Combatting human errors in foundries

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We've all heard the excuse: "it's down to human error" with the assumption that there's nothing we can do about it. However, when any type of quality issue is caused by a person doing something incorrectly there will be a deeper root cause of the incident. In any situation there are likely to be many factors that can lead to a human error, and these precursors or preconditions are referred to as *human factors*.

The study of human factors is about people in their working environments, and it is also about their relationship with equipment and procedures. Just as importantly, it is about their relationships with other people – their co-workers and managers. Its objectives can be seen as: safety, efficiency and effectiveness. Human factors answer the question: "Why do smart people sometimes do stupid and/or dangerous things?"

human errors are caused by human factors

The consideration of human factors first emerged in aviation MRO (maintenance, repair and overhaul) and now it is being applied in many other manufacturing and service sectors.

Combatting human errors requires a systemic approach that ideally prevents their occurrence in the first place or mitigates the severity of their consequences if they happen, and then puts in place a countermeasure to ensure they never re-occur.

Types of situations relating to human error

Hazards – are potential occurrences or unsafe conditions, which could, if left unreported and un-addressed, lead to a human error, a near miss and possibly a nonconformance and/or safety concern.

what could happen – proactive

Events – are realised occurrences, which can be notified via a number of existing processes such as 'down-stream' problems, customer returns/complaints, CARs, major quality failures, audit non-conformities and accidents

what has happened – reactive

If we can reduce the number of human errors within the foundry by understanding the human factors that are their root cause(s), the possibility of a serious incident/accident resulting from manufacturing will be diminished proportionally and the COPQ (cost-of-poor-quality) will be reduced.

Commencing the search for human factor root causes

The process starts by agreeing on a clear and concise statement of the event/hazard under consideration. The search for the real root cause of an identified human error can then commence by asking:

- what did the operator not do – that they should have done?
- what did the operator do – that they shouldn't have done?

The search then continues by repeatedly asking:

- Why didn't they do that?
- Why did they do that?

Yes, it's an application of the '5-WHYs tool' working backwards from the event/hazard (i.e. the problem) to the root cause (i.e. human factor) – but we can do better.

Directing the search using directed brainstorming

The concept is that when we have an event/hazard that was caused by an operator doing something incorrectly, there must be a reason for their behaviour. There are many 'factors' that can cause a situation where a human error can occur, some lists include over 300 human factors!

An Ishikawa diagram is an excellent 'visualisation tool' for categorising the potential causes of an event or hazard to identify its root cause(s). It prompts teams to brainstorm possible root causes from different perspectives – each 'perspective' is identified by a 'spoke' or 'bone' of the diagram (this is why it is also referred to as a Fishbone Diagram). In essence, it's 'directed brainstorming'.

Various 'models' have been developed to direct the search for human factors from different perspectives. The more popular models include:

- The PEAR Model to characterise human factors[1]
- IAQG's human factors root causes[2]
- SCMH root cause categories – manufacturing-focused[3]
- The 'dirty dozen' human factors – maintenance-focused[4]
- The SHELL model focused on working environments[5]
- The bow-tie model[6]

Using one or more of these models enables the 'spokes/bones' of the Ishikawa diagram to be pre-formatted to indicate the different perspectives the team needs to consider. An example based on the 'IAQG's human factors root causes' is shown in fig.1. Of course, they can be created to correspond to human factors causes identified in the foundry environment.

Guiding team brainstorming sessions

The selected 'pre-formatted' Ishikawa diagram provides the initial focus for problem-solving teams. The team facilitator first selects one of the 'spokes/bones' and asks WHY? – which provides the first level of a 'why tree'. The facilitator continues the search by asking the team:

- Will addressing this (direct) cause prevent the event/hazard?
- If not, can we see the next level of cause?
- If not, what do we suspect as the next level of cause?
- How can we check and confirm the next level of cause?
- Will addressing this level of cause prevent the event/hazard occurring?

If not, the facilitator continues to ask 'why' until human factor cause(s) are determined. Attention is then redirected to consider the remaining 'spokes/bones'.

When searching for the human factor-related 'root causes' of complex problems, simple 5-whys may not be sufficient in the foundry environment. The drawback is that an event/hazard can be produced by multiple causes and multiple combinations of causes. Using 'linear 5-whys' alone works if there is only one cause for every effect identified by the team.

The 'logical' connectivity between events and all their causes can be revealed with a 'why tree'. Building a why tree gives the team a much better chance of spotting all the issues that could have been in play prior to the event/hazard occurring. By only asking 'why questions' without the why tree as a guide, the team may never find all the real root cause(s).

