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A better understanding of Magnetic Separators and Metal Detectors used in conveyor systems

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A BETTER UNDERSTANDING OF MAGNETIC SEPARATORS AND METAL DETECTORS USED IN CONVEYOR SYSTEMS

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SYNOPSIS:

Magnets are mainly used for two reasons. To protect processing machinery from expansive damages caused by tramp iron. Equally, to protect the conveyors transporting the material from unwanted tramp iron damaging the belting and putting the conveyors out of action causing extensive and consequential damage to the receiving plant.

To achieve these objects, the magnets need to be efficient, well designed, chosen for the correct application and installed correctly.

If one of these above requirements is neglected the magnets will be of little value to the user.

Magnetic separators have, during the years, the dubious distinction of being a necessary evil, something which has to be included in the layout of every new project.

When confronted with the design of a conveyor system, the planner is aware that, somewhere, somehow, magnetic separators have to be included.

The application is clear in his mind but there often seems to be some confusion where to install the magnetic separators. That is why it regularly happens that they are erected in placed most difficult to reach, to service, to check, for instance on top of big crushing or screening buildings, in transfer houses over huge surge bins, and similar places. That magnetic separators have a mass average of 15 tonnes seems irrelevant to the planner.

The scope, design requirements and electric/magnetic requirements are often vague in Enquiry Documents being issued and objective performance guarantee rarely called for.

It also happens that suppliers of magnetic separators are called in by estimators and told what budget has been allocated for magnets on a project. Usually the amount is too little.

It is therefore not surprising to see so many magnets performing poorly on existing installations.

It is wrong to conclude that this is a fact of life, that one has to live with it. It is false economy on the part of any user to choose incorrectly such magnetic separators.

A BETTER UNDERSTANDING OF MAGNETIC SEPARATORS AND METAL DETECTORS USED IN CONVEYOR SYSTEMS

1. INTRODUCTION:

This paper has been written to describe and explain the value of magnetic separators, their importance and their performance when properly utilised.

A magnetic separator is never a poor magnet. If it does not perform well, it is simply that the wrong type has been selected, or that the installation is incorrect.

If you have a 10 ton load to transport at once obviously you are not going to use a bakkie; and if the 10 ton truck blows a tyre, you are not going to use the jack of your car to change the truck's wheel.

This is very obvious but when the subject concerns magnetic separators, it appears that many people concerned with materials handling believe that any type of magnetic separator can be used. Others believe that it is impossible to achieve a good recovery of tramp iron and therefore it is a waste of money and energy to use magnetic separators.

A magnetic separator, with a mass of say 16 tons, will cost approximately R100 000 installed, including the suspension tackles, supporting frames and some chuting. That seems rather expensive machinery. Belting after all, only costs approximately R200/m installed for say a 1 500 wide fabric belt. What is often forgotten is the fact that a magnetic separator on average protects four to five thousand metres of conveyors, which means eight to ten thousand metres of belting taking the return belt into account. Therefore the magnetic separator costing R100 000 protects R1 600 000 to R2 000 000 of belting.

What is also often neglected when projecting costs over a life period of a mine, or a power station, is that the belting will have to be replaced a few times due to wear, and in ten years time, when say on average the entire belting has to be replaced, there will be no need to replace the magnetic separator; but in ten years time the belting will probably cost more than double the price of the original belting.

2. MISUNDERSTANDINGS:

Many people are not conversant with magnetic separators and misapplications and misunderstandings occur frequently This of course, is detrimental and leads to wrong choices and ultimately to grief.

The following are some misapplications:

(a) At the design stage, the depth of burden of material is not calculated and is "guestimated". This may not bear any resemblance with reality.

(b) The depth of burden is not clarified. Is the given depth of burden a fully loaded belt with free edge board as per SABS or is it for overflowing conveyor, in other words, when spillage is likely to occur.

(c) It is possible that lumps of coal sit on top of the given depth of burden.

These three cases will result in the magnetic separator being installed on site with a much greater distance between the belt and the face of the magnet. The magnetic field will not reach the bottom of the burden and unwanted tramp iron will not be reclaimed, resulting in unjustified complaints from the user.

Another common occurence is that a magnet delivered on site has a mass of ay 20 tons but nothing has been allowed for erecting the magnet in position and providing hoists and crawl beams for maintenance.

