Process, Plant and Equipment UP-TIME

Technical know-how for maintainers to fix plant maintenance and reliability problems.

From www.feedforward.com.au – Technical wisdom to fix plant maintenance and reliability problems.

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Process Control Talk

How Control Valves Work

ABSTRACT

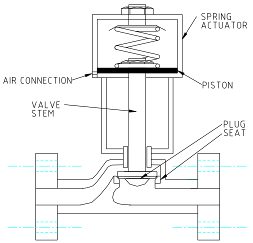
How control valves work. Control valves regulate the flow of a liquid or gas by opening or closing internal passages. They form part of a control loop used to control a process. The control valves responds to instructions from the controller and adjusts the internal openings accordingly. Keywords: sensor, set point, trim, actuator, sealing class, tuning, proportional, integral, derivative.

PURPOSE OF CONTROL VALVES

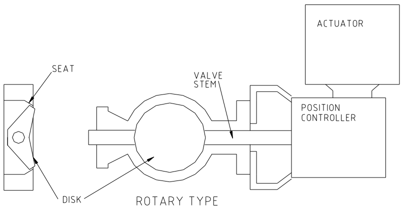
A control valve varies the rate of flow passing through itself. The valve stem moves, altering the size of the passage and this increases decreases or holds steady the flow. The control valve opening is altered whenever the process parameter being controlled does not equal the value it is meant to be (the set point).

OPERATION OF A CONTROL VALVE

A control valve consists of three key components - the valve, the actuator and the controller. The valve can be one of two basic types. A plug and seat design, in which a plug is closed against a seat or a quarter turn valve in which a disc, ball or cone is turned against a seat. The drawings below show the two types of control valve.



PLUG TYPE CONTROL VALVE



ROTARY TYPE CONTROL VALVE

The actuator is used to move the valve stem. They are usually air (pneumatically) or electrically driven. The controller calculates the size of the change to the valve internal passage to bring the flow to the desired rate.

The rate of flow through the valve depends on the pressure difference between the inlet and outlet. To slow the flow the valve is closed which causes more back-pressure and a greater difference between the inlet and outlet pressures. To increase the flow the valve is opened which reduces the back-pressure and the pressure difference across the valve.

INTERNALS OF A CONTROL VALVE

The portion of the valve that regulates the flow is known as the valve trim. It consists of a fixed-in-place seat and the movable plug, disc, ball or cone. The trim can be selected to create a variety of passage shapes that control the flow in deliberate ways.

CONTROL VALVE TUNING

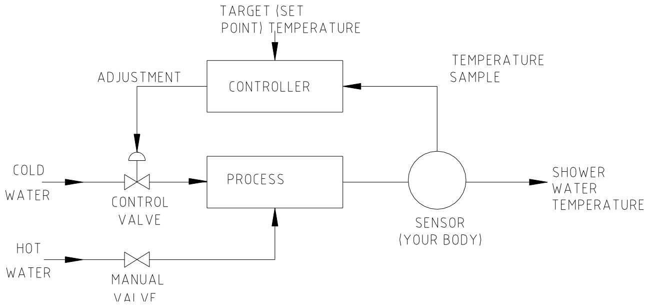
The controller tuning dictates the way the valve responds to the changing process parameter. Tuning of a control valve sets the speed and intensity of the valve response when the need for a correction is detected.

The controller contains internal logic that produces an output to the actuator to move the stem a predetermined amount. This logic looks at:

- the size of the discrepancy between the set point and the current value of the controlled parameter (Proportional)
- the length of time the discrepancy has been present (Integral)
- the speed at which the discrepancy has been changing (Derivative)

and then determines how fast and how far to move the stem.

Once the position of the trim is altered the controller waits for the next sample signal from the sensing element to check the difference remaining to the set point. The valve stem is moved and the flow altered until the difference between the set point and the actual value of the controlled parameter is within tolerance. An example of tuning a control valve can be likened to a person under a shower adjusting the taps to get the water temperature right. The sketch below shows the logic involved in controlling the water temperature.



