



## CONSTRUCTION

Prevention Engineering for HAVS within Construction

### ABSTRACT

Exposure to vibration in construction is incredibly difficult to predict and therefore difficult to control through risk assessment alone. This paper sets out to explain why HAVS continues to be a reason for skilled workers to be taken off the tools, as well as explain how technology can be used to manage your employees' exposure and prevent irreversible damage effectively and inexpensively.

Reactec Ltd

March 2022

## Executive Summary

Hand-Arm Vibration Syndrome or vibration white finger is not a new industrial disease. When regulations were released back in 2005 to control workers' exposure to vibration at work, the HSE set a goal of eliminating the disease within 10 years. Fifteen years on and HAVS is still the highest reported industrial disease (outside of COVID-19).

This paper sets out to explain why, in an industry sector where manufacturers' declared vibration emission levels for tools are frequently used to assess an employee's risk, HAVS continues to be a reason for skilled workers to be taken off the tools. Fundamentally, exposure to vibration in construction is incredibly difficult to predict and therefore difficult to control through risk assessment alone. Having highlighted the factors which make HAVS exposure management difficult, the paper goes on to explain how technology, such as Reactec's, can be used to manage your employees' exposure and prevent irreversible damage effectively and inexpensively.

20 years of experience, collaborating with industry leaders, academia, and the HSE, has given Reactec unequalled understanding of HAVS as a condition and how the source of damage can be controlled. Whether your perspective is employee welfare or corporate compliance you can be assured that proven technology exists to meet your needs.

Immediate and long-term gains require a shift towards prevention rather than simply compliance; by measuring what's happening, you can tailor your controls faster, engineer out risk and actively protect your workers' health in the workplace.

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## 1. Introduction

Hand-Arm Vibration (HAV) is the term to describe exposure of the hands and arms to vibrating surfaces. It can be caused by operating hand-held power tools, such as rock hammers, cut off saws, angle grinders and pole scabblers.

Occasional exposure is unlikely to cause ill health. However, regular, and frequent exposure to HAV can lead to Hand-Arm Vibration Syndrome (HAVS) and Carpal Tunnel Syndrome (CTS).

Exposure to this type of vibration energy through the hand is known to cause irreversible damage to nerves, blood vessels, muscles, and bones. Once the damage is done it is permanent.

The HSE estimates that 2m people in the UK are at risk of developing HAVS due to their work. HAVS related illness is the highest reported industrial disease with around 25% of all HAVS RIDDORS reportable incidents coming from the construction sector, according to the HSE data, before COVID-19.

## 2. Hand-Arm Vibration: Key Statistics in Construction

Hand-arm vibration can be a significant health risk wherever hands are exposed to vibration for prolonged periods of time, and it is a common injury within the construction sector.

Construction sites have a range of different activities involving vibrating tools and machinery; construction workers are particularly at risk because of the work they do, the equipment they use, the variety and often unpredictable nature of tasks performed daily.

# 25%

Approximately 25% of all HAVS RIDDOR reportable incidents come from the construction sector<sup>i</sup> (HSE)

# 33%

33% year-on-year increase in the number of HAV breaches recorded on construction sites<sup>ii</sup> (Building Safety Group 2018)

# 76%

There is a 76% underestimation from typical HAV exposure risk assessments of those most at risk (Reactec Analytics data)

# £15.9m

HAVS/CTS costs employers circa £15.9m per annum<sup>iii</sup> (Loughborough University 2018)

# 300%

300% rise in financial penalties relating to HAVS fines since new sentencing guidelines were introduced in 2016<sup>iv</sup> (Hidden Threat Report)

# 10

**Six figure** HSE HAVS related **fines** between 2014 and 2018 (HSE)

### 3. Legal Obligations

The Control of Vibration at Work Regulations came into force on 6 July 2005 and aim to protect workers from risks to health from vibration. This regulation and associated guidance require the following:

- Elimination or control of vibration exposure risk to as low as reasonably practicable (ALARP).
- An assessment of the risks to employees from exposure to vibration, including assessment of employees' daily exposure to vibration.
- Information, instruction and training to tool users and their managers.
- Health surveillance when required.

A suitable and sufficient assessment of HAV exposure risk requires a determination of:

- **Duration** of exposure and
- **Probable vibration magnitude** during exposure.

As a regulation, it leaves two critical areas of judgement to be applied by a duty holder - areas of judgement that require either a significant investment to become a subject matter expert or consideration of technology to bring clarity to a daunting task:

- **What is a suitable and sufficient assessment of HAV risk?**
- **What is the probable vibration magnitude during tool use?**

### 4. Why Does HAVS Still Dominate RIDDORS?

The traditional method for carrying out a risk assessment of a worker's exposure to vibration could yield unrealistic, unrepresentative information because it relies on data from one person's use of *one* tool during *one* activity at *one* point in time. It doesn't account for the variability or unpredictability that most certainly influences an individual's actual, long-term exposure to vibration.