In this 'variant' the facilitator again focuses the team on each perspective but allows alternative answers to be presented to the 'first level why question' (four in this illustration). Once all the possible first level causes have been identified the teams are directed to follow the different 'logic paths' in turn until human factor root cause(s) are determined.

A further enhancement may be added in the form of Boolean logic. For example, the team may consider that any of the different 'logic paths' are feasible – this equates to an *OR-gate*. Similarly, and *AND-gate* may be identified which demands that two or more 'why questions' must occur simultaneously, and so on.

In situations where the focus is on 'what the operator did not do – that they should have done', a *NAND-gate* is useful which is referred to as the 'Swiss cheese' model.

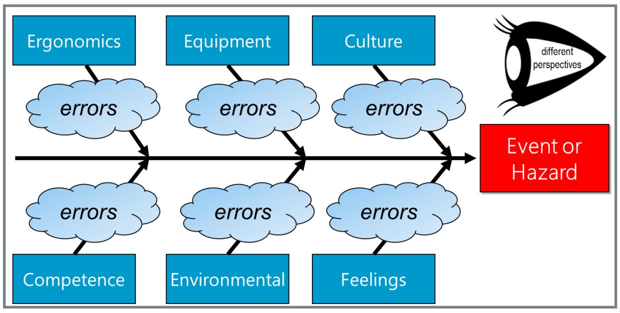

Fig.1 Example of a pre-formatted Ishikawa diagram based on the IAQG's (International Aerospace Quality Group) human factors root causes

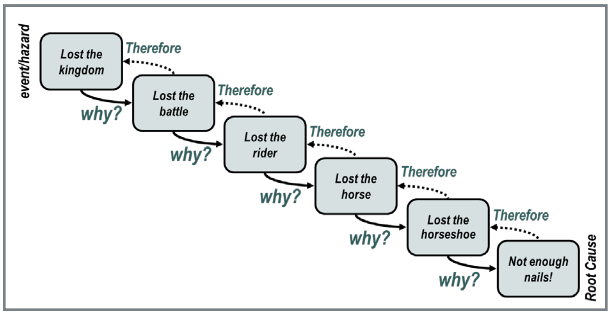

Fig.3 Test the 5-WHY 'stream of logic' in reverse order and insert the word 'therefore' between each step. If the logic path makes sense in reverse, then the logic is probably solid

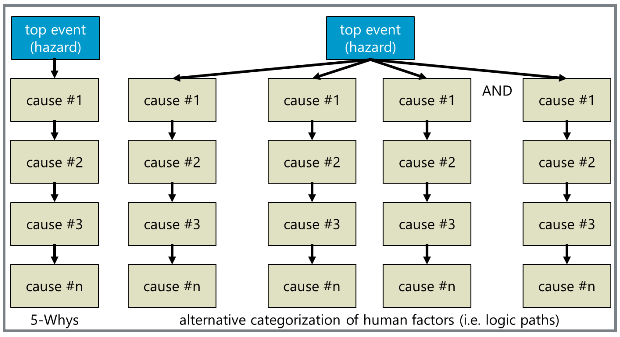

Fig.2 Comparison of simple (linear) 5-Whys with a 'Why Tree'

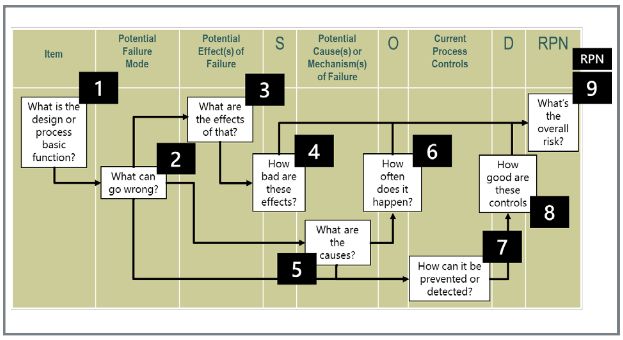

Fig.4 Schematic of an FMEA (failure modes and effects analysis) diagram

Verifying human factor root causes

It is possible, indeed likely, that the use of the Ishikawa diagram and the why tree methodology will uncover several root causes. Each of these causes must be scrutinised by the problem-solving team to elicit the most likely.

The therefore test

One method – favoured by TEC Transnational – is to use the 'therefore test' to check the team's 5-why work! The purpose of the 'therefore test' is for the facilitator to check the logical flow of the 'causal chain' from the earliest point in the sequence up to the event/hazard. After completion of any causal chain, go to the earliest link reading each statement in turn with the word 'therefore' between links as illustrated in fig.3.