If the hot water is first put on, the control valve becomes the cold water tap. Your body senses the temperature of the water. If the water is too hot you open the cold water tap. You wait a while (the time lag) to sense the effect of increasing the cold water flow. The cold water is adjusted until the temperature from the combined flows is just right. Once the temperature is right the valves are left alone and the temperature is stable. If a change occurs, such as someone doing the laundry with cold water, a drop in cold water flow to the shower occurs and the water temperature gets hotter. You again sense the changing temperature and make the necessary adjustments. In response the cold water tap is opened further or the hot water tap is closed.

This whole process involved sensing the temperature and moving valve positions until the parameter under control (temperature) stabilised. A control valve works the same way.

PROBLEMS WITH CONTROL VALVES

- Control valves may not properly regulate the parameter they are controlling. If the process cannot be controlled product quality issues arise.

- Control valves can be sized to large. An overly large control valve is wasted money and is insensitive when fine adjustments are needed. Usually control valves are one or two line sizes smaller than the pipe.
- A control valve can have excessive lag (react too late) because the sensor is located too far away.
- The actuator air supply may be low or leaks away and so produces insufficient force to move the stem.
- The control valve stem can become sticky if the packing is tight or product leakage causes binding of the stem.

CONTROL VALVE SEALING CLASSIFICATION

Metal seated control valves are classified into classes reflecting the quality of sealing. The higher the valve class, the smaller the leakage rate allowed when closed; the finer the manufacturing requirements and the more expensive to buy. Table 1 shows the various control valve sealing classifications.

Class	Test	Test Procedure	Allowed Leakage	Fluid Notes
I	-	-	-	No test performed
II	Water or air	385 – 490 kPa	0.05% of full rated capacity	Pres & flow measured to +/- 10%
III	Water or air	385 – 490 kPa	0.1% of full rated capacity	Pres & flow measured to +/- 10%
IV	Water or air	385 – 490 kPa	0.01% if full rated capacity	Pres & flow measured to +/- 10%
V	Water	Max differential pressure	0.0005 ml per minute per inch diameter per 7 kPa	Pres & flow measured to +/- 10%
VI	Air or Nitrogen	350kPa	Varies with diameter. See ANSI B16.104	Eg 6 or less bubbles for 3" diam valve

TABLE 1 Sealing classes for control valves

Mike Sondalini - Maintenance Engineer

Bridging in Silos and Hoppers

ABSTRACT

Bridging in silos and hoppers. Bridging is the name given to the self-created arch that develops just above the outlet of a bulk material silo or hopper as it empties. A bridge forms when wall friction holds up the ends of the arch. To overcome bridging the wall friction must be reduced or prevented from occurring.

Keywords: live bottom, cohesive, powder, hopper design, angle of repose.

There are two types of arch. One is mechanically formed by relatively large particles (above 3 mm) interlocking, while the second is formed when powders bind together under compression (cohesive arch). The resulting arch can support the weight of the material above it and prevent flow. Figure No. 1 shows the two types of arch.

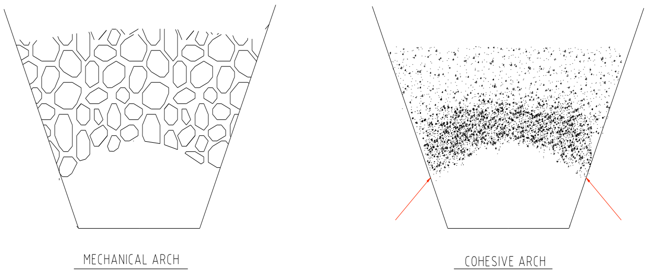


Figure No. 1 Mechanical arch and cohesive arch

It is easy to tell if a silo has a material flow problem by looking for 'hammer rash' on the wall. If the product is not moving freely through the silo and outlet the operator will strike the side walls to rattle the material free.

WHAT CAUSES BRIDGING?