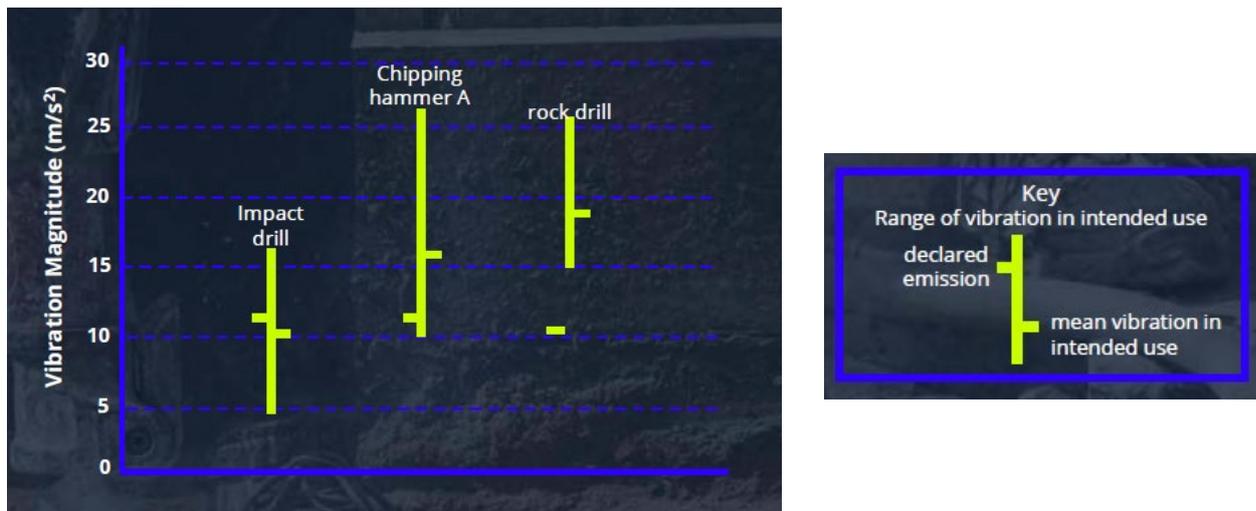
Therefore, it's important to understand all the factors, many of which are unpredictable, that provide the greatest insight into what affects a worker's exposure levels:

1. Does the risk assessment match the real tool use?
2. How representative is vibration data used for risk assessments?
3. Do you have inadequate or ineffective controls in place?
4. Operator competency – how well does each operator use the tool?
5. Operator compliance – are your operators following your controls such as work sharing?
6. Is the right tool being used for the job?
7. Tool condition – is the tool fit for the job?
8. What is the condition of the tool accessory?
9. What material is being worked on?

To illustrate just how impactful these factors can be, the HSE has published data on the possible range of vibration magnitude for typical tool types within a document titled "Sources of Vibration Magnitude Data"<sup>1</sup>. The data gathered from tool measurements carried out by the HSE laboratories in the field is tabulated showing the lower (10%) and upper (90%) percentile of vibration magnitudes measured.

The graphic shows, for three different tool types, the possible range of vibration magnitudes generated by the tools during normal or appropriate use of those tools. The impact drill varied from  $5\text{m/s}^2$  to  $16\text{m/s}^2$  depending on its use, while the manufacturer declared its emission at  $11\text{m/s}^2$  and the mean of the HSE measurements was  $10\text{m/s}^2$ .

The “so what” in this data is: if you have an employee operating at the bottom of the range of the chipping hammer’s measurements then they can **legally work for 2 hours** at this level. However, if their work or skill results in the level at the top of the range then they can only **legally work for 18 minutes**.



You may look at the data and ask are manufacturers inappropriately declaring the data for their tools? The answer is no, as they have specific conditions under which their measurements must be taken, methods using laboratory conditions to eliminate variables such as operator techniques. This approach means all tool manufacturers will take measurements in a consistent manner, allowing the declared data to be used to compare against different manufacturers. However, generally, and specifically for the type of tools used in construction, the **manufacturer’s declared vibration magnitude is NOT suitable for informing a HAV risk assessment**.

## 5. How Good Are Your Risk Assessments?

Even with the right training, it’s hard to know just how closely everyone is following health and safety protocols. Individuals taking unanticipated risks, and unchecked exposure could damage your organisation down the line.

The challenge is how to accurately measure the problem. Manual methods, whether they be estimated tool time use or operator trigger time, can only ever be that - estimations. With considerable margins of uncertainty, operators deemed low risk could be exceeding exposure limits on a regular basis.

*For example:* The graphic below shows the results of a study conducted at a utility company to understand the effectiveness of a generic risk assessment of HAV exposure.