The team leader starts by reading aloud the statement of the selected root cause, followed by the word 'therefore'. The team then considers the identified cause immediately before the root cause to test the 'stream of logic' in reverse order. This process is continued until the beginning of the 5-why causal chain is reached (i.e. the first level of the 'why tree').

At any point in the process, if the team is not able to insert the word 'therefore' and make sense of the analysis there is a gap in the logic! Whenever gaps are encountered the team will need to fill these gaps with additional facts.

Is – is not structured questioning

Another method of root cause verification returns to the initial statement of the event/hazard, and the team is prompted to ask:

- What **IS**: what's wrong? (e.g. the event/hazard)
- What **IS <u>NOT</u>**: what logically could be wrong, but is not?

These structured questions may be extended to focus on:

- What castings (were involved)?
- Where (on the casting)?
- Where (physical location on the casting; location in the foundry; subcontractor site)?
- When (was the problem discovered)?
- How many (castings affected)?
- Who (was the operator/supervisor)?

Frequently, the team will require further information if an answer is not known. The team must then test all possible root causes (human factors) to eliminate causes that do not make sense and possibly assign a percentage contribution to each 'possible'. The facilitator prompts the team to ask to fill in the blanks –

"if ___________________________ is the root cause of ___________________________" –

- "How does this explain <u>both</u> IS and IS NOT?"
- "Which root cause has the fewest assumptions (%)?"
- "How can we check our assumptions?"

Addressing the root cause(s) of events/hazards

With the root cause(s) determined in terms of human factors (i.e. 'why' the operator did something incorrectly), attention must be switched to devising 'controls' to 'prevent' the cause (preferred) or 'detect' that the cause has happened and mitigate the consequences.

A cross-functional team familiar with the casting process concerned must investigate 'controls' that will either prevent or detect the established root cause(s). Options are frequently found, and the team must first verify that these 'controls' will be effective and will not result in any undesirable side-effects and/or cause further problems/events. Cost implications must also be considered.

The chosen controls are then deployed and checked to ensure that either:

- further re-occurrences don't happen, or
- further occurrences will be detected and not released.

Other tools may prove to be useful in this process.

FMEA (failure mode and effect analysis)

Failure modes and effects analysis (FMEA) is a step-by-step approach for identifying possible failures in the product/service design (DFMEA) or in a manufacturing process (PFMEA), as illustrated in fig.4.

The terminology failure mode means the way(s), mode(s), in which something might fail. Failures are any errors or defects, especially ones that affect the customer or downstream operations – they can be potential (hazards) or actual (events).

The terminology 'effects analysis' refers to studying the consequences of those failures and determines their severity (inconsequential – catastrophic).

The bow-tie model

Initially the bow-tie model was primarily intended for use by aviation safety managers, but it may also be applied to foundry operations. It ties together previously distinct risk philosophies and tools into a single purpose for a specific application as shown in fig.5.

Using the bow-tie will expose all of these elements in one way or another,

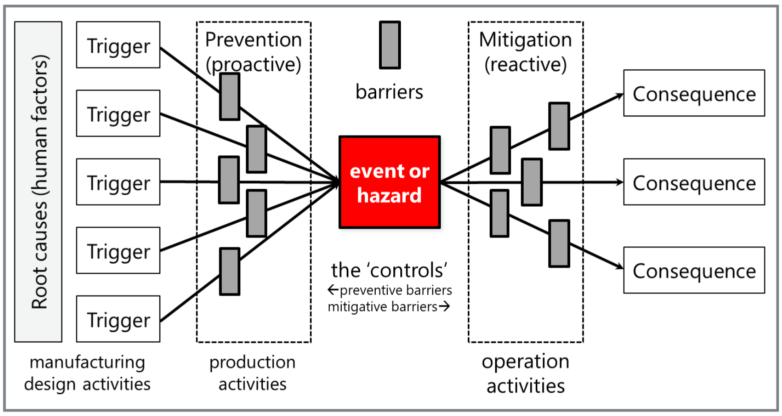

Fig.5 The bow-tie model ties together previously distinct risk philosophies and tools into a single purpose for that application