Bridging starts when friction stops the product at the wall and a neighboring particle wedges in behind or sticks to it. The product binds to itself until an arch is formed. Product from above compacts it into place and makes the arch so strong that it supports the overburden. Sketch No. 2 shows a simplified view of the arch building process.

Whether bridging occurs depends on a number of factors.

a) The angle of the discharge section wall.
b) The material of which the silo or hopper walls is made.
c) The stickiness (cohesiveness) of the bulk material.
d) The amount of attraction between the particles of the bulk material.
e) The extent of settling (consolidation) within the bulk material.
f) The natural strength of the material forming the arch.
g) The amount of moisture in the bulk material.
h) The ease with which the bulk material slides over itself.

This list can be divided into two categories – effects that depend on the **bulk material properties** and effects that depend on the **silo and hopper design**.

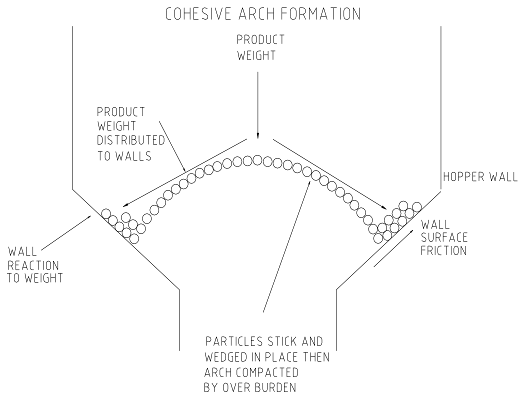


Figure No. 2 The arch building process

OVERCOMING BRIDGING IN HOPPERS

Solutions to stop hopper bridging focus on reducing the stresses created in the bulk material at the bottom of the hopper. If wall friction can be reduced or removed then the arch cannot get a foothold against the wall. If the cohesiveness if the bulk material can be reduced then the arch cannot span the gap before it collapses under the weight of the overburden. If the weight from the overburden can be directed away from the arch it will prevent compaction.

The best approach to prevent bridging is to correctly design the hopper and silo for the product being handled. Standard tests can be done on samples of the bulk material to determine the necessary hopper angle and opening size for the product or range of products put through the silo. The Centre for Bulk Solids and Particulate Technologies at the University of Newcastle, NSW do bulk materials testing. These tests cost AUD$3,000 per product but they pay for themselves with a proper silo design producing free flowing product.

One method to prevent an arch developing is to make the discharge hole from the hopper so large that the arch will collapse into the opening because the side wall is not present to provide support. In existing silos the size of this hole can be determined by viewing the position on the hopper wall at which the arch is supported and adding an additional 20% to the measurement. A 'live bottom' would also be required to feed the material out of the discharge opening.

Another method is to convert the hopper into one with a long rectangular opening of length equal to the width of the silo. This removes the wall on one side of the hopper and allows the material to collapse into the long discharge slot. The width of the slot need only be half the size of the equivalent round opening to discharge the hopper. A feeder the full length of the slot would be required to remove the product.

Improvements to the flow can also be gained by having a steeper hopper angle combined with resizing the outlet. The steeper walls reduce the friction and the outlet is again sized larger than the point at which an arch forms.

Mechanical methods are also available to overcome bridging. Stirrers, internal screw feeders, flexing air pads mounted inside the hopper and air-blasting devices can be used. These operate by fluidising (aerating) the bulk material and reducing the cohesive forces in the product. Vibrating shakers mounted to the wall of the cone only help compact the contents.

A recent invention is the live bottom bin activator for cone shaped hoppers. It promotes flow by installing a steep upward pointing funnel cone inside the hopper portion of the silo where the arch would form in order to prevent compressive stresses developing throughout the product. The material is feed between the gap separating the skirt of the internal cone and the wall of the hopper by vibrating the separately suspended bottom cone. This design overcomes the effects of both the wall and the internal bulk material stresses.

Mike Sondalini - Maintenance Engineer

Glued and Applied Coatings

ABSTRACT
Glued and applied coatings. Coatings provide industry with low cost solutions to difficult chemical corrosion problems. This article covers the use of rubber, fiberglass, and epoxy linings. Keywords: rubber lining, resin, composite glass fibres, overlap joints, adhesive, primer, corrosion barrier, repair.

