HERO ENGINEERING

AS/IEC 61508 Application to Guidelines in the Australian Mining Sector – Part 2 Underground Winding Systems

For

Safe Work Australia – Public Discussion

Code of Practice
Underground Winding Systems

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1 Introduction

1.1 During 2011 Hero Engineering became involved in underground winding systems. The involvement has stemmed from several shaft sinking projects requiring AS/IEC 61508 “Functional safety of electrical/electronic/programmable electronic safety-related systems” compliance. AS/IEC 61508 is a standard in which Hero Engineering has a number of staff certified by the Internationally recognised German TUV Rhineland organisation.

1.2 Hero Engineering does not claim an extensive history with winding systems and as such has approached the subject from fundamental aspects. As such we have reviewed the history of winders, the existing legislation, the existing guidelines and the proposed guidelines.

1.3 In applying a standard like AS/IEC 61508 to winders there are a number of fundamental issues, first of which is the standard itself. Secondly there are the derived standards and thirdly the worldwide lack of basic training and expertise in the application of these standards. As such it can be difficult for statutory authorities to enforce and for application engineers to prove compliance to these standards. This can be even more exaggerated in any industry where there is a scarcity of knowledge and practical experience with these standards.

1.4 The issues with AS/IEC 61508 and related standards were discussed in Part 1 of this document. This part document will discuss the history of winders and some of the existing guidelines

1.5 Finally there is proposed a method of classifying winders such that the safety functions as described in regulations can be attributed to winders based on clear engineering parameters.

1.6 This document is intended to be read inclusive with part 1 and should not be taken in isolation. the conclusion of Part 1 included the following:

> **6.1** Although complex and still in its infancy AS/IEC 61508 and its related standards are the way forward for not only the Australian Mining Sectors but for other sectors as well.
>
> - The tested and certified components for use in safety systems worldwide are following this system. Any other system would or could lead to engineers being unable to use components with any degree of certainty.
> - There exist well developed guidelines from other industries and nations which have been developed that can provide the basis for all Australian Industries developing similar and consistent guidelines.
>
> ***In terms of existing guidelines for underground winders New South Wales has had in place for 8 years a guideline with parts based on AS/IEC 61508.***
>
> ***Any step for winder guidelines away from this standard can only be evaluated as a step backwards and is only likely to increase risk and hazards to both personnel and machinery.***

2 The Markham Report

2.1 No discussion on winders can be without mention of the Markham report. This is actually a series of reports into the fatal accident at the Markham Colliery in England in July 1973. The first of these reports was "Presented to both Houses of Parliament by Command of Her Majesty" April 1974 by J.W. Calder H.M. Chief Inspector of Mines and Quarries.

2.2 In terms of the history of winding this report is central to the safety of winders for the last 38 years. It is particularly significant in some of the concepts it recommended including the response to detected faults in safety circuits.

2.3 The original report is available for viewing on the Durham Mining Museum web site at:

http://www.dmm2.org.uk/uknames/5557-01.htm

2.4 Of interest in the original Markham report is item 54 (repeated in Figure 1 below) on "single line" components and in particular the final sentence. This section of the 1974 Markham report is repeated in the box below (bold italics ours). In terms of the current standards the term single line could be taken as "single channel" or "simplex" or "non-redundant" or a "hardware fault tolerance equal to zero".

'Single line' components

54. The centre rod in the spring nest is an example of a 'single line' component as the safety of the men in the cage was completely dependent upon it. Such components should either be eliminated or so designed as to prevent danger, for example, failure of any 'single line' component in a braking system should cause the winding system to be brought safely to rest. ***Overspeed and overwind protection should not rely on single components***, but where this is not possible they should be reliable and monitored to give warning of failure, or, alternatively, they should fail safe. All winding engines which are dependent upon only one brake path should be modified as should those where automatic application of the brakes is dependent on a single solenoid. ***Furthermore, there should be indication of any electrical fault in a safety circuit which could render it ineffective or, alternatively, the winding engine should be automatically brought to rest if a fault occurs in a safety circuit which would give rise to danger.***

Figure 1. Markham Item 54 (bold text ours)

Note: the above excerpt was found on the Durham Mining Museum web site at http://www.dmm2.org.uk/uknames/5557-10.htm

2.5 Also in the original Markham report are the recommendations in section 71 which includes:

- Critical safety functions to not to rely on single devices or to operate in a fail-safe manner channels (item ii);
- The now common concept of repeated testing at regular intervals (item iii). In AS/IEC 61508 this is called proof testing;
- Design of safety functions for the life of the machinery or plant (item iv).
- The use of electrical braking as part of a safety function (item v).