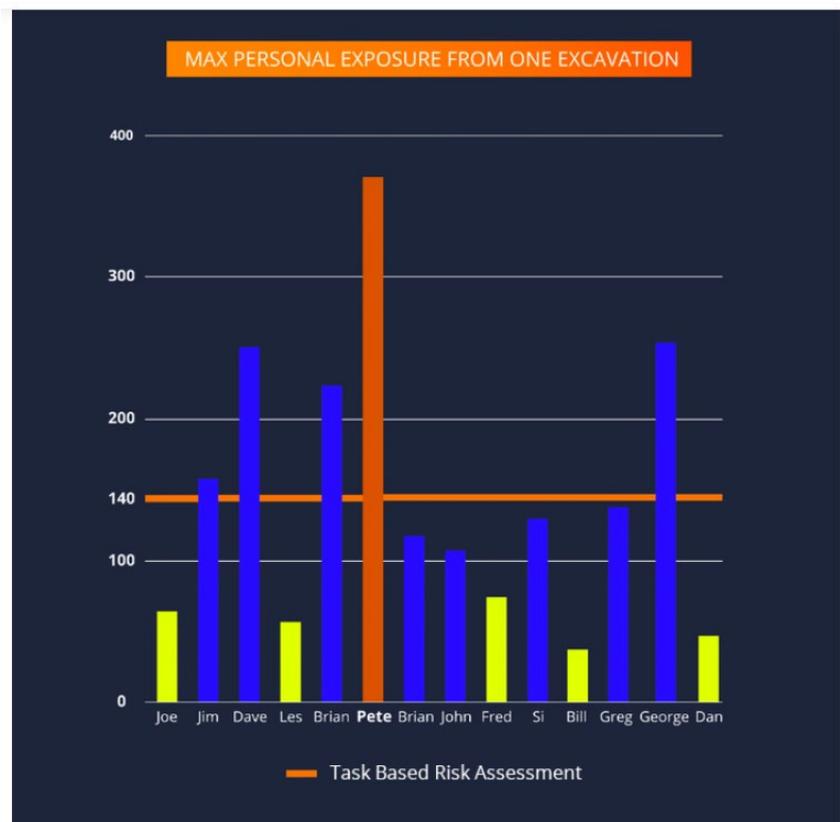
Several 2 and 3 worker teams were tasked with digging the same sized hole in the same type of road, with the same tool and with a typical control requiring the workers to work-share. Detailed measurements of trigger time and tool vibration magnitude were taken, with the task being

repeated over ten times. The collected data was used to establish an average time of exposure and average vibration magnitude during exposure. With this data we established a task-based risk assessment that put the maximum individual exposure for a 2-worker team as 140 points, or less than the HSE EAV of 100 points if working in a 3-worker team.

However, the reality for the individuals in this exercise i.e., their individual measured maximum exposure from any one hole, is shown in the graphic. Five out of 14 individuals exceeded the risk assessment level and Pete approached the legal limit of exposure. Studying video footage from the exercise showed that Pete did not follow the work sharing control and his technique was such that he angled the tool into his body, resulting in less of the tool's energy being transferred into the road surface. This slowed the breaking process but also resulted in more of the tool's energy being transferred into his hands and body. A simple act with potentially grave consequences.

The utility company was astonished to see the results of their data; the potential result being that Pete is at high risk of developing HAVS, potentially within 6 years, if he continues to be exposed at this level which he experienced in just one excavation.

The effort and expense undertaken to carry out such a detailed risk assessment led to one stark conclusion: the task-based risk assessment did not reflect the workers' risk reality.



## 6. Do You Know How Competent Your Workers Are?

The following example is taken from an HSE published business case.<sup>vi</sup>

A manufacturer of vibration-reduced pneumatic paving breakers made vibration measurements in real working conditions and found that the vibration exposures were highly dependent on the way the machines were operated.

It was found that untrained operators were exposed to vibration levels of about 9 m/s<sup>2</sup> and this was due to those operators not switching off the breaker before lifting it, therefore increasing the vibration. By further training the operators to stop the machine before moving it, as well as improving their technique whilst using the breaker, the average vibration was reduced to approximately 5.5 m/s<sup>2</sup>.

In taking these steps, the trigger time to reach Exposure Action Value increased from 35 minutes to 100 minutes.

Not only did the training produce substantial reductions in the vibration exposures, but it also improved efficiency, leading to 17 times more output per day, without increasing vibration exposures.

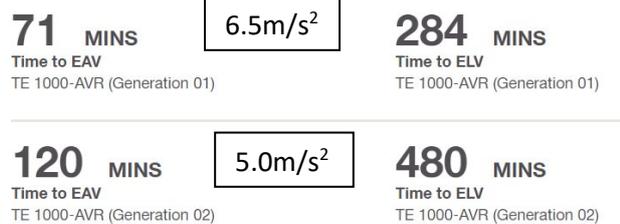
Through proper training, safe time on the tool was increased from 35 minutes to 100 minutes while operational output per day increased by a factor of 17.

More effective management of HAV exposure has a direct additional benefit of improved productivity.