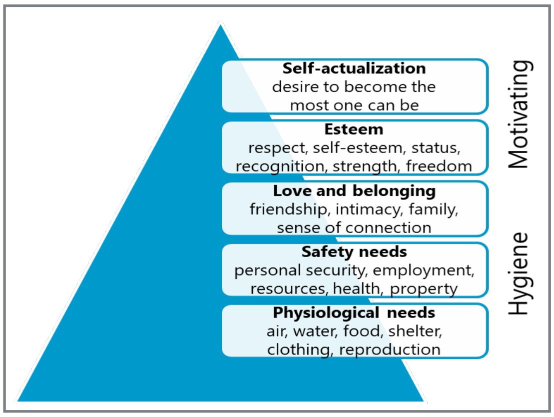

Fig.6 Maslow's hierarchy of needs comprises a five-tier model of human needs, often depicted as hierarchical levels within a pyramid. Needs lower down in the hierarchy must be satisfied *before* individuals can attend to needs higher up. From the bottom of the hierarchy upwards, the needs are: physiological, safety, love and belonging, esteem and self-actualisation.

Herzberg built on Maslow's theory and showed that individuals are not content with the satisfaction of the three lower-order needs at work; for example, those needs associated with minimum salary levels or safe and pleasant working conditions, which are viewed as 'givens'. Rather, individuals look for the gratification of the two higher-level psychological needs relating to achievement, recognition, responsibility, advancement, and the nature of the work itself.

and it does so in a single, concise visual chart that resembles a bow-tie. The bow-tie relies on four elements to do this which are:

1. Root causes (human factors) that trigger the…
2. The event/hazard that leads to…
3. Impacts on manufacturing operations (i.e. downstream or the customer); and…
4. The relevant risk 'controls' (barriers) to the event/hazard and their impact

The explicit purpose of the bowtie is to show the flow of a safety event including:

- Causes (threats) that aligned to create a problem (i.e. why trees)
- The events that funnelled 'upstream' to the…
- The event (or hazard) (i.e. the critical point of the event)
- The cascading events of the event (or hazard) that lead 'downstream' to…
- Impacts that adversely affect the organisation or the casting; and…
- The failure/success of each risk control measure (equivalent to 'detection' in an FMEA) in the sequence of events

Influencing operator motivation – practical psychology

Clearly it is far preferable to avoid human error happening, as a result of one or more human factors, in the first place! Systematic use of one or more of the above models will determine these root causes, so that robust 'controls' may be put in place.

Nevertheless, we are dealing with human beings who are subject to human factors which could lead to human errors and their negative consequences. What we want is highly motivated operators who will adhere to the robust planned arrangements now deployed to guarantee right-first-time performance.

The problem is how to motivate? – this is where Maslow and Herzberg come in (see fig.6).

From Maslow's[7] hierarchy of needs and the practical work of Herzberg[8] it is clear that you cannot motivate another person to do anything (it has to come from them) but you can influence them. This is the basis of CBT (cognitive behavioural therapies) which are a range of 'talking therapies' based on the theory that thoughts, feelings, behaviour (i.e. what we do) and how our body feels are interconnected[9][10]. If we change one of these we can alter the others. Consequently, 'wrong' (i.e. negative) thoughts and feelings (i.e. mindset) can directly affect an individual's perception and trap them in a vicious cycle of incorrect behaviour (i.e. continuing to make human errors in their work). You don't have to be a qualified therapist to make CBT work[11] in the manufacturing environment, you just need to be convinced that it works and know how to use it effectively. Obviously, thoughts and feelings are internal (i.e. 'behind the eyes') to the person concerned, and they may not be aware of the activity.

"The flesh is the surface of the unknown" – Victor Hugo

A person's behaviours (what they do or don't do) and results (how well they do it) are external (and can typically be observed and measured). So, focus on behaviours and results, and provide operators with on-purpose/situational feedback when things have gone wrong **and** when things have gone right. In the words of Ken Blanchard: "feedback is the breakfast of champions". The more feedback you give to people, the better it is, as long as the feedback is objective and not critical.

Once the human factor(s) are determined, the operator must take responsibility and work with their colleagues to design and use effective controls to ensure that the event/hazard is prevented. Also, managers must recognise that every interaction they have with an operator generates an 'experience' for them.

As Tim Autrey[12] suggests, you can consciously engage them 'on-purpose' in a 'situational context' relating to the result of their behaviour – in other words it's a feedback loop.

The objective, in the words of the old song, is to: "accentuate the positive, eliminate the negative and don't mess with Mr In-between". The question is, how?…

A tried-and-tested approach that is proven to work is to focus on TGW (things gone wrong) and TGR (things gone right), and use a modified process based on Ken Blanchard's 'one-minute reprimand/praise' approach.