2.6 At the time of the report's release in 1974 the technology available at the time would have made meeting these recommendations more difficult than today. The first safety relay module produced by Pilz the PNOZ was only released commercially in 1987.

2.7 As Markham predates the standards and predates the availability of components capable of the tasks it describes it can be viewed as a landmark work in the development of functional safety. What is surprising is that the mining industry is one of the poorest industries for application of functional safety standards.

2.8 Surprisingly the current United Kingdom (UK) regulations and guidelines do no in general to appear to have developed since that time. The UK Mines (Shafts and Winding) Regulations 1993 for winders section 10 amounts to the following:

Regulation 10

The owner shall ensure that winding apparatus is suitable for the purpose for which it is used, and have effective and suitable: -

(a) brakes;
(b) except in the case of lift apparatus, brake locking devices and brake interlocking devices;
(c) means of controlling power to the winding engine;
(d) means of preventing overwind;
(e) means of preventing a conveyance or counterweight travelling at excessive speed;
(f) means of safely stopping and holding a conveyance or counterweight in the event of an overwind; and
(g) means of monitoring the movement of every conveyance in the shaft.

2.9 The above list is also repeated in the HSE Guidelines L42 Shafts and winding in mines – Approved code of practice on the Mines (Shafts and Winding) Regulations 1993, with guidance that does not effectively add to what Markham recommended. For instance item 86 for safety circuits reads:

86 Safety circuits should not be dependent upon single line components for function essential to safety and should be protected against electrical faults.

2.10 This is effectively less than Markham 54 (see Figure 1 above) which says you should bring the winder to a rest when a fault in a safety circuit occurs.

3 Existing Winder Safety Technology

3.1 In winding technology there are 2 particular safety components of note the "Lilly Controller" (LC) and the Brookhirst Igranic "Long Range Hunting Tooth Limit Switch" (LRHTLS). Both of these pre-date the Markham report by decades. Both have proven themselves in use.

Note: Brookhirst Igranic no longer exists and the current manufacturer of these Long Range Hunting Tooth Limit Switches is Eaton under the Cuttler-Hammer brand.

3.2 In recent discussions regarding winders it has be related about a LRHTLS that was brought of a winder after 30 years of service in the Broken Hill area and was still serviceable. Hero Engineering, in the course of investigating the history of LRHTLS, related this to the current manufacturer, who pointed out they had had similar components provide decades of service without fault in the British steel industry.

3.3 Unfortunately the current manufacturer of the LRHTLS cannot inform us as to what standards or requirements it was originally made to. The ownership of manufacturing has changed hands 3 times. The manufacturing of LRHTLS relies on some drawings dating from the 1950s with a few some revisions dating from the 1970s.

3.4 The Lilly Controller (LC) in various models and configurations has been around for a century. Hero engineering was able to obtain a copy of a manual for the “Lilly Hoist Controller – Model C and auxiliary equipment for Mine Hoists”. We are uncertain as to when this particular manual was printed but it does refer to:

> Regulation 16.9 which requires that “every winding engine shall be fitted with at least one effective automatic overwinding prevention device as well as an effective automatic overspeed prevention device”.

3.5 To date Hero engineering has been unable to identify the origin of the regulation referred to, however it is consistent with other know regulations.

3.6 In respect to both the LC and LRHTLS there can be no doubting the reliability of either when maintained. The longevity of both, while properly maintained is clearly established. The issue for both in the AS/IEC 61508 system is safety reliability data – there simply is none available. This makes validating the safety functions when using these problematic. It may be that the regulating authorities make a judgement and provide to industry an acceptable set of data.

3.7 If there exists issues with both the LC and LRHTLS is in training and maintenance. During the course of investigating the Lilly controller a company was found on the internet advertising both training of personnel and maintenance of Lilly controllers. The person listed as in charge had passed away several years earlier. This highlights the greatest issue with the Lilly controller, which is not the age of the units being used, but the lack of available expertise. In most cases the most renowned and skill persons with these units are either retired or close to retirement.

