travel is actual travel +20%. Example:
If total travel = 12", and the cold and hot settings are at 1 and 9, then the actual travel = (1-9)x12/10 = 9.6".

The red bars bolted to the bottom of the cans are travel stops for Anvil (orange arrows). When installed, the travel stops are swung up over the travel scales and lock the travel indicator pins in place. Travel stops are installed for shipping and often for hydro-static testing. They must be removed before operation.

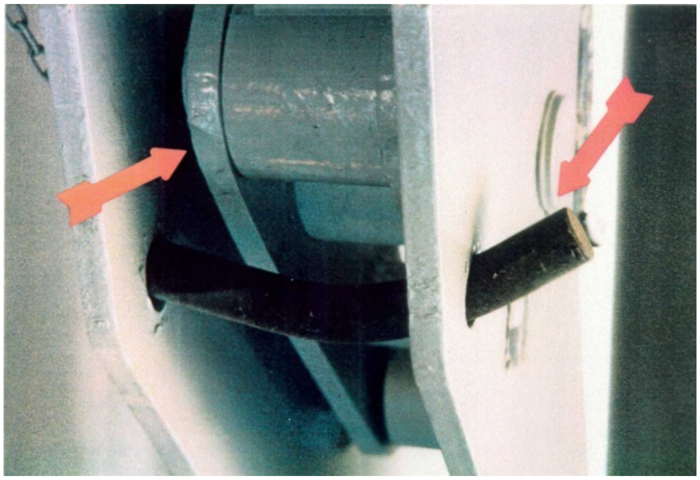


This is an Anvil large load vertical constant support hanger supporting a large air duct. These particular hangers have a problem of failing at the lever arm link plate (red arrows). The weld has failed and the arms are separated. Looking at the travel indicator, it is topped out (blue arrow). It can be confirmed that no load is being supported by the lack of tension at the load yoke (green arrow).

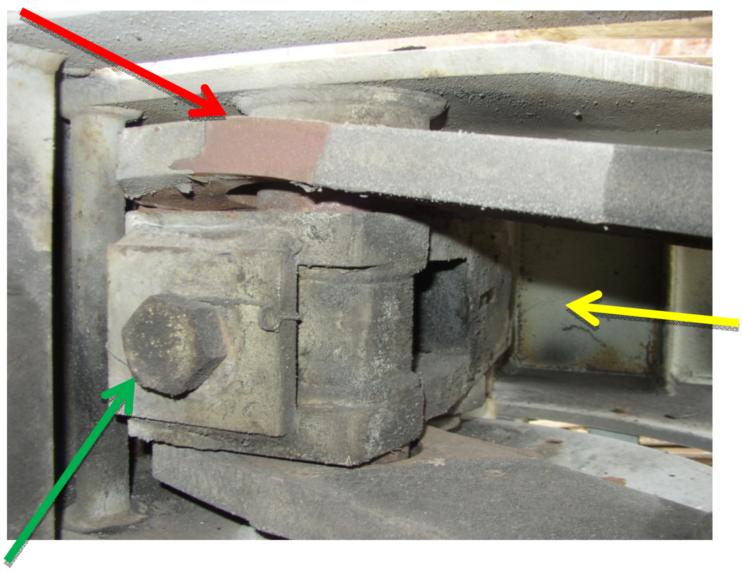


The photo above shows how the lever arms should be held together by the plate. However, this particular can was heavily attacked by corrosion.

As shown in the photo to the left, the spring was corroded all the way through wall.