The result is that the user is forced to strip the magnet of many of its components, erect and re-assemble. Later, complaints are coming thick and fast that the gearbox falls apart, that the belt is not trained or runs in reverse, that pulley bearings are packing up, etc.

In some instances, the user decides to uprate the conveyor capacity and increases the belt speed but leaves the magnet as it is. In reality, the time exposure in which tramp iron is exposed to the magnetic field is now reduced and the magnet misses some objects.

It is therefore very important that the end user must be aware of the possibility of uprating a conveyor system and to request a magnetic separator adopted to any future requirement.

One of the most common misunderstandings can be summarised by the reflection of somebody who said to me: "I took a bolt and held it at a distance to the face and the bolt was barely attracted by the magnet. Just imagine if that magnet cannot attract a bolt, what are the chances to attract larger pieces of steel, like a rod, or an angle or a liner plate?"

Many people do not realise that it is unrealistic to expect all small objects of a certain shape and size to be recovered by the magnet, but larger irregular shaped pieces of metal will readily be attracted by the magnetic separator.

3. IDENTIFICATION OF THE UNWANTED TRAMP IRON:

In the coal industry we usually deal with two types of mining operations, i.e. underground and open cast mines.

With an underground mine, we usually deal with roof bolts and continuous miner picks which are dislodged from their frame during mining operations. These picks are made of EN19, EN23 or EN24 material and have various amounts of nickel and chrome content which is absent in ordinary EN3 steel. In addition, the tip of the picks is composed of tungsten carbide.

Many statements have been made about continuous miner picks being less attracted to magnetic fields than mild steel composed of EN3 material. It is said that the picks with a high content of non-magnetic material are difficult to retrieve from a full depth of burden on the conveyors. The most common statement is that a continuous miner pick is 30% less attracted by a magnetic field than a mild steel object of the same size.

I have initiated some tests with picks of various material contents and with mild steel pieces turned down in a lathe to the exact shape of a continuous miner pick. Two series of tests were conducted, the first with no material covering the picks, the second using coal collected from a local mine.

The tests demonstrated that:

(a) Continuous miner picks and mild steel picks respond magnetically in the same pattern.

(b) The orientations of the picks embedded in the coal has a definite influence to the distance when a pick becomes attracted by the magnetic field.

(c) If picks are placed close to each other, there is a chain reaction and the picks are attracted to the magnetic field faster than isolated picks.

From the results of the tests, conducted under supervision, continuous miner picks are not less attracted to a magnetic field than mild steel of the same shape, under the same conditions.

This applies to an underground mine, but opencast mines are facing different types of tramp iron, such as bucket teeths, which come loose during operation.

The items likely to be found in the conveyed material should, as much as possible, be identified and described.

Usual objects buried in coal are plates, liners, angles, rods, cutters, idler rollers, idler bases, tins (such as paint tins), tools, crowbars, etc.

The larger of these items are easy to remove but smaller items in the less than 2 kg range can be harder to remove, especially when the trend of faster product conveyor belt speed is considered.

Unusual objects buried in coal can be small gearboxes, parts of bicycles, wheelbarrow, etc. Therefore, when specifying tramp iron removal, one must be specific in describing the tramp iron which will damage equipment with respect to size (both dimensional and mass) and shape.

Keep in mind that, the more information you supply to the manufacturers of magnetic separators, the better understanding of the required performance of the magnet will be grasped by the supplier.

4. SUSPENDED MAGNETS OVER CONVEYORS:

Overhead suspended magnets separate unwanted tramp iron from materials conveyed in bulk form. Basically, the suspended magnets can be of either two types, permanent magnets and electro-magnetic separators.

For work of the application where retrieving of unwanted tramp iron is essential electro-magnetic separators are used to that effect.

4.1 Suspended Electro Magnet:

This type of magnet is generally suspended from a travelling trolley on a crawl beam through a set of slings. The suspended magnet can be pulled clear of the conveyor before the iron is discharged, through de-energising. This is called manual cleaning. They are ideal for application when only occasional small amounts of tramp iron are found; but, although the magnet might have been designed to cope with the extraction of tramp iron, what can happen is that a power failure de-energises the magnet whilst it is over the conveyor and all tramp iron that had been retrieved from the burden drops back on the conveyor.