3.8 Of note with both the “Lilly Controller” (LC) and the Brookhirst Igranic “Long Range Hunting Tooth Limit Switch” (LRHTLS) is that both are purely mechanical devices. So long as the number of drum rotations for either design is not exceeded then both will not lose position so long at the physical link between the device and winder is maintained.

3.9 From the review studies Hero Engineering has undertaken this potentially the easiest and most valuable concept that could be lost in advancing winder safety into the AS/IEC 61508 environment. There has been related information regarding incidents where systems based on incremental encoders have lost their position reference, due to power outage or other.

3.10 This is extremely important for future guidelines as power outages or irregularities at mine sites are expected occurrences and AS/IEC 61508 systems are fundamentally electrical and rely on electrical power. Many industrial motion control applications are designed to fail safe on power failure. As most industrial motion control systems can be easily re-referenced after power recovery the consequences of position loss for a winder may not be obvious to those engineers less familiar with the application.

3.11 Currently there are several manufactures of incremental and absolute encoders certified for use in AS/ICE 61508 safety systems. There are matching logic solver solutions for these encoders and it is likely their use will become widespread and may eventually replace the LC and LRHTLS.

3.11.1 Some of the incremental encoders have secondary absolute systems, some of which allow the encoder to complete up to 4096 revolutions before numerical overlapping. in these systems the absolute encoder value can be used to check the incremental position. Some of these encoders are in fact dual encoders in a single package with multiple absolute systems. In these devices the absolute values can be checked. Although these devices are well tried and well proven in applications such as robotics, the reliable long term use of these devices in min site environments and winder applications is unproven.

Until such time as the long term reliability of encoders can be proven secondary back up and checking systems are highly recommended.

3.11.2 Complete reliance on a single electrically powered absolute encoder cannot be justified under any of the current guidelines or accepted practice. As such an encoder would most likely be placed on the side of the winding drum opposite the drive it would have the same issue that existing Lilly and LRHTLS systems have with mechanical failure of the drive linkage.

As such it is recommended that any future guidelines for the use of encoders should retain the existing guidance on mechanical failure detection.

3.11.3 There are a variety of technologies used in rotational control measurement and motion control applications including incremental encoders, absolute encoders, resolvers and magnetic encoders. In respect to incremental encoders there are 2 fundamental types; quadrature and Sin/Cos. Quadrature uses 2 offset square wave signals the direction of rotation is detected by the order of switching. Sin/Cos encoders are similar to resolvers in that the 2 signals are sinusoidal; one being 90^o displaced hence the Sin/Cos terminology. The significant advantage of Sin/Cos encoders is the inherent diagnostic function of $\sin^2 + \cos^2 = 1$. Faults in the signals and hardware are easily recognised and Sin/Cos encoder systems have higher safe failure fractions than other technologies.

3.12 Future regulations and/or guidelines should provide guidance, boundaries, minimum requirements and possible limits on usage of electrically powered encoder systems and include factors on:

- Power supply redundancy or backup;
- Automatic encoder reference checking;
- Automatic speed limitations for systems that have lost position;
- Documented recovery procedures for systems that have lost position.

There can be no value in trying to advance regulations or guidelines into the AS/IEC 61508 framework if in doing so some of the inherent safety features of the existing Lilly and Long Range Hunting Tooth systems are lost.

4 Winder Regulations and Guidelines

4.1 Winder Regulations

4.1.1 All states in Australia have rules or regulations that specify certain requirements be met for winders. In most cases these rules require specific functions exist, but as is the case with such regulations, very few specifics are mandated. For example:

- All winders shall have speed controls, but no specifics on how those controls shall be done are provided. There are no specifics on how speed shall be measured only that a speed limit of (usually) 110% the winders design speed if exceeded shall stop the winder.
- All winders are to have over-wind limits, but there are no specifics to how many a given application may require.

4.1.2 There are inconsistencies with the state to state regulatory system. This is something the development of national guidelines is addressing and there is no requirement to detail the discrepancies here.

4.2 Specific Winder Guidelines

Note: In the current discussion the terms "guidelines and "code of practice" are for practical discussion to be considered the same.