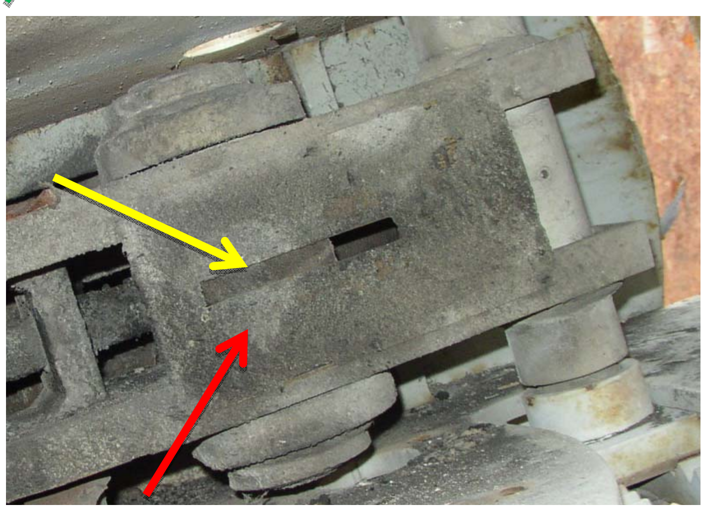


With this manufacturer the travel stop is a pin and the plant started up with the travel stop installed. The internal lever arm bent the travel stop and dented the lever arm. It is not visible in this photo, but the hanger frame had a crack propagating from the pivot pin hole due to this mistake.



This is a similar style constant support hanger in which the travel stop was left in place during operation. The internal support plate is bent and the can had to be replaced (Red arrow).

Constant support cans are adjusted for load by turning a load adjustment bolt (green arrow), which moves the pivot point of the lever arm. There is a load adjustment scale which is almost always difficult to read (yellow arrow).



Another view of the load scale: They are usually difficult to read even when they are visible. After clean-up, there would be marks on the plate, red arrow representing 2% change in load per mark. There is an arrow for increased and decrease load. The indicator is a scribed line on the load block which is faintly visible, yellow arrow.

GUIDELINE 9: CONSTANT SUPPORT HANGER LOADS MAY VARY PLUS MINUS 6% OVER THE FULL RANGE. IT IS NOT PREDICTABLE WHETHER THE LOAD INCREASES OR DECREASES AT VARIOUS POINTS IN THE RANGE. THIS LOAD VARIATION SHOULD BE CONSIDERED IN THE PIPE SUPPORT DESIGN BY LIMITING THE NUMBER OF CONSTANT SUPPORT HANGERS, IF POSSIBLE.

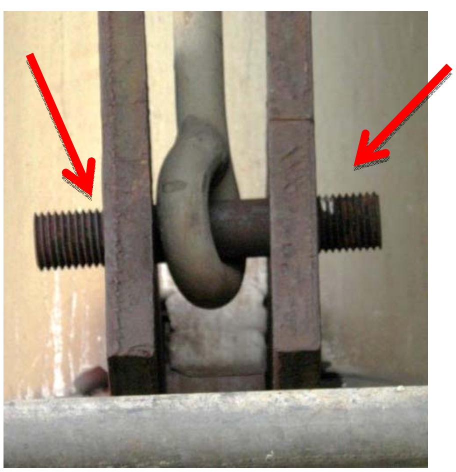
- ***AVOID USING <u>ONLY</u> CONSTANT SUPPORT HANGERS TO SUPPORT A SYSTEM***
- ***LOOK FOR OPPORTUNITIES TO INSTALL ONE OR MORE RIGID SUPPORTS TO STABILIZE THE SUPPORT SYSTEM.***
- ***USE VARIABLE SPRING HANGERS, IF POSSIBLE BECAUSE THE LOAD CHANGE IS PREDICTABLE AND TENDS TO "SELF-COMPENSATE".***
  - ***IF THE PIPE STARTS TO SAG AT A VARIABLE SPRING, THE LOAD INCREASES, LIMITING THE SAG.***
  - ***IF THE VARIABLE SPRING IS OVERSUPPORTING, THE PIPE WILL TEND TO MOVE UP, LIMITING THE LOAD.***

6.0 PIPE ATTACHMENTS

A critical portion of any pipe support design is the attachment to the pipe to transfer the load from the pipe to the pipe support and eventually to the structure. Much of the damage found in pipe supports are in the pipe attachment, and sometimes the damage propagates into the pipe wall requiring repair of the pipe. This section is organized into three sections, Pipe Clamps on Horizontal Pipes, Pipe Clamps on Riser Pipes and Welded Attachments