An auxilliary permanent magnet unit can sometimes be incorporated to safeguard against this in the event of power failure, but I have not seen one yet in operation.

It also happens that black operators de-energise the magnet without swinging the magnet clear of the conveyor, with the result that the tramp iron falls back in the material carried by the conveyor.

In order to overcome this, limit switches can be mounted at the end of the crawl beam supporting the magnet so that the magnet can only be de-energised when it is clear of the conveyor.

In applications where large amounts of unwanted tramp iron are likely to be extracted, the use of a suspended electro magnet can be somewhat unreliable. This results from tramp iron build-up on the face of the magnet with the distinct possibility of the collected tramp iron being dislodged and returned into the conveyor burden.

In my opinion, suspended magnets have no place in the coal industry as the amount of tramp iron mixed in the coal is too high. In the case where continuous miner picks are recovered, I have found that often the face of the magnet is perforated by the impact from the sharp end of the picks acting like a bullet against the bottom plate of the magnet.

I have often seen repairs made on site by the operating personnel, welding additional plates to the bottom of the magnets, and this remedial repair is just not "kosher".

4.2 Electro Magnetic Self-cleaning Overband Separators:

Overband separators are merely suspended magnets to which an endless conveyor belt with slats has been incorporated. The belt forces the tramp iron attached to the face of the magnet to move to the end of the separator, therefore becoming automatically self-cleaning.

These self-cleaning overband separators should be used whenever the amount of tramp iron is great enough. (In other words, nearly always).

The self-cleaning overband separators discharge the unwanted tramp iron parallel to the material flow when mounted at the head of a conveyor over the material trajectory (in-line) or at right angles to the flow of material when suspended across the conveyor. (Cross-belt). Self-cleaning magnets discharge the tramp iron via a chute into a container.

If the chuting and container, i.e. trolley etc., have been provided for, the tramp iron will usually be reclaimed and not thrown back onto the belt as can happen if provision has not been made to collect it.

4.3 Magnetic Pulleys:

For lighter applications or for fiery conditions, permanent magnetic pulleys are used.

Permanent magnetic pulleys have a uniform magnetic field across the full feed width to ensure that all material is subjected to the same pull. The permanent magnetic pulleys are unaffected by atmospheric conditions, material temperatures and failure of electric supply. Control gear and transformer rectifiers are not required.

Electro magnets are used for the tougher iron separation problems involving higher speeds, heavier burden depths and hard-to-separate materials. The electro magnetic pulleys produce a maximum depth of magnetic field.

4.4 Principle of Operation:

As the tramp iron contaminated material comes within the pulley's magnetic field, the tramp iron is attracted and held to the belt until it reaches the underside, passes out of the magnetic field and is separately discharged.

The cleaned, non-magnetic material is discharged over the pulley in a normal trajectory.

The divider between the discharge chute and the tramp iron chute should be adjustable to permit best positioning for specific conditions of material and tramp iron discharge. The divider must e of non-magnetic material, i.e. stainless steel or non-magnetic manganese steel.

4.5 Limitations:

High pulley revolutions cause unwanted centrifugal effect which spoils the magnetic pulley performance. Pulleys are not suitable on their own for deep burden depth.

For deep burden depth, the magnetic pulley must be used in conjunction with an overband magnet.

4.6 Design:

The magnet pulleys must be adequately designed to prevent failure during operation, as these pulleys are also acting as head or drive pulleys.

5. IN LINE VERSUS CROSS BELT MAGNETIC SEPARATORS:

5.1 Cross belt magnetic separators have these advantages:

(a) If installed at ground level, for instance on overland conveyors, discharge chutes are not necessary. The unwanted tramp iron can be directly discharged into the ground.

(b) It is also possible to have the unwanted tramp iron discharged directly into a waste bin that can be collected at leisure.

(c) There is no additional heavy loading to be distributed into the framework of a building.

(d) The adjustment between the face of the magnet and the burden is easy as it is only in one plane.

(e) Long pieces of steel are now easily ejected by the self cleaning belt.

(f) They can be readily inspected as they are at eye level.

(g) It is more easy to check if they are energised. One must remember that it does not mean that because the magnetic separator belt is moving that the magnet is energised.

(h) Nowadays magnets are very powerful and provided the conveyor belt speed is reasonable and the depth of burden not excessive, cross belt magnetic separators can be very effective.