4.2.1 There exist a number of guidelines in existence, several of which do relate to the AS/IEC 61508 family of standards. In particular the "Electrical Technical Reference for the Approval of Power Winding Systems" (MDG 2005) produced by the Mine Safety Operations Branch - New South Wales Department of Primary Industries, actually lists winder safety functions and sets AS/IEC requirements for those functions. Under draft at this time the NSW DPI has an updated set of guidelines EES-008 "Electrical Engineering Safety – Design of Powered Winding Systems" (5 parts) which do describe different winder types and usage and goes further in describing AS/IEC 61508 functionality than MDG-2005.

4.2.2 As mentioned in section 2 the United Kingdom has a winder code of practice. This document reads very similar to parts of the Western Australia guidelines and current Work Safe Australia draft code of practice. There are only some slight differences in landing speeds. However the UK L42 Code of practice like the proposed SWA Work Safe Australia draft code of practice makes no mention of AS/IEC 61508.

4.2.3 The draft guideline produced by Work Safe Australia is a comprehensive document encompassing many aspects of winder functionality and mechanical design. Hero Engineering is primary an electrical, control and safety system design engineering business and as such have no comment on the mechanical aspects of this document. However with knowledge and having reviewed MDG-2005, EES-008 and UK-L42 the electrical control and safety system aspects of the proposed guideline are completely inadequate.

4.2.3.1 The proposed guidelines are at best a repeat of existing state legislation and or UK-L42. The only value in the draft guideline would be to provide a level of consistency between Western Australia, South Australia, Victoria, Tasmania and the Northern Territory.

4.2.3.2 Engineers in both New South Wales (with the MDGs and EES guidelines) and Queensland (who use AS/IEC 61508) will be guided by fundamentally more up to date engineering practice. Both MDG-2005 and EES-008 (even on draft form) are superior guidance documents.

4.2.3.3 Engineers in states using the proposed guidelines would not be guided by current standards and practices and potentially be vulnerable to negligence claims under occupational safety legislation in which the term “practicable” includes definition of “current knowledge” or “best practice” would be at significant disadvantage.

4.2.3.4 There is no escaping the simple fact that since 2003 there has been a guideline accepted for use tabled by an Australian government authority that uses AS/IEC 61508 as the basis for classifying and design the safety systems of underground winding systems. The only practical path forward nationally is to:

- Adopt MDG-2005 in current form; or,
- Adopt EES-008 when accepted; or,
- Use MDG-2005 and EES-008 as the basis of a new national guideline.

5 Proposed Classification Scheme for Underground Winders

5.1 The projects that Hero Engineering has become involved with are shaft sinking projects requiring AS/IEC 61508 compliance. As such these projects have a wide variety of winder types, power rating and design speeds. Some of these winders had design speeds below 0.5m/s some were capable of over 10m/s. The motors ranged in power from 15kW to over 1.2MW and are of both electro mechanical and electro-hydraulic drive designs.

5.2 We are quite well aware that there are winder systems with considerably more speed and power than these systems. We know that winder systems in drifts have other requirements. We know that friction winders have other fundamental requirements. What we find in winder guidelines, and accept it may be problematic, is a system based on engineering parameters that classify winders.

5.3 Guidelines such as MDG-2005 and EES-008 comprehensively list the fundamental functions and the basic SIL requirements. What is lacking in these guidelines is under what circumstances particular functions are:

- Optional; or,
- Not required as specified safety functions but still required under basic control; or,
- Not required at all because they are particular to a specific winder type or application; or,
- Require additional safety requirements than normal because of:
    - Speed; or,
    - Power; or,
    - Man riding or the number of men riding.

5.4 Another feature lacking in these guidelines are overrides. The most obvious overrides found on most winders are back out switches. these are used to test the override limit switches and temporarily override the safety interlocks to back out of the override state. There may also be overrides for things like:

- Crosshead separation – common in shaft sink applications for tipping and passing through the stage platform

- Radio links for when a radio system has lost transmission and the winder must still be operated.

5.4.1 In the AS/IEC 61508 framework overrides have particular requirements as principally they suspend one or more safety functions. These overrides are sometimes called MOSs (manual override switches) and the principle issue is not one of activating a MOS it is one of clearing it once no longer needed.

5.4.2 In designs so far seen by Hero Engineering there has been a back out switch system that performs this function automatically by linking the back out switch to hunting tooth limits that only allow the back out switch to operate for a limited range of motion. As AS/IEC 61508 systems can do these overrides in software or other configurations the automatic cancelling of such overrides will need to be clarified in future guidelines.