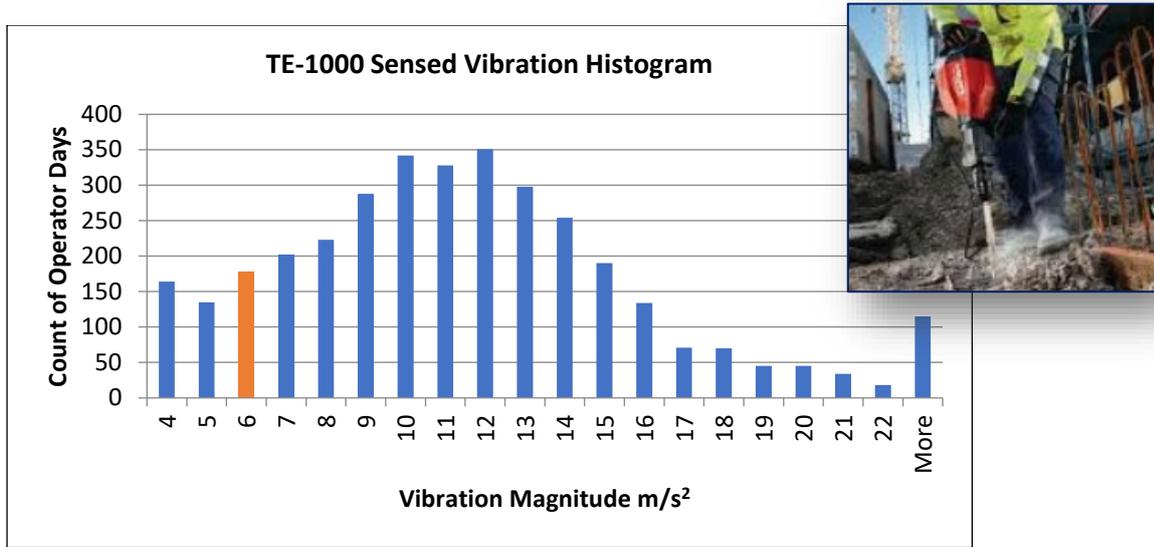
## 7. Top Tools Used in Construction

The following histograms have been developed from a large data set within Reactec’s data base. Analysis of such a large data set allows a third dimension to be added to the data published by the HSE as shown in Section 4. Reactec’s real use field data shows how frequently vibration levels from specific tools occurs i.e., at what level is the tool most likely to operate.

For instance, in the HSE Appendix C, a breaker is said to have a potential vibration magnitude range from 7 to 18m/s<sup>2</sup>. One such tool - the TE-1000 from Hilti - was measured in the field by Reactec using ISO compliant instrumentation and was found to have an average vibration magnitude of 11.9m/s<sup>2</sup> while Hilti declare the tool as 6.5m/s<sup>2</sup> or 5m/s<sup>2</sup> depending on whether a first- or second-generation tool is being used<sup>vii</sup>.



The histogram of real use data from Reactec, having 2,850 hours of records of the tool use, shows how unsuitable the manufacturer’s data is to quantify the true exposure risk of worker.



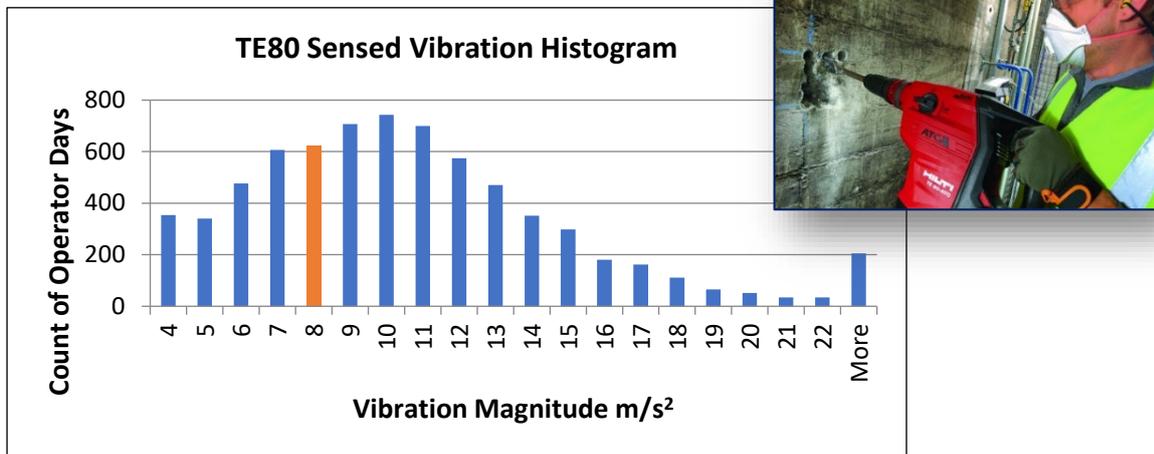
Below shows similar data for another three common construction tools:

**Impact Drill:** 4,811 trigger hours of data

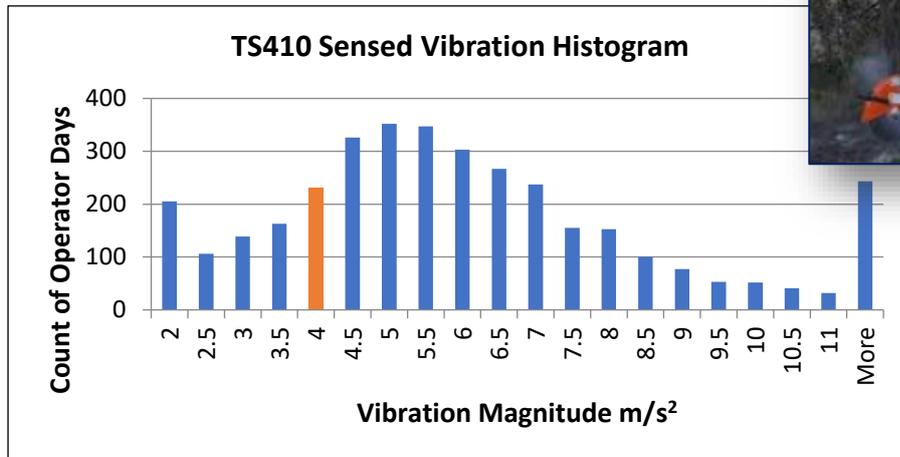
Manufacturer declared: 7.5 m/s<sup>2</sup>

Weighted average: 11.2m/s<sup>2</sup>

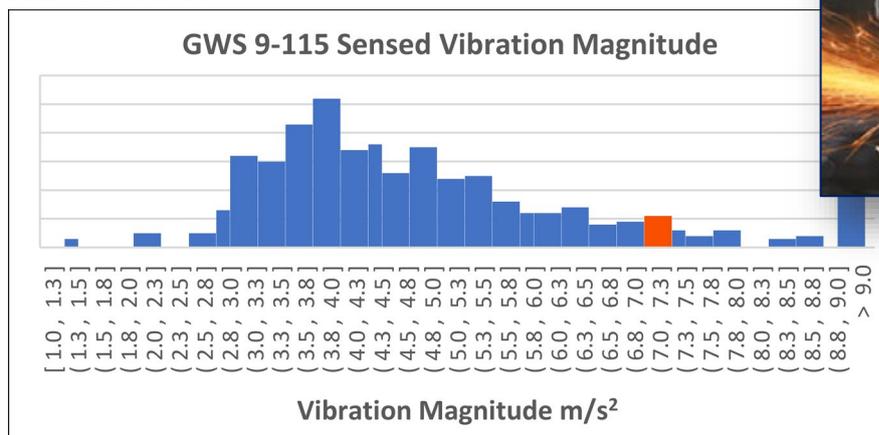
HSE: 7 to 13m/s<sup>2</sup>



**Cut Off Saw:** 1,755 trigger hours of data  
 Manufacturer declared: 3.9 m/s<sup>2</sup>  
 Weighted average: 6.1m/s<sup>2</sup>  
 HSE: 5 to 14m/s<sup>2</sup>



**Grinder:** 1,728 trigger hours of data  
 Manufacturer declared: 7.5 m/s<sup>2</sup>  
 Weighted average: 4.9m/s<sup>2</sup>  
 HSE: 3 to 10m/s<sup>2</sup>



## 8. Hand-Arm Vibration Prevention

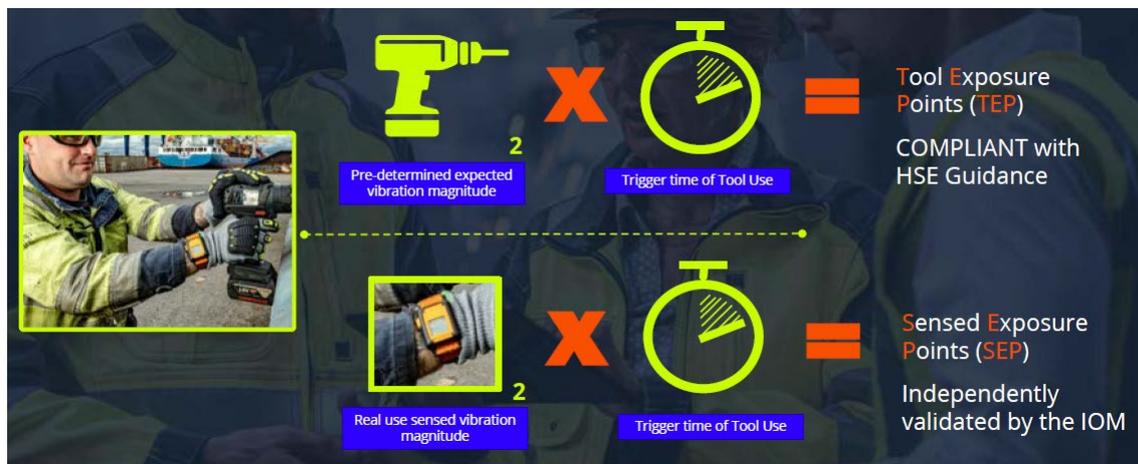
Exposure to this type of vibration energy through the hand is known to cause irreversible damage to nerves, blood vessels, muscles, and bones. Once the damage is done, it is permanent. However, HAVS is preventable and Reactec believe that, with the vast number of variables at play, only through the collection of real use data will you be adequately informed to properly prevent your employees developing this debilitating disease.