(i) If for some unkonwn reason the magnet appears to become ineffective, it is easy to reach the magnet and check if the distance between the face of the magnet and the belt conveyor has not been increased.

(j) The slats can now be easily replaced or refastened.

(k) Cross belt magnetic separators can be installed any time on existing conveyor system without disrupting production.

5.2 In line magnetic separators come into their own when the conveyor belt speed is higher than 3,75 m/s. It is often said that an in-line magnetic separator is cheaper as it requires a less powerful magnetic field.

What is not taken into account is the extra chuting required. This chuting arrangement has to have a wide throat to prevent any rod or similar profiled steel from jamming into the chute.

Extra beams and hoists are required for the adjustment which has to be in two planes.

Often the head pulley has to be made of non-magnetic material. This also applies to the top of the chute platework. The mass of the magnet has to be carried by the structure of the building.

It is true to say that as the material leaves the head or discharge pulley the material opens up and is more readily attracted to the magnet, but what can also happen is that a long rod can actually jam between the conveyor belt and the magnet self-cleaning belt, which usually moves only fractionally faster. The rod, wedged between the two belts can create havoc in slitting one of the two belts right open.

In-line magnetic separators will magnetise all surrounding platework and the head pulley and produce local concentration of fine metallic swarf.

5.3 Arguments against Cross Belt Magnetic Separators:

It is believed by a section of the professional public that cross belt magnets are comparatively inaffective due to their short magnetic length in the direction of material travel. It is also said that cross belt magnets have to remove tramp iron from a settled material burden, which renders removal through the burden difficult.

What I can say is that tests have been carried out overseas by a reputable manufacturer of magnets and these tests have shown that the magnetic field required with cross belt magnets with reasonable bed depths and conveyor speeds is not much greater than that required with in-line magnets.

These tests changed the view of this particular manufacturer as he was previously convinced that cross belt magnets required a much greater magnetic field.

6. CHECKING A MAGNETIC SEPARATOR:

The checking of a magnet should first be done in the workshop where it is constructed and the magnet should only be sent to the site once the tests have been successfully achieved.

That seems quite obvious, yet most of the magnetic separators are sent on site without the final user or his representative being involved at that critical stage.

To avoid any possible conflict on site and costly delays and also being confronted by the risk of damage to the conveyor systems being left unprotected whilst the magnet is sent back to the workshop, it is suggested that the following checking measures are taken in the workshop:

(a) Flash testing shall be conducted prior to the mounting of the coils into the casing. The magnetic separators will be energised for a continuous period of not less than 24 hours, in an ambient temperature of not less than 20°C.

(b) To evaluate the magnet characteristics, a saturation temperature curve shall be plotted and compared with the original design details, and any subsequent tests for comparison purposes. The current consumption shall also be recorded.

(c) The plotting of the flux density shall be recorded at specified distances and across both axis of the magnets at 200 increments and compared with the original guaranteed flux densities.

Here I must stress that a good gaussmeter must be used. This meter must be calibrated against a calibration test meter.

There are basically two types of probes available depending on field direction response: Transverse and axial.

For accurate readings, the probe must be used within its specified range of measurement; for instance, when a 10 kG probe is used for measurements higher than 10 kG, increased deviation from linear response will result. Such measurements would not be accurate as absolute readings.

I should also point out that there are variations in readings taken by any two trained individuals because of the way a gaussmeter is read and the reading probe is handled. This has been recognised by the "Magnetic Equipment Standards Council" in the United States.

Due to the field direction in magnetic separators and magnetic pulleys, we believe that a transverse probe should be used.

(d) In the case of oil cooled magnetic separators, the casing shall be pressure tested to not less than 0,5 Bar above atmospheric pressure and such test shall be maintained without leakage over a period of not less than 30 minutes.

A static test of the magnetic separators shall be as follows:

(a) A template manufactured from stainless steel plate, and of the same profile as the conveyor belt to be protected, shall be used for static testing of the magnetic separator.

(b) Unwanted tramp iron of the sizes to be found in the particular application shall be buried at random under a burden of material of the profile similar to the material carried by the conveyor and the template shall be moved under the magnetic separator.

(c) The static test shall only be considered successful when the guaranteed percentages of extraction of the unwanted tramp iron pieces are achieved.