5.5 The proposed classification system is similar to that described in AS 4343-2005 Pressure equipment - Hazard levels table 1. That system uses the basic parameters of pressure and volume to define hazards in pressure vessels, vacuum vessels, boilers and pressure piping. Allowances for the type of gas or fluid are covered by this system. The fact that this is a well-established and working Australian system that covers a significant variety of equipment types shows that a similar system for winders should be achievable.

5.5.1 The fundamental parameters are maximum design speed (Vdm) and total winder drive power (kW). Based on speed and power one of 5 categories is assigned. Category A winders having the least requirements up to Category E winders having the most requirements. There are separate tables for manned and unmanned winders.

5.5.2 Respecting the speed ranges in the tables below the next speed in the unmanned sequence would be 32.0m/s and for the manned 27.0m/s. To date Hero Engineering is unaware of any winder achieving either of the speeds in normal operation.

NOTE: The following tables are provided for the purpose of discussion and development of future guidelines and or codes of practice. Any practical use of this information in any form in any project is neither authorised or approved by Hero Engineering and may be an act of gross negligence on the part of the user.

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Table 1. Winder Classification for Unmanned Winders

Drive Power	Maximum Design Speed (Vdm m/s)			
	0.5 m/s	2.0 m/s	8.0m/s	
<= 100kW	A	B	C	D
<= 200kW	A	B	C	D
<= 400kW	B	C	D	E
<= 800kW	B C	C D	D	E
> 800kW	C	D	E	E

Notes: 1 - Winders with > 400m of rope increase the category by 1 place
2 - Winders with > 800m of rope increase the category by 2 places

Table 2. Winder Classification for Manned Winders

Drive Power	Maximum Design Speed (Vdm m/s)			
	1.0 m/s	3.0 m/s	9.0m/s	
<= 100kW	B	C	D	E
<= 200kW	B | C	C | D	D | E	E
<= 400kW	C	D	E	E
<= 800kW	C | D	D | E	E	E
> 800kW	D	E	E	E

Notes: 1 - Winders with > 400m of rope increase the category by 1 place
2 - Winders with > 800m of rope increase the category by 2 places

5.5.3 Once a winder is classed its required functions could be read from a table such as shown below in Table 3. In table 3 the equivalent MDG-2005 requirements are shown.

Table 3. Winder Safety Function Requirements

Winder Safety Function	MDG-2005		Winder Class Minimum SIL					Basic Response
	Type	SIL	A	B	C	D	E	
Emergency Stop	Prim.	2	2	2	2	3	3	Immediate
Quick Stop	Prim.	2	1	1	1	2	2	Immediate
Ultimate Over Travel	----	----	2	2	2	3	3	Immediate
Final Over Travel	----	----	0	0	1	2	3	Immediate
Over Travel	Prim.	2	1	1	2	2	3	Immediate
Over Speed	Prim.	2	1	1	2	3	3	Immediate
Gear Loss	Prim.	2	1	1	2	2	2	Immediate
EUC Derail	Prim.	2	1	1	2	2	2	Immediate
Communication Loss	Prim.	2	1	1	2	2	2	Immediate
EUC Gates	Prim.	2	1	1	2	2	2	Immediate
EUC Hydraulic Pressure	Prim.	2	1	1	2	2	2	Immediate
Slack Rope or Rope Slip	Sec.	1	1	1	1	2	2	Immediate
Safe Coil	Sec.	1	1	1	1	2	2	Immediate
Brake Wear	Sec.	1	0	1	1	2	2	End of Motion
Brake Lift	Sec.	1	0	1	1	2	2	Delayed
Drift Profile	Sec.	1	0	1	1	2	2	Immediate
Motion Detection	Sec.	1	0	1	1	2	2	Delayed
Drive Fault	Sec.	1	0	0	1	2	2	Immediate
Drive Train Fault	Sec.	1	0	0	1	2	2	Immediate
Hydraulic Unit Protection	Sec.	1	0	0	1	2	2	End of Motion
Drum Pit Protection	Sec.	1	0	0	1	2	2	Delayed
Cross Head Separation	----	----	1	1	1	2	2	Immediate
Hydraulic Drive Overpressure	----	----	2	2	2	2	3	Immediate
Hydraulic Drive Boost Under Pressure	----	----	1	1	1	2	2	Immediate
Drive Synchronisation	----	----	1	1	2	2	2	Immediate

5.6 Notes & Comments on Tables 1, 2 and 3

5.6.1 It is expected that the opinions of others will differ on the speed and power values in tables 1 and 2. The speed separation points are based on what we have seen in the underground mining industry in projects are involved in or have project information from vendor advertising materials.