6.1 Pipe Clamps On Horizontal Pipes

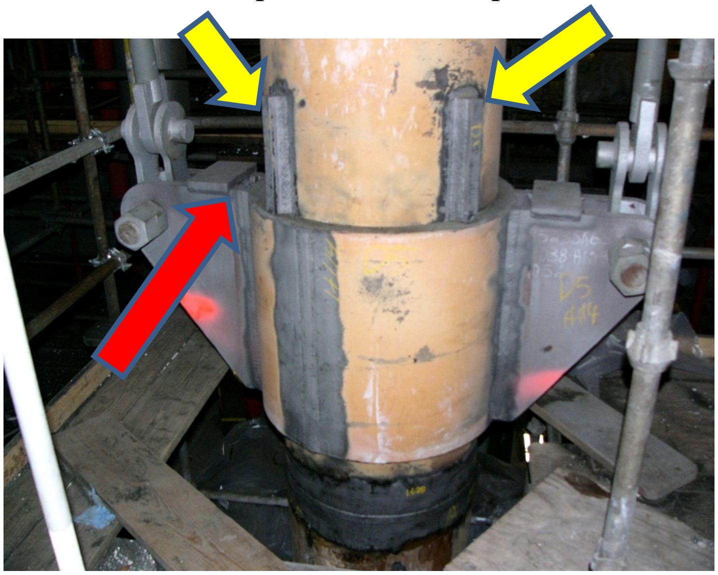
All pipe support vendors supply several styles of pipe clamps that can be bolted on the pipe. Load is transferred by shear into the load bolt, and the clamp usually is supporting load in only 1 direction, usually vertical. Clamps are generally reliable if the load is specified properly. There are 3 bolt pipe clamps with 2 bolts holding the clamp in place and the third bolt transferring the load to the rod. The clamp should be oriented properly with the load bolt centered in line with the top of the pipe.



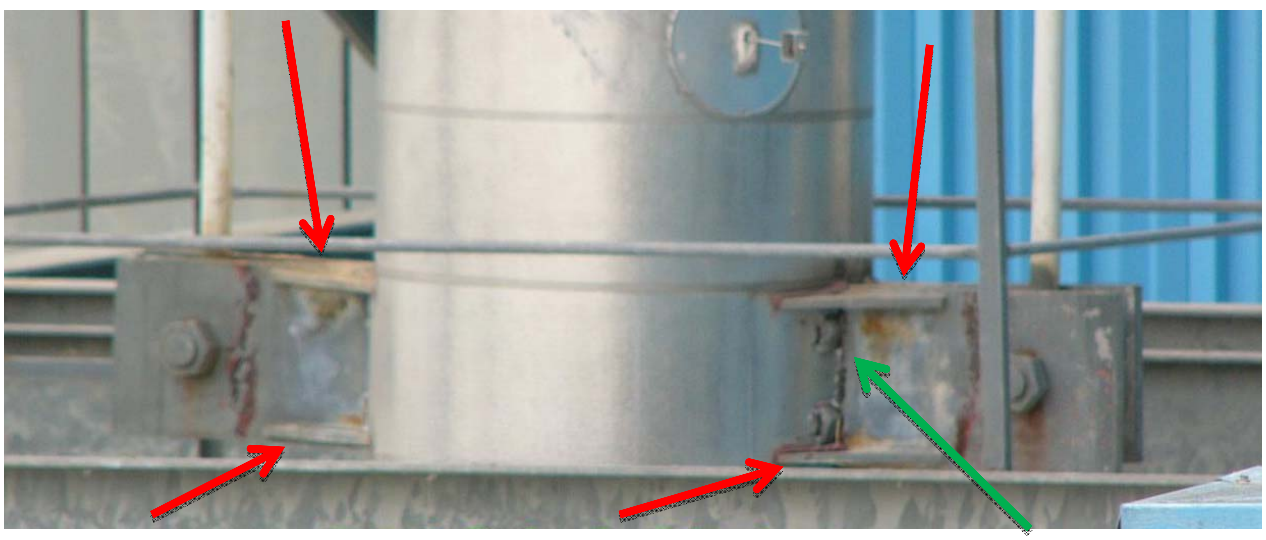
In general the load bolt is the weak point in any of these arrangements, and the bolt is typically one size large than the rod size. Missing nuts on the load bolt as shown to the left, (or cotter pins if it is a load pin) can lead to the load bolt falling out of the holes.