(d) The magnetic separator units that have successfully passed the flux density and the static tests shall then be declared acceptable for despatch to the site.

(e) After a period of time agreed between the supplier and the user they shall jointly repeat the tests undertaken prior to despatch. The records of the tests in the workshop shall be used for comparison purposes to confirm that no deterioration in magnetic performance has taken place.

(f) The test will be considered successful if the magnetic performance is within 2½% of the original results.

7. PERFORMANCE GUARANTEE:

When the depth of burden has been calculated and a working gap between the conveyor belt and the magnet face established, it is then possible to call for a performance guarantee provided the unwanted tramp iron has been identified.

Assuming a magnetic separator has to be installed over a conveyor carrying coal originating from an underground mine, most of the unwanted tramp iron to be recovered will be in the shape of miner picks or objects slightly larger. These can be descrived as tramp iron items of mass 0,5 to 5 kg. Larger pieces could be described as tramp iron items of mass 5 to 10 kg. While liner plates could be described as tramp iron items of mass 10 to 50 kg.

A percentage by number of items expected to be attracted and recovered by magnetic separation and/or magnetic pulleys should be stated by the manufacturer.

To be fair to the supplier of magnetic separators, the description of test pieces under 5 kg should be given by the end user. For instance, the description could be made as follows:

20 mm x 300 mm long
30 mm x 150 mm long
40 mm x 300 mm long
50 mm x 300 mm long

and not cubes or balls which are irrelevant in most applications.

These pieces should be provided by the manufacturer of the magnetic separator. These pieces would be used when testing on site. The test pieces should be randomly placed in the burden depth. I have found it useful, in the past, when site testing, to have the test pieces painted in different colours, using say red for test pieces buried under the complete depth of burden, yellow for test pieces buried two-thirds down, blue for test pieces buried half-way doen, and so on. Also attached to the test pieces was a length of string and a tag of the same colour as the test piece. The tag, lying on the top of the material conveyed, identified for me any test piece which was not recovered by the magnetic separator.

It is important to remember that a magnet performance must be rated with the magnet under operation conditions. Therefore all tests have to be conducted when the magnet has reached maximum temperature or saturation point.

Usually, 24 hours after a magnet has been switched on, it will have reached its maximum temperature.

An important point is to check that the working gap between the conveyor belt and the magnet face ties up with the distance given in the performance guarantee.

8. <u>FORCE INDEX:</u>

There is a specification in the United States that has been published by the "Magnetic Equipment Standards Council".

This specification advocates the use of the Force Index Method.

Tables included in this specification give the static Force Index of some objects sized, for instance bolts or rolls, hexagonal nuts, cubes and plates.

In South Africa suppliers of equipment originating from the United States favour the "Force Index" method for selecting suitable magnets for individual applications.

At least one Corporation in this country specifies the force density they require at a certain distance in any enquiry that is issued for tender purposes.

What really is the "Force Index Method?"
The Force Index Method is an index or indication of the force that a given magnet can exert on an object in its field.

It is defined as the product of gauss times gradient. Gradient of a magnetic field is simply the change in gauss from one point in the field to another divided by the distance between the points.

$$FI = \text{gauss} \times \frac{\text{Change in gauss}}{\text{Change in distance}}$$

<u>GAUSS:</u> Gauss is the measurement of a number of magnetic lines of force per square centimeter.

A gaussmeter is used to take the measurements. The gaussmeter has a detector element mounted at the end of a probe. When a probe is inserted into the magnetic field it is essential that the detector element is perpendicular to the lines of force so that the maximum possible number of lines will go through the detector element and give the maximum reading.

Remember that: $\text{GAUSS} = \frac{\text{MAGNETIC LINES}}{\text{AREA CM}^2}$

An argument frequently used by the advocates of the "Force "Index rating method is that, too frequently the rating is made at non-essential points.

What is suggested to overcome this problem is to request, at enquiry stage, for the tenderers to submit a plot of the flux density up to a distance where, when the conveyor is overlowing with material, this material barely touches the face of the magnet. These readings should be provided across both axis of the magnet at not less than 300 mm increments.

Having all this information at his disposal it becomes easy for the evaluator of the tenders to calculate, if required, the force density or force index at any distance from the face of the magnet. This leaves the choice of using the "Gauss Rating Method" or the "Force Index Method" to the evaluator's discretion.

9. METAL DETECTORS:

Metal detectors are used to determine what tramp iron metal volume is included in the material conveyed. From the detector counts, the user is able to face the fact of metal frequency.

Note that the sensitivity level is adjustable making it possible to discriminate between metal pieces of a certain size upwards, small harmless ones being overlooked such as washers, nuts, etc.

A metal detector is a highly sophisticated detector system. It is installed around a conveyor. Ideally, it should be designed to fit existing conveyors without cutting the conveyor belt.

For mining installations, the metal detector must be of strong, rugged construction to withstand the rigours of its application.

To protect the metal detector an automatic crash bar operating independently of the metal detector should be fitted if installed over Run of Mine coal. This crash bar should be so designed that any lump of coal striking the bar will trip the conveyor belt before the lump coal reaches the metal detector.

Metal detectors can be installed anywhere over the length of a conveyor but must be away from head or tail pulley and must be fitted mid-way between two sets of idlers, because moving or vibrating metal near the search head can interfere with the operation of the unit. Excessive vibration also interferes with the operation.

It is also important that the control unit be mounted outside the stream of material. Again, this control unit should be of robust construction, with double doors, the internal door consisting of a glass panel. All the instruments inside the control unit should allow for clear and visible reading of the instruments, i.e. with lighting mounted inside the control unit. This is particularly relevant for people of my age who need glasses whenever something has to be read.

METAL DETECTOR COUNTER:

In order to test the efficiency of the magnetic separators, metal detector counters are sometimes installed downstream over a conveyor to record tramp iron not recovered by the magnetic separators.

It should be possible to set the detector/counter for magnetic or non-magnetic materials, or a combination of both. The detector shall also be capable of detecting a given size of metal or layer, i.e. smaller pieces will not cause counting to take place.

10.1 Recording Equipment of the Metal Detector Counter:

The automatic electric detection counter should have a minimum of six large size digits and provision should be made for relaying the readings to a central control room. The digits should be visible from the outside and the counter sealed against ingress of dirt and moisture. The manual reset knob should not cancel the readings in the control room.

If the monitoring is conscientiously done, this will enable us to pinpoint any faulty equipment and take the necessary action.

11. BOOSTING OF MAGNETS:

This is a concept which has recently been applied on a large scale on some of the recent conveying systems supplying Power Stations.

Provided the incidence of metal is low one can use a metal detector in conjunction with a magnet. The metal detector, installed upstream of the magnet will send a signal whenever tramp iron passes through its field. The magnet is then automatically switched on. This prevents loss of power due to heat build up and a stronger magnetic field is thus made available. The loss of power varies according to the way the magnet has been designed but say that generally it within the order of 30% loss when the magnet is hot.

12. CONCLUSION:

I believe we have come into an area where custom design of magnets must come into its own. This will help to maximise magnet performance.

Although the science of electromagnetics is relatively simple, the optimisation of magnets has only recently been taken seriously.

Larger units than ever before have been supplied and it is vital for the mining industry to monitor the performances of the magnets in their installation on a daily basis, as it is done for other expensive equipment.

Remember basically that two equally important aspects have to be examined when enquiring about magnets.

(a) Preventing conveyor belt ripping.
(b) Preventing damage to downstream equipment.

Equipment that can be damaged include all sorts of machinery such as crushers, screens, mills. Vertical mills are particularly susceptable to pieces of steel jamming their suspension points. Horizontal mills, however, (at least I am told so) relishes steel.

Anyway, one thing for sure, the conveyor belting is always vulnerable and the belting contributes ± 45% of the value of a conveyor.

Therefore, magnets are paying for themselves. The initial outlay of money is wisely spent and I hope that this will be appreciated.

Ending this paper, I sincerely hope that the message has got through. To the end users, you will do yourselves a favour in giving the correct and detailed parameters to which you want the suppliers of magnetic separators to adhere to. You will be rewarded by having magnetic separators that will give you the performance you require.

To the manufacturers of magnetic separators this paper might help to avoid facing the dilemma of either having to offer a sub-standard magnet to clinch the order or to offer what you in your experience estimate to be most adequate but losing the contract as you are pricing yourself against the competition.

So to conclude I will say to the end users "Don't be vague, ask for what shall I call it".