It is our view that risks can be better managed when they are measured. For over 20 years, we have seen our clients easily and quickly achieve compliance, whilst gaining absolute control of their operations and improve their productivity.

HAVWEAR from Reactec is a wearable device giving unique insight into individual exposure levels to Hand-Arm Vibration and personal alarms to directly influence behaviour.

More powerfully, combining the HAVWEAR with automatic data capture to the rich environment of the Reactec Analytics, all levels of management have enabling information at their fingertips, to effectively manage the HAV exposure of their workforce.

HAVWEAR provides two concurrent assessments of exposure to HAV – Tool Exposure Points (TEP) and Sensed Exposure Points (SEP) based on the measured trigger time of tool use and two alternate sources of vibration magnitude:



TEP is fully compliant with HSE Guidance, using a pre-defined expected vibration magnitude for the tool. Several sources can be used for this data including: a specific tool measurement carried out by an appropriately trained technician; using the HSE recommended 75<sup>th</sup> percentile of Appendix C; or applying a safety factor to manufacturer declared vibration magnitude.

SEP is based on a real use vibration magnitude measurement taken by a triaxial accelerometer within the device. Reactec use algorithms developed using the specialised equipment within the laboratories of NIOSH in the US, to compensate for the transmission through the hand and therefore approximate the real use vibration magnitude at the grip point of the hand.

Comparing the real use data of SEP with the expected data of TEP gives unprecedented insight to factors such as tool wear and worker technique.

The HAVWEAR watch informs the wearer of their exposure by calculating and displaying, in real-time, their HAV risk assessment exposure points or the time remaining for safe use of the tool. Sound and vibration alerts inform the wearer if their personalised exposure thresholds have been exceeded.

## 9. Assessment/Monitoring vs Measuring: Approximately Right or Exactly Wrong

Significant confusion exists in the marketplace on what constitutes an appropriate measurement of HAV exposure. It should always be remembered that the legal requirement is to carry out **suitable and sufficient assessments** of exposure to HAV based on **the time of exposure and probable vibration magnitude**.

Obviously, and advised by the HSE in their L140 guidance, it is not always necessary to carry out a “measurement” of exposure to HAV. An ISO standard (ISO5349-2) exists for the “measurement” of exposure to HAV. This standard requires the use of an ISO8041 compliant instrument to take a measurement with an accelerometer firmly attached directly to the grip point of the tool within 10mm of the hand. The specific requirements of using these standards results in the need for a trained technician and for the measurements to be taken for very short periods of typically 1 minute. At best, some organisations may take three such measurements for the tool being used for one purpose, once per year.

Again, rather obviously, the data obtained from an ISO compliant measurement is almost inevitably not accurate for the real and future use of that tool.

Hence “measurement” of HAV exposure is advised to be generally not necessary.

Several technologies have been developed with a different purpose to that of the ISO standards referenced above. These technologies are aimed at “monitoring” a worker’s full working day, in an unsupervised manner, accumulating data from all the HAV exposure activities they undertake across their working day. No device which can provide such data meets the detailed requirements of ISO5349-1(2) and ISO8041-1.

However, the HSE accepts the benefits of monitoring technologies to help inform risk assessments, to assess the effectiveness of controls and indeed to act as a control for high-risk employees. To use any monitoring technology, the HSE simply ask that the device captures the time of use of the tool and that the vibration magnitude data be representative.

## 10. Is HAVWEAR SEP Representative?

The Institute of Occupational Medicine (IOM) - a globally recognised organisation focused on workplace health and safety - completed an in-depth, independent review of HAVWEAR.

The purpose of the IOM report was to study the suitability of the vibration magnitude data determined by HAVWEAR and whether the resulting Sensed Exposure Points (SEP) data is appropriate as a Risk Assessment / Risk Management tool.

The study was conducted in real tool use environments including Grounds Maintenance, Road Maintenance, Forestry, Metal Work, Workshop and Garage environments.

The results speak for themselves:

- **Suitable risk assessments:** The IOM found that the data generated by the HAVWEAR system provides a useful source of information to inform a suitable and sufficient risk assessment as the sensed vibration data is comparable with data collected by conventional means.
- **Risk reduction:** The HAVWEAR information gathered on a regular basis does inform the development of risk reduction control measures and can be used to identify trends in risk reduction.
- **Greater accuracy:** The IOM found that HAVWEAR may be more accurate than the use of trigger times and manufacturer’s data or other data sources compiled for a limited range of tool activity.