To select an appropriate lining material the supplier must be told:

i. the chemical(s) in contact with the lining
ii. the range of concentrations
iii. the process temperature range
iv. the pressure conditions
v. whether the item to be lined is old or new
vi. whether there is agitation present
vii. the size and shape of the item
viii. whether the lining is to be done on-site or at their workshop

RUBBER LINING

Hydrochloric acid will corrode a 6 mm thick steel tank in a matter of hours. Yet when the tank is lined with rubber hydrochloric acid can be stored safely in it.

Rubber is available in a variety of types each with its own chemical resistant properties. Successful rubber lining depends on the quality of the surface preparation, the adhesive used and the applicator's skills.

The surface must be clean, smooth and solid. At least a class 2.5 surface finish as noted in Australian Standard 1627 part 4 is required for metal. A class 2.5 blast exposes the metal surface and removes all loose surface rust and dirt. A class 3 blast is back to a completely bare metal surface. The adhesive must match the chemical resistance and temperature properties of the rubber. The applicator must be experienced with the type of rubber used.

After the surface is cleaned a primer is applied. Adhesive is put on the surface and the back of the sheet. The sheet is then laid and worked so all voids are removed. The edges are beveled back sharply to make a wide incline. The adjoining sheet edge is beveled to the opposite angle. The second sheet is prepared in the same way and pushed against the first sheet so the beveled edges overlap. The quality of the jointing is critical, as any future leaks must first make their way through a joint. For added protection a sealing strip can be stuck over the joint.

Getting the proper radius of bends and corners is critical. Rubber cannot be bent to a sharp crease. The minimum bend radius is twice the thickness of the rubber. Fabricated items must be built to this requirement.

Once the rubber has been placed it is necessary to use heat to vulcanise it. Vulcanisation is the process that chemically creates the long chain molecules that give rubber its properties. Some rubbers can become vulcanised by themselves at room temperature. Spark testing for pinholes or thinning is required to prove the lining's integrity.

FIBERGLASS

Fiberglass is a composite material consisting of fibers of glass held together with resin. The fiberglass can be long, continuous rovings, chopped strands or woven mat. Fabrication can be by winding around a mould or by placing sheets of strand or mat over a mould. The resin is impregnated into the glass fibers as they are laid. The fibers carry the forces and applied loads and hold the structure together. The resin bonds the glass fibers together and fills the cavities between the fibers.

A fiberglass wall is constructed in layers of glass fiber and resin. To increase the strength of the wall the fibers in alternate layers are offset to each other. If woven or chopped strand glass sheets are used an overlap of 50 mm between sheets is required for strong connections. When nozzles are installed additional reinforcing is required around the penetration.

Usually the wall consists of three different layers – a corrosion barrier of suitable resin about 0.5 mm thick, a backing layer about 2.5 mm thick and a structural layer of suitable thickness to take the working loads. The corrosion barrier and backing layer can be both on the inside and outside of the structure in corrosive environments.

The resin used in the corrosion barrier is expensive. To minimise costs a cheaper resin is used in the structural layer. Chemical protection is provided entirely by the outside corrosion barrier. If the corrosion barrier is breached the resin in the structural layer will fail quickly.

EPOXY LININGS

Epoxies are resistant to a large range of chemicals including acids and caustics. They are a two-part coating system consisting of base and a hardener. Once the components are mixed there is a short period of time to apply the coating before it sets.

Proper surface preparation is critical for successful application of epoxies. A minimum class 2.5 blast is necessary on metal surfaces and all dirt, greases, oils, fuels and impregnated contaminants must be removed. Often a high-pressure hot detergent wash is used to first clean the surface followed by garnet blasting to prepare a key for the epoxy. All sharp edges and sharp peaks need to be rounded else the paint 'runs away' from the edge or tip and does not cover it to the required depth.