This is an unusual 3 bolt pipe clamp failure that was caused by a carbon steel clamp being installed on a high temperature line. It failed due to high temperature creep degradation. The clamp should have been an alloy steel rated at over 1000F. If an inspection had been performed prior to the failure, the inspector should have noticed elongation of the clamp, and probably damaged insulation from the elongation.

6.2 Riser Clamps On Vertical Pipe



The standard riser attachment is a riser clamp with shear lugs (yellow arrows). All vertical load is transferred from the pipe to the shear lugs and then to the clamp. The clamp at the two load bolts is basically in shear, while the clamp around the pipe is in shear and bending. Most clamps are a single depth from ear to ear, but for these large loads on the order of 50,000 lbs or more, the clamps may be contoured as shown here. This clamp is unusual with the two halves being welded together with plates (red arrow), instead of being bolted together.



Above is a typical riser clamp with consistent plate size from ear to ear and gusset plates for stiffness (red arrows). Note partially visible bolts at insulation hold the clamp halves together to the pipe (green arrow). This clamp is bowed up at the load bolts. Bowing can be an indication of a damaged riser pipe clamp.

Load Bolt Hole Crack Initiation Load Bolt Hole

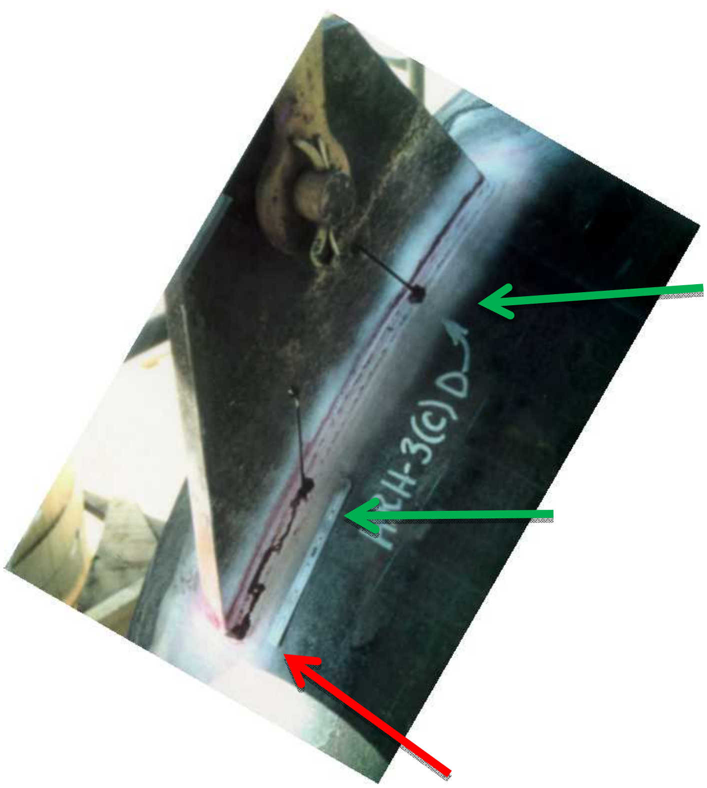
A failed 33" diameter riser clamp that catastrophically broke on the curvature of the clamp at the tip of the gusset plates. It is shown on the ground in 4 pieces. The failure started at the bottom gusset plate (red arrow) due to high bending stress, and possibly because the gusset weld was not post weld heat treated. It then propagated up the clamp due to creep – fatigue. (The failure is nearly identical, 180^0 away, on the other half of the clamp.)