5.6.2 It is expected that that the opinions of others will differ on the safety function assignments in Table 3. We have used the basic list as described in MDG-2005. We have noted in several winder designs the basic assessments are that MDG-2005 overstates the requirements for low speed or lower winders such as shaft sinking stage winders.

5.6.3 The opposite side of any discussion that MDG-2005 may overestimate requirements is that it may also understate the requirements of very powerful or very fast winder systems. As such Table 3 includes SIL 3 functions for the class E winders for emergency stop, over speed and over travel. Respecting the argument that SIL 3 is difficult to achieve for an AS/IEC 61508 system, the following points are made:

- Where the final elements for such systems are contactors to depower motors – there exist readily available contactors on the market available from most major suppliers that can be used in SIL 3 applications usually in a dual configuration and utilising mirror or mechanically linked contacts as described in AS 60947.
- Where the final elements are variable speed drives - there exist readily available variable speed drives from a number of manufacturers with inbuilt or optional safety modules which can provide stop functions up to SIL 3.
- Where the final elements are variable speed drives - there exist readily available variable speed drives from a number of manufacturers with inbuilt or optional safety modules which can provide speed limiting functions up to SIL 3.
- There are encoders available from several manufacturers which are independently certified for use in SIL 3 systems.
- There are logic solvers available from several manufacturers which can read encoders and perform safety related motion control functions up to SIL 3.

The designing, installation, testing and validation of systems using the types of components described above are neither trivial or straight forward. Considering the current lack of skills and understanding the use of such components in winder applications should only be attempted by teams comprising the necessary skill set and with the full support of the suppliers involved.

The point being made is not should this be done. The point is that if future guidelines do call for SIL 3 functions on underground winding systems such guidelines would not be placing impossible or unreasonable conditions on engineers.

5.6.4 It is expected that that the opinions of others will differ on the concept that at a depth of 400 meters the class of winder goes up 1 category and at a depth of 800 meters goes up another category.

- It not only likely but expected that there is expertise in the winding rope industry who can better set any such depth limits for increased safety function requirements.
- It is similarly expected that the depths at which safety functions requirements increase is different for other winder types such as drift and friction winders.

The point being mad is that at some depth (or depths) some of the safety function requirements should be increased.

5.6.5 It is expected that that the opinions of others will differ on the safety function assignments in Table 3 so far as that it is based on Hero Engineering's work on current shaft sinking projects. We fully understand that there are other winder types and that there is more expertise and experience in those winder types than we have. We expect that if such expertise and experience is utilised then it is most likely that different versions of Table 3 would be developed for different winder types or applications.

The point being made in this is that based on speed, power and depth it is possible to classify a winder and from that classification the winder safety functions can be defined.

5.7 Other possible means of classification.

5.7.1 Hero Engineering accepts that other opinions may differ and that speed and power are no the best 2 fundamental parameters for classifying a winder.

- It is possible that the design payload tonnage is better than power.
- It is possible that one factor may be a combination of 2 parameters as is the case for pressure hazards as per AS4343.
    - It could be that the tonnage multiplied by the design speed is used – which is the momentum of the conveyance;
    - It could be the half the tonnage multiplied by the velocity squared is used – which is the kinetic energy of the conveyance;
    - It could be the tonnage multiplied by the depth of the shaft is used - which is proportional to the potential energy of dropping the conveyance.
- It could be that the weight of winding rope at a particular point of travel is used.
- It could also be that for different winders different parameters are used to classify winders, such as the angle a drift winder operates at.

6 A Practical Example of Winder Classification

NOTE: The some of the information in this section relates to a real winder application and is only provided for the purpose of discussion and development of future guidelines and or codes of practice. Any practical use of this information in any form in any project is neither authorised or approved by Hero Engineering and may be an act of gross negligence on the part of the user.

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The purpose of this section is to give a practical example for the purpose of discussion of the use of the classification system described in Section 5 above.