The quality and experience of the applicator is an important requirement when applying epoxy coating. It is the applicator who has the responsibility of preparing the surface, applying the primer and placing the epoxy. If the individual steps are not done well the coating system will fail. Surface temperatures and relative humidity affect paint application. If surface rust reappears on a previously blasted surface it must again be blasted. To prevent this situation the primer should be applied straight after blasting or within four hours at the latest.

Usually an epoxy system has a 50 to 75 micron primer and a 100 to 150 micron epoxy coating. If the item is exposed to the sun or weather a third sealing topcoat of 50 to 75 micron is applied to prevent chalking. Spark testing or a dry film thickness test can be used check the paint thickness.

RUBBER LINING REPAIRS

A repair to rubber lining involves cutting out the section of rubber containing the hole. An additional 300 mm of rubber is removed beyond the contaminated area to insure the edges are sealed to a reliable surface. Where the corroded surface is damaged it must be repaired. In the case of a steel tank the area is replaced with a new section of wall and the welds ground flat. If wall replacement is not viable it can be repaired with appropriate fillers and contoured to suit. All old adhesives must be removed and the surfaces cleaned and edges of rubber prepared as if new work was being performed.

FIBERGLASS REPAIRS

Successful fiberglass repair requires use of resins compatible with the chemical being contained. If the repair comes in contact with the process it is necessary to apply a corrosion barrier, a backing layer and a structural layer as if it were new fabrication. The extra fiberglass layers give structural integrity to the repair that a corrosive barrier applied over the crack alone cannot provide.

It is critical to get a key into the old fiberglass. This is done using an abrasive disk on a hand drill worked over and around the crack to a distance of 100 – 150 mm either side of the crack. The crack is ground out and the ends rounded. All evidence of the sheen from the previous surface must be removed prior to apply the new fiberglass.

Prime the surface with the resin and apply the fiberglass matting, overlapping 50- 75 mm either side of the crack. Wet the matting thoroughly with resin and apply the second layer of glass. Continue in this way till the repair is as thick as the crack was deep. Finally apply the corrosion barrier over the repair and onto the remaining keyed surface. Where a fiberglass vessel stores dangerous goods it is advisable to get a qualified fiberglass repairer to do the repair job.

EPOXY PAINT REPAIRS

Where painted coatings are to be repaired or touched-up the surface must be roughened to make a key for the new paint. Depending on the extent and severity of the repair it may be necessary to blast the area back to metal. At the very least all dirt, oil loose material and any other contamination must be removed and the surface wire brushed or sand papered. The repaint requires applying a primer, an intermediate coat and a topcoat as per the original specification.

Mike Sondalini - Maintenance Engineer

From the Mechanical Workshop

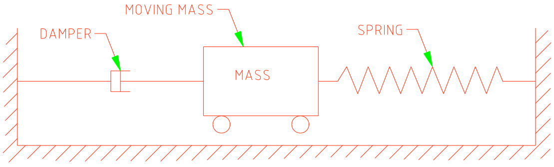
Vibration and its Control

ABSTRACT

Vibration and its control. Vibration in equipment is the result of unbalanced forces. Out-of-balance is corrected by adding or removing material so that when the equipment is operating the unbalance is controlled to an acceptable level. Keywords: spring stiffness, damping, center of rotation, center of mass, natural frequency, isolation mount, counter balance, out-of-phase.

The transference of unbalanced forces through equipment into neighbouring structures causing them to shake is vibration. The motion of a body is limited by what connects it to a machine and the walls in which it moves. Every time there is a change of direction unbalanced forces produce a shock. This shock travels throughout the machine and is transmitted to all connected items.

Mostly a spring is used to isolate vibration movement or a damper is used to absorb the movement. A full explanation of vibration control requires calculus and is beyond the scope of this article. The spring-mass-damper system sketch below is a simplified representation of a vibration control system.



Spring force and damper pressure control the mass' movement. The damper piston moves and so absorbs the vibration. Where as the spring flexes and isolates the movement from its attachment.