[Access the full IOM report here](#)

## 11. Reactec Analytics

Reactec’s Analytics software is the heart of Reactec’s ecosystem and will help you turn exposure data into actionable intelligence. The intuitive analytics software is securely hosted on a robust and fully GDPR compliant cloud platform.

With a clearer understanding of the source and levels of exposure, the Reactec Analytics plays a central role in providing the most representative exposure assessment of risks and insight to enable employers to prioritise and mitigate risks – proactively at all levels and stages.

The platform allows you to easily share reports and alerts with all stakeholders via readily accessible online reports, which can also be auto emailed. Reports provide granular detail on tasks and tool usage such as:

- Highest risk tool by usage
- Highest risk operatives – average daily exposure
- Worker activity
- Operator competency – tool utilisation
- Tool condition – tool performance

Reactec Analytics provides clear and pertinent information to help prioritise efforts on the hierarchy of controls. It can support a company's continual risk reduction plan by allowing managers to add intervention notes, as well as log and track control measures against targets.

- **Record and monitor control measure success:** log applied control measures and track their effectiveness in reducing risk by the impact on workforce average daily HAV exposure.
- **Log and authenticate interventions:** log intervention notes allocated to individual employees and electronically sign to acknowledge.

## 12. Tool Use Training

Assigning a RASOR device will allow a roaming employee or supervisor to gather live HAV data from colleagues up to 30m away. This empowers supervisors to provide immediate interventions in the field to HAV alerts.

The RASOR also includes a tool training app which provides immediate feedback of risk levels during actual tool use. This allows managers/supervisors to train operators on their technique, grip, force, pressure etc, to help lessen their risk and improve productivity.



## 13. What Does the Industry Have to Say?



We have been able to apply resources and measures more effectively to address our vibration risk. One of the key benefits of introducing a wearable monitor was that it raised awareness of HAVS at source, while also providing a good investment in the long-term health of employees. It is testament to Murphy proactively investing in HAVS technology that we have been given a bursary from our insurance company. Ultimately, the introduction of HAVS wrist monitoring is an investment in the long-term health of employees. They can react in real time before thresholds are breached.

**J. Murphy & Sons**

Deploying Reactec HAVWEAR is recognition that compliance to the directive is not enough. Continuous digital monitoring goes beyond the directive and establishes a useable management tool to raise awareness and educate tool users.

"The Reactec Analytics Platform delivers an auditable, tamper-proof system that shows each individual operator's exposure. This data can be recalled at any time, either from the platform or the archive, to show an operator's total exposure history. This would be irrefutable evidence more robustly protecting both the business and the client.



**Morgan Sindall**



It made an invisible risk tangible and helped us immediately refine and better design our measure of controls. Overall, we have already seen a drop in exposure since we deployed the Reactec Analytics Platform. What is incredibly useful is that the HAVWEAR also senses the wearer’s vibration exposure during actual tool use which we can view online in the Analytics reports. This extra layer of information allows us to check for unexpected levels of exposure. It may also help with future training of operators by assessing their technique which can have a huge impact on exposure levels.

**Sir Robert McAlpine**

One such example was, by having access to more accurate exposure data including real-time vibration magnitudes, we could assess which tools were best for particular applications. We consider Hilti breakers to be one of the best available and realised that, through the Reactec data, we could replace a Hilti breaker TE1000, used for a wide range of applications for a larger TE2000. Even though it was more expensive it helped complete work tasks quicker and exposed the operator to less exposure during use, so it was a win-win for worker health and project efficiency.



**Mitchellson**



Reactec’s technology is particularly beneficial if you have got high-risk tasks or workers exposed to multiple vibration sources in the same day. If employers need confidence that their risk management measures are working effectively, in those situations it becomes too complex to do it manually.

**Laing O’Rourke**

## 14. Why You Should Invest in HAVWEAR: A Business Case

Collecting manual records of HAVS exposure is expensive and unproductive, costing around £400 per person per year. This is based on 5 minutes per worker per day to record, and 10 minutes per worker per week to administer. In addition, there is approximately 1 hour per manager per week checking these records.

The average liability claim per worker is £30,000 and HSE fines have increased threefold in recent years.

