Technical Paper

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Accidents caused by poor ergonomics

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Most people think of ergonomics as the science of fitting the workplace to suit the human, so that strains can be avoided. This is, of course, an important part of ergonomics, but what I want to consider here is to show how poor ergonomics can contribute to the cause of an accident. To do that I'm going to look at different accidents where poor ergonomics have been a factor.

In general, we standardise on colour codes, directions and so on. So a green button starts a process, a red one stops it, rotating a knob clockwise increases the process value, etc. Be very careful of ever deviating from these conventions. But there are other areas where we have varying practices.

For many years, cars of British origin had the indicator switch on the right side of the steering column and the wipers on the left. With cars of Continental origin, it was vice-versa. So those of us who started on British cars when then driving, say a Renault, would occasionally indicate our intention to turn left by turning on the wipers. This may not be that critical, but the following examples are much more serious. And in the case of the Kegworth air crash, the change from left to right with different models was one of the factors.

Note that in some of these examples, poor ergonomics did not directly cause the accident, but meant that operators (or pilots) took the wrong action to correct the initial cause

Example 1 DC8 Ground spoiler control

On larger aircraft, there are spoilers which are sections of the wing's top surface that hinge up to disrupt the airflow over the wing. On some aircraft these a primary flight controls, so don't get upset if you see them operating in flight from your Airbus window. However, on the DC8 they were purely for ground use and they would be fully deployed to dump the lift on landing as the weight was transferred to the undercarriage.

On the DC8 they could be operated either manually or automatically, but the lever to deploy them manually was the same lever that was used to arm their automatic mode. You lifted it to arm the automatic deployment and slid it to deploy them manually. On the approach, the pilot would lift the lever to arm them. If he slid the same lever, he would dump the lift and, at low level, this means that the aircraft crashes. So let's recap: Lift the lever to arm the spoilers on every approach; slide