The rate of vibration is called the frequency. It is measured in cycles per second and has the units Hertz. A four-pole electric motor rotates at about 1500 RPM. This is 25 cycles per second or 25 Hertz. Vibration caused by an external applied force is known as a forced vibration because the mass oscillates at the frequency of the external force. An example is the shake produced by the moving pistons and crankshaft in a car engine.

The equation for the natural frequency of an undamped spring-mass system moving in one direction is

f_n = _ ▯ (K/M) where K is the spring stiffness and M the mass.

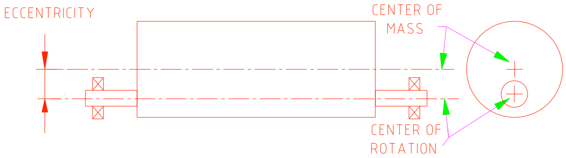
This equation lets us find the resonance frequency for a mass–spring system. Such a system can be represented in the drawing above by removing the damper.

Wild gyrations develop when the forced frequency nears the system natural frequency. Every system has a natural frequency and will shake to destruction if it is forced to move at that rate. This phenomenon is known as resonance. An example would be the shattered wineglass caused by an opera singer's voice or vibrations in long, thin shafts that start and then stop as the shaft speed goes through its natural frequency speed.

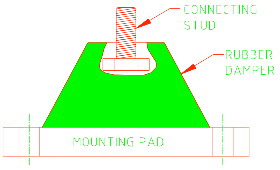
The four methods of vibration control are listed below.

Reduce or eliminate the exciting force by balance or removal.
Use sufficient damping to limit amplitude.
Isolate the vibration source from the surrounds by using spring mounts of appropriate stiffness.
Introduce a counterbalancing force opposite in phase to the exciting force.

Most importantly every moving mass must be balanced about its center of rotation. The topic of rotary machine balancing was introduces in the December 1999 edition of FEED FORWARD FLYER. The article indicated that rotating masses must be balanced to an acceptable standard. Out–of-balance rotors cause vibration because the center of mass of the rotor is eccentric (not running true) to its center of rotation. The spinning off-center mass is continually being flung outward. The machine's bearings hold the mass in place and react against the developed forces. Vibration results as first the mass is on one side of the bearings and then it is on the other. Balancing aims to distribute the mass evenly about the running center. The drawing below shows eccentricity between the center of mass and the center of rotation.



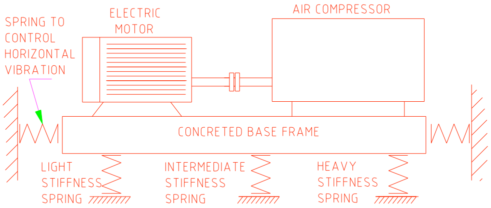
Materials such as rubber dampen shaking. The rubber flexes and absorbs the movement within itself. The sketch below is of a simple rubber vibration damper. Because rubber cannot compress much to accommodate movement, rubber dampers are normally used for low amplitude, high frequency vibration where noise transference is a problem. Shock absorbers are used for large amplitude, low frequency situations where springs alone would produce bouncing. An example is in car suspensions.



The natural frequency can be moved away from the forcing frequency by changing the weight of the system. Making the frame of a vibrating machine heavier will lower the assembly's natural frequency. Concrete added to the base frames of lightweight fans reduce vibration by lowering the natural frequency and moving it away from the forcing frequency produced by the rotating blades.

A vibrating mass can also be isolated from its surroundings by springs. The springs deflect under the shaking body. Installing isolation springs make the spring's natural frequency the governing frequency for vibration transfer. Altering the spring stiffness allows us to select the desired amount of isolation.

Spring stiffness controls the amount of vibration transferred to the attachment. Too stiff will transmit vibration, while insufficient stiffness will cause bounce. The correct spring stiffness can be found using charts available from specialist vibration control companies. The isolation springs must not have a natural frequency near the forcing frequency of the isolated equipment. In such a case the system would start to resonate and jump about. The sketch below shows an air compressor supported on springs.
Stiffer springs are at the heavier end of the machine to both keep the machine level and to prevent resonance developing as the mass increases. The drawing also indicates that vibration is usually in more than one direction.