TGW (things-gone-wrong):

1. Tell everyone beforehand that you are going to let them know how they are doing and stress that the foundry will always investigate instances of 'human error' in a systematic manner without the 'blame culture'.
2. Involve relevant people immediately the event/hazard is discovered, and include them in the search for the true root cause(s).
3. Once the cause(s) are determined, highlight the human factor(s) involved and explain what their contribution was.
4. Involve relevant people in the development of alternative actions that can:
   (i) prevent the event/hazard happening again, or (ii) mitigate the consequences should it happen – focused on the established cause(s).
5. Select and deploy the most effective solution to permanently fix the identified root cause(s) so that re-occurrences don't happen/will be detected.
6. Let the people know that you (the manager) is honestly on their side, and remind them how much you value them and their input to event/hazard prevention.

TGR (things-gone-right):

1. Tell people right from the start that you are going to let them know how they are doing.
2. Praise people immediately you discover a significant incident where the person used their initiative to:
   (i) prevent an error from occurring, or (ii) brought safety-related information to light (which may have occured many days before!)

3. Tell people what they did right – be specific.
4. Tell people how you feel about what they did right (behaviour), and how it helps the foundry, other people who work there, and the customers.
5. Stop for a moment of silence to let them 'feel' how good you feel.
6. Encourage them to do more of the same.
7. Shake hands or make the appropriate gesture in a way that makes it clear that you support their success in the foundry.

Remember the saying: "different strokes for different folks", so you will need to customise, to an extent, how you provide the feedback to individuals. But do it and be consistent.

"influence motivation with on-purpose/situational feedback"

The core principles to boost motivation

As an essential first step to influence motivation, a foundry must establish and maintain a just culture – that is, an atmosphere of trust in which operators are encouraged (even rewarded) for providing essential safety-related information, but in which they are also clear about where the line must be drawn between acceptable and unacceptable behaviour.

Such a 'climate' will naturally cultivate the ethical behaviour in operators in which:

- The safety and lives of others are dependent upon the skill and judgment of operators is stressed.
- Operators will never undertake work, or approve work, which is beyond the limits of their authority or knowledge.
- Operators will never pass any casting about which they have doubt regarding previous work, inspections or tests.

Consistently operating positive feedback (TGW/TGR) with operators will ensure that they will espouse the following core principles:

- **Proactive passion**
  Continuous sustainable drive for improved performance in all things
- **Independent thinking**
  Being responsible for oneself – questioning everything, seeking to understand and innovate
- **Honesty**
  Complete transparency and immediately admitting to errors in a 'no-blame' (just culture) atmosphere
- **Integrity**
  Always doing the right thing, the right way, for the right reasons
- **Safety**
  Knowing that the safety and lives of others may depend upon one's own skill and judgment
- **Sanity check**
  A quick test to evaluate whether an action is appropriate in a given context
- **KISS (keep it short and simple)**
  Make the complex simple, tangible and 'visual'

Applying the ISO 9001:2015 core concepts to human factors

At the heart of all ISO 9001:2015-based standards[13][14] (e.g. AS9100:2016 series[15] and IATF 16949[16]) are the three core concepts:

❑ risk based thinking
❑ process approach
❑ plan-do-check-act

These 'concepts' underlie everything we have been discussing relating to human errors and their causes – human factors. They are applied in the following manner:

Risk based thinking

Continue to look for possible human factors that could lead to human errors (hazards) and determine the actual human factors that caused identified human errors (events) – take actions to prevent occurrences/reoccurrences.

Process approach

Remember the words of Edwards Deming: "If you cannot define what you are doing as a process, you do not understand what you are doing". Continually strive to remove human factors that lead, or can lead, to human errors by improving the process.

Plan-do-check-act

Plan: Identify human factors that can cause a situation where human errors can occur – these are precursors or preconditions for hazards/events.
Do: Identify human error-related KPIs (key performance indicators) and their goals – ensure that operators know what these are.
Check: Monitor and measure the human error-related KPIs – provide feedback to individual operators or teams based on bad (TGW) and good (TGR) results against goals, and agree improvement plans whenever necessary.
Act: Take necessary actions to improve performance (zero human errors) and continue to monitor progress going forward. In the words of Edwards Deming: "it is not necessary to change, survival is not mandatory."

Conclusion

In closing, analyse human factors and develop effective controls using the expertise of those with relevant knowledge. The resulting processes (i.e. foundry working practices) must be relevant to those who need to know this information – they are a company's stakeholders. Only by engaging with stakeholders – for example, employees in a particular department – can the human errors be eliminated or, if they do occur, their consequences can be minimised, and future reoccurrences avoided.

This is not 'psychobabble' but practical psychology that has been proven to work in both service and manufacturing sectors.

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