When the crack had propagated about 2/3 of the way up the clamp, the last third failed in a brittle fracture. Upon analysis, the distance from the load bolts to the pipe was too long for the strength of the clamp at temperature. Incorrect Post Weld Heat Treatment of the gusset plate weld may have also contributed.

6.3 Welded Pipe Attachments

Many of the rigid supports shown previously are welded to the pipe. In designing guides and anchors, welded attachments should be avoided, but welds may be necessary. If properly engineered, these welds can be effective over a long period of time, but there are some inherent problems that are difficult to overcome. If there is an alternative to a welded attachment, it should be strongly considered.

1. If the pipe is insulated, the temperature of the attachment at the pipe wall will be different than the attachment outside the insulation. This thermal gradient can create a thermal stress that will cause cracking of the weld.
2. When an attachment is welded to the pipe there is a strong probability that a bending moment will exist at the pipe wall. Reinforcement of the pipe may be necessary as pipes are not sized for externally applied bending moments.
3. Welded attachments must be pre-heated and post weld heat treated as required for any other pipe weld. Often these attachments are made in the field and heat treatment is not performed properly.
4. If a crack develops at a welded attachment, it may propagate into the pipe wall, weakening the pressure boundary of the pipe and threatening a through wall leak.

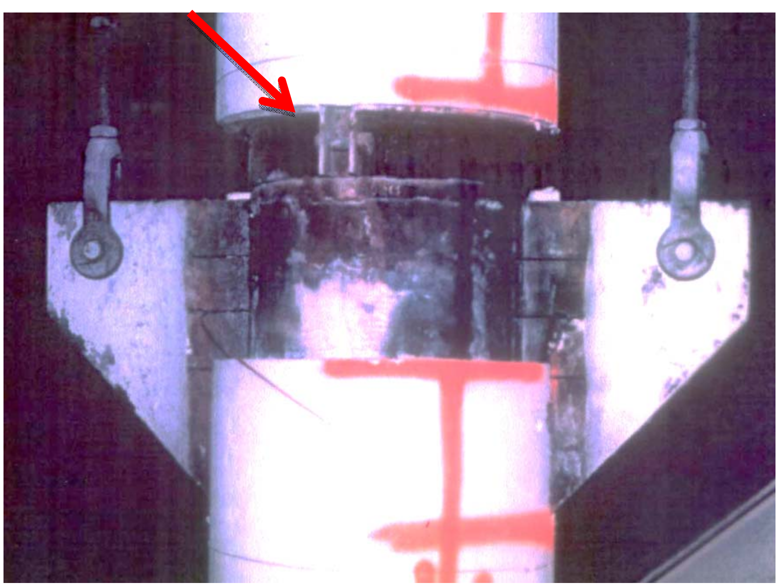


A rod pipe support with a welded attachment plate on a bend of the pipe from a riser to horizontal run: The weld is strong enough to hold many times the design load, but the weld has cracked virtually from one end to the other. (This is a dye penetrant examination and red dye shows weld indications.)
Mouse holes were included in the design to attempt to relieve stresses created by the thermal gradient (green arrows). As with this case, the mouse holes usually do not work and just become stress intensification factors that help initiate cracks.

Some Piping Engineers have a design rule NEVER to weld to a bend or elbow because:

- An elbow is counted on for thermal flexibility and the attachment stiffens it
- A welded attachment creates an undefined stress intensification factor.

This is a detail photo of a welded plate attachment on a horizontal pipe for a rod hanger. The yellow chalk shows the location of a crack start at the edge of the plate weld. This is a typical result of any welded attachments, and some owners have replaced the welded attachments with pipe clamps to avoid the potential for cracking.



This type of pipe attachment is often called a "batwing" riser support welded directly to the pipe. Instead of a riser clamp and shear lugs, one or two plates are welded to each side of the pipe, and the load bolt is connected. Commonly cracks are found at the top and bottom of the batwing welds to the pipe. (A sharp-eyed reader may think they spot a shear lug above the clamp, but that is a temporary spacer to hold the insulation above the clamp in place during a weld inspection.)

In the yellow chalk circle is the typical start of cracks in a batwing style support.

Shown is one of four trunnions attached orthogonally to a riser pipe. The 4 trunnions rest on the steel and then are guided laterally. Both the vertical load and guide load are point loads at the steel, which result in shear and bending stresses at the pipe. The engineer added reinforcement plates at the pipe. But plainly visible is a large crack from the bottom of the reinforcement plate weld to nearly the top of the weld. This support was re-designed with a clamp and shear lugs to eliminate the bending moment at the pipe wall.

GUIDELINE 10: WELDED PIPE SUPPORT ATTACHMENTS SHOULD BE AVOIDED DUE TO POTENTIAL FOR FAILED WELDS.

- ***FOR RISER SUPPORTS USE SHEAR LUGS WITH A RISER CLAMP TO AVOID PUTTING THE ATTACHMENT INTO BENDING AT THE PIPE WALL.***
- ***ON HORIZONTAL PIPES USE CLAMPS INSTEAD OF WELDED ON PLATES.***
- ***ON BENDS, ATTEMPT TO RELOCATE THE SUPPORT TO STRAIGHT PIPE INSTEAD OF WELDING TO THE BEND.***

6.4 Trapeze Supports

Several photos have already been shown of trapeze style supports. These are typically used when a rod hanger is needed, but there is not enough space from the top of the pipe to the steel to install the pipe clamp, rod and possibly spring. In some cases there is space, but the longer rod length of a trapeze support is used to keep the swing angle below 4^0.

Rigid rod trapezes work well in most installations. However, variable spring and constant support trapezes are very difficult to keep in proper adjustment. If at all possible, avoid trapeze spring hangers. Some of the causes of the problem include:

1. The pipe rotates from ambient to operating temperature, causing an eccentricity in the load.
2. The springs may not be adjusted to the same load, particularly after aging and one spring will have more load than the other.
3. When curved saddles are used under the pipe to the trapeze, the location of the point load to the trapeze steel literally can move several inches on the trapeze from ambient to operating load.

Shown is a trapeze variable spring hanger that is poorly adjusted. The left can is very near bottomed out and the right can is floating within scale. (Scale is not visible in this photo.) Trapeze is at about a 30^0 angle. Based upon the bolts (blue arrows), the pipe is attached to the steel with a U-bolt, and there is probably a curved pipe saddle underneath the insulation.

GUIDELINE 11: VARIABLE SPRING AND CONSTANT SUPPORT TRAPEZE SUPPORTS SHOULD BE AVOIDED.

DURING DESIGN LAYOUT PHASE, THE DISTANCE FROM PIPE TO STEEL SHOULD BE MAXIMIZED TO HAVE ROOM FOR A SINGLE ROD ARRANGEMENT AND TO KEEP THE SWING ANGLE LESS THAN 4^0.

7.0 SUMMARY

1. All potential loads need to be calculated, or conservatively assumed prior to designing any pipe supports.
2. Assure all components of a pipe support are adequately designed for the expected loads.
3. For any type of rod hanger (rigid, variable spring or constant support), maximum swing angle measured pin to pin should be 4^0.
4. Sliding supports often do not slide as expected. The slide plates may bind up and rotate support steel, or damage the pipe to attachment welds.
5. Slide plates may "walk off" their support steel or stanchion. This can cause undrainable low points, and damage to the pipe support, pipe and support steel.
6. Hydraulic snubbers are a maintenance item to assure the fluid reservoir is full, and the snubber functions as intended.
7. Variable spring hangers should have a maximum load variability of 25%. On many systems load a maximum load variability of 10% is set to assure the piping system is well supported at all times.
8. Constant support hangers have a specified, yet unpredictable load variability of plus minus 6%. Avoid supporting an entire system with constant support hangers as it will be very difficult to keep the entire system in balance.
9. Welded pipe support attachments should be avoided if there is any reasonable alternative.
10. Variable spring and constant support trapeze hangers should be avoided since they are so difficult to keep in balance.
11. Variable spring and constant support hangers can be damaged, if travel stops are left installed during operation.