6.1 By fortune or misfortune there is shown on the cover of the Safe Work Australian draft code of practice Underground Winding Systems and also on pages 4 and 5 of that publication. Hero engineering has been engaged to re-design the safety and control systems for 2 such shaft sinking systems. Figure 2 below is the block diagram for one of those systems.

6.2 The basic parameters of the 2 winders are detailed in Table 4 below. From Table 2 above the service winder is class C. Despite the standard practice of no man riding on a stage platform the stage winder in this system is not by Table 1. Although under normal procedures for this system no man is to ride on the stage system when moving, the stage winder is also the backup emergency egress. As such, despite no normal expected use, this system would also be classified under Table 2 and the stage system is class B. If in this system there was another winder designated as the emergency egress winder then the stage would not need to be man rated and could be classified under table 1 and would be class A and not class B.

Table 4. Winder System General Data

	Service Winder	Stage Winder
Main Drive Power	110kW	22kW
Main Drive Type	Electro-Hydraulic	Electro-Hydraulic
Drum Diameter	1520mm	760mm
Drum Arrangement	Single Drum	Double Drum
Design Speed	2.0 m/s	0.17 m/s

6.3 Hero Engineering expects that others will recognise some of the components by acronym in Figure 2. We also expect that competent engineers would discern without us having to state it, that the safety related signals are in red and standard signals in black. we only mention this so as to be clear in the discussion.

6.4 In the aforementioned OLF 070 (part 1 section 4) guideline there is the accepted concept of exceptions. Looking in Table 3 above for a class B winder the overspeed function is SIL 1. The encoders for the stage system in Figure 2 are not connected to the safety system but to the basic control system.

- In this particular stage winder the drums are mechanically linked via a clutch. the position of which in this system is monitored by the safety controller.
- This stage system has a design speed less than 0.2m/s, which places it in not only in the bottom of the slowest speed range but also in the bottom of the lowest power range.

These 2 points could form the basis of a re-assessment of the required safety functions as described in OLO 070 section 7.7. This is not to say such a re-assessment shall happen or that this will be the final design, only that it is possible based on some basic fundamental parameters of the system.

6.5 Of note in the concept shown in Figure 2 is the Head Frame Ultimate Overwind switch and that it is NOT connected directly to the safety controller. The HF_UOW in this concept is directly connected to an independent safety rated logic solver.

6.5.1 It is readily agreeable that the worst incidents in winders either involve the conveyance falling down the shaft or striking the head frame and then falling down the shaft. Irrespective of current information a winder conveyance reaching the last limit in the head frame is one of the most serious circumstances that can happen in a winder system.

6.5.2 The system in Figure 2 is based around a configurable safety controller that is configured by software run from a portable or fixed personnel computer. As such it has a vulnerability to inadvertent or undocumented change. No matter how unlikely or how remote the circumstances are there is only 1 conclusion in such a system if the conveyance reaches the HF_UOW point. ***Both the basic and safety control have failed and as such the HF_UOW cannot be expected to function as expected.***

6.5.3 In the AS/IEC 61508 framework this design concept is referred to as an independent layer of protection. There is no requirement in any regulation, guideline or code of practice relating to winders for such an independent circuit.

The conclusion reached in this design concept was that - while AS/IEC61508 remains with some of its current issues keeping the HF_UOW outside of software configurable systems for winders that approach the head frame on a regular basis is practicable and advisable.

6.5.4 Is such a system tamperproof? NO, it can be by-passed with a screw driver. Does such a system have more or less integrity? Neither, it would be expected to have the same or very similar integrity.

What such a system has is that that the HF_UOW function cannot be by-passed or rendered ineffective through a software change.

6.5.5 An issue with winder systems using software configurable controllers will be the approval by regulators. Although a system as concept such as Figure 2 will provide a challenge for the approval process. This part of this design is in part done to provide confidence to the regulatory authorities of sound engineering practice.

Whether or not the last head frame limit is required to be specified as not being software configurable in regulation, code of practice or guideline is yet to be determined.

7 Final Comments

7.1 A simple system of winder classification is not only possible it is practical and would remove most of the inconsistencies that exist between the Australian states.

7.2 We hope those who read this will find it useful in raising purposeful discussion points in developing the new Australian code of practice for underground winding systems.

7.3 The New South Wales DPI has led the way by developing first MDG-2005 and later EES-008. Without either of these this document could not exist. As they were freely provided to the wider mining community we also provide this document free of charge.