An out-of-phase mass is a method not often used to control vibration. It is possible to use a weight with an opposite vibration pattern to negate the out-of-balance forces. This method has been used in motor car engines where a shaft with an eccentric mass is spun in the opposite direction to the crankshaft.

Mike Sondalini - Maintenance Engineer

Asset Management.

Benchmarking using Replacement Asset Value

ABSTRACT

Benchmarking using Replacement Asset Value. A benchmark is the end distance point from the start. In the world of maintenance it is the name for the targets that an organisation sets for itself in an improvement program. Benchmarking is often against world-best practice and it is used to provide direction and focus in an organisation's efforts to improve. When RAV is chosen as the benchmark it means that the annual cost of maintaining the plant will be measured against the value of the plant. RAV is a percentage of the cost to replace the plant. The lower the RAV the more effective the maintenance effort. Keywords: metric, maintenance cost, percentage replacement value

The percentage of annual maintenance costs, as a proportion of replacement asset value (RAV) is becoming the universal way of benchmarking companies across a particular industry. It involves collecting the total annual maintenance costs and then dividing the RAV into it and multiplying by 100 to give a percentage.

The RAV is, strictly speaking, the current cost to rebuild your plant today exactly as it is today. It is the current cost to construct the plant to its present design. This approach takes in the effect of inflation on both the project costs and the spare parts and maintenance costs. The difficult part is how can you cost the rebuild of your plant today?

The most accurate way is to give all your design and construction drawings of the plant and facility as-it-is-today to a contractor and ask for a current price to build it. But that is a huge job and most people don't keep that sort of detail on their plant. You can go to your insurer and ask them to let you use their replacement cost data for the equipment in your plant and then, asset number by asset number, give it a current cost. But few insurers would have all the data you need. The last option is the one most used and that is to get the as-constructed asset value from the company accountants for each asset and then increase the as-constructed cost for inflation over the intervening years since construction.

The last option is not to hard to do if you use an average annual inflation increase on all the as-constructed values. Some complications arise if the assets have been revalued. When assets are revalued the revaluation is the monetary worth of the asset at that point in time, it is what people will pay for it and not actually what it costs. In that case take the as-constructed figure and multiply it by the average annual inflation rate. Complication also arises if a lot of capital work was done on maintenance and expensed. In that case the asset values in the asset register are undervalued. This is not usually a major issue.

Unfortunately using as-constructed costs does not take into effect the savings made from the introduction of new technology into the plant. Using new and better technology means the plant can now be made for less cost. But the accountant's books only register actual historical costs and would show a higher value than it would really need to be. This also is not usually a problem unless your plant has had a major technological change introduced into it since construction. Talk to the accountants in that case and come up with new asset values that they are happy with.

If you cannot get as-constructed values (the asset register should have them) then a rough way to estimate RAV is to get the total asset value for the entire plant as it is today from the accountants. The current value allows for depreciation. Then factor back in the average depreciation and the average inflation rates by asset number. The accountants will have both those rates.

The other side of the benchmarking equation is the annual maintenance costs. How true are your maintenance costs? If you include plant improvements, safety improvements, environmental improvements, site security improvements, small capital works and equipment modifications in the maintenance cost then you have an unreal, higher figure than the true maintenance cost for maintaining your plant. Your benchmark result will be higher than it should be.

Maintenance costs are really the cost to repair and return an item to its as-designed function and specification - like-for-like. Anything else is really a capital expense. But don't argue with people over definitions, as it is not worth the stress. Just be aware of the issue and if it clearly is affecting the figures then talk the issue and its implications through with the people at your place, and come to an acceptable decision for true maintenance costs.

If you do not collect your real maintenance costs separately to your total accounting costs then you need to introduce a CMMS (Computerised Maintenance Management System) so you know where your money is going.

Mike Sondalini – Equipment Longevity Engineer