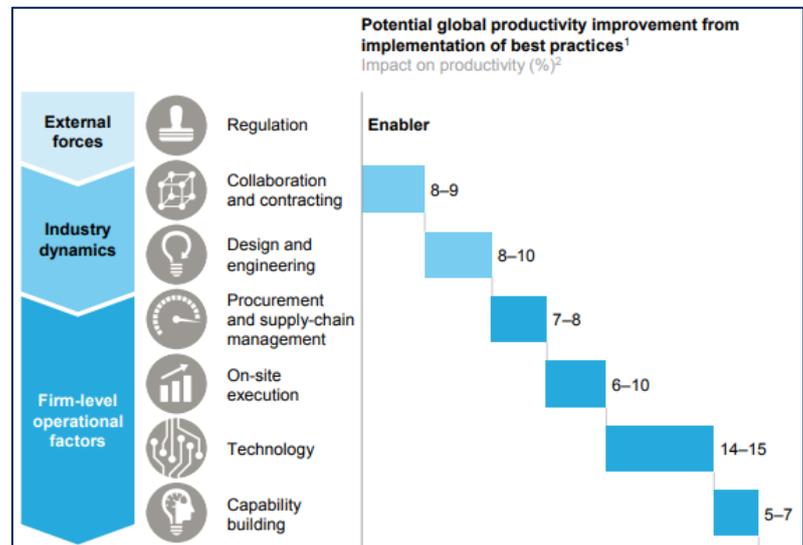


The cost per person of manual HAV exposure records is £1,152 compared to £451 when using HAVWEAR, across a three-year period. Investing in Reactec is lower cost and delivers data to help evidence compliance and drive productivity measures.

## 15. The Challenge to Construction

In 2017 McKinzie Global Institute published research<sup>viii</sup> challenging the construction sector's productivity and its adoption of technology as lagging other industry sectors.

"Despite being a key industry in countries across the world, accounting for 13% of the global GDP, construction has suffered for decades from remarkably poor productivity relative to other sectors. Other sectors have transformed their efficiency, boosted productivity, and embraced technology. For example, in manufacturing, lean principles and aggressive automation have been transformative. In comparison, much of construction has evolved at a glacial pace.



It is not easy to make assumptions about how productive a sector should be in comparison with others, but global labour-productivity growth in construction has averaged only 1 percent a year over the past two decades (and was flat in most advanced economies). This contrasts with growth of 2.8 percent in the world economy and 3.6 percent in manufacturing."

Reactec see the adoption of HAV management technology as an opportunity to not only prevent a debilitating workplace disease but give insight which can directly improve productivity.

## 16. 20 Years' Experience: Our Journey

Reactec began back in 2001 as a spin-out from The University of Edinburgh.

In the early days as a consultancy, Reactec assembled a team of experts to specialise in understanding the impact of vibration on employees exposed to vibration as part of their everyday work.

That research eventually helped Reactec to develop the first tool for monitoring workers' exposure to HAV. That tool, the HAVmeter, was released in 2008 as a tool-mounted device and became the precursor to the wrist-worn HAVWEAR that is offered today.

Having successfully deployed this technology to over 100,000 workers to date - giving employees real-time feedback of their risk level and employers informative data on what is happening in the field - Reactec has seen risk levels materially reduce, and its technology has measurably improved customer's ability to refine and implement more effective risk reduction controls.

Reactec has seen how more relevant, more representative data can help prevent injury and damage to worker health, and that's why it remains committed to its mission of engineering risk out of the workplace.

Reactec is doing that by working to create a comprehensive ecosystem of workplace wearables for the Connected Worker: a community of products, technology and resources designed to provide workers and employers with the best data available for monitoring risk in the workplace,

whether it be exposure to unsafe levels of vibration, noise or dust, proximity to dangerous tools, or the unique threats posed to lone workers.

Reactec began with a passion for understanding the impact of vibration on workers in heavy engineering and construction. That passion has grown steadily into an ambitious, important goal of enabling a workplace designed to prevent injury and damage to worker health, wherever, and however it may occur.



## 17. Reactec Credentials

With 20 years of experience behind us, over 100,000 UK operators are now supported by the Reactec system, helping over 1000 customers to manage and prevent workplace health risks. Our clients include Balfour Beatty, Morgan Sindall, BAM, Ferrovial, Network Rail, British Airways, BAE and over 100 Local Authorities.

All data management is GDPR compliant and is stored and transferred between devices in a robust and resilient way with the very latest encryption technologies. Both internally and with external authorities, we robustly and continuously validate the resilience and reliability of what we do.



Microsoft  
Partner

Application Development  
Application Integration

## 18. References

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<sup>i</sup> [HSE Report – Construction Statistics, Great Britain 2021](#)

<sup>ii</sup> [Building Safety Group reports 33% increase in HAV breaches on construction sites](#)

<sup>iii</sup> [Loughborough University – Institute of Civil Engineering – Cost of Occupational Ill Health in Construction](#)

<sup>iv</sup> [The Hidden Threat: why industry needs to go above and beyond in the fight against HAVS](#)

<sup>v</sup> [HSE – Sources of Vibration Magnitudes App3](#)

<sup>vi</sup> <https://www.hse.gov.uk/vibration/hav/campaign/construction/operatortraining.htm>

<sup>vii</sup> <https://www.hilti.co.uk/content/hilti/E1/GB/en/products/drilling-and-demolition/breakers/world-of-breakers/avr-for-breakers.html#overlay/close>

<sup>viii</sup> [McKinsey Global Institute – Reinventing construction through a productivity revolution. February 27, 2017](#)