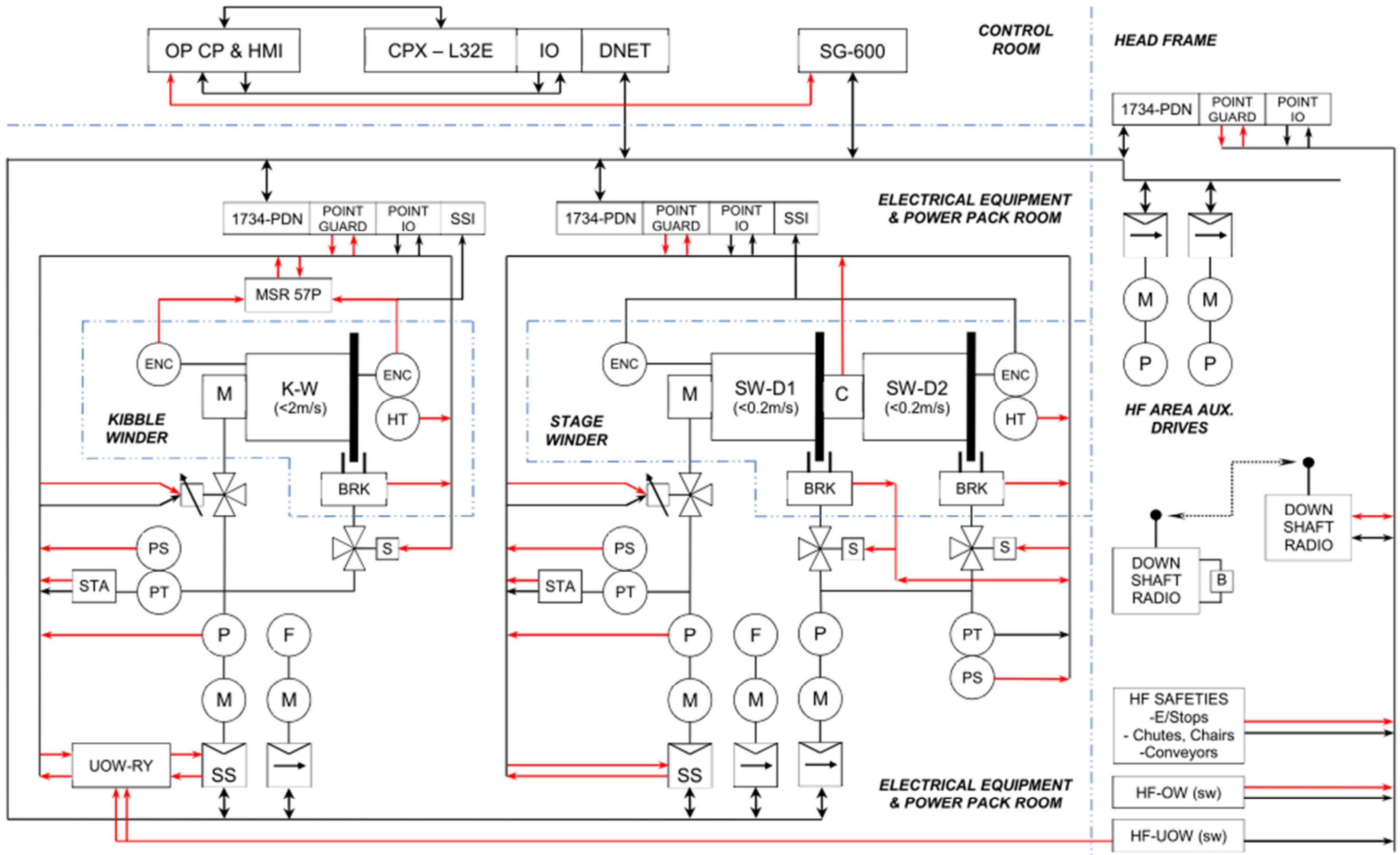

Figure 2. Example - Shaft Sink Control System Block Diagram

NOTE: Figure 2 above relates to a real shaft sink winder system that is ***under development***. The above diagram may not reflect the final design or any of the components used in the final design. Reproduction of or use of any part in the above system is neither authorised or approved by Hero Engineering and may be an act of gross negligence on the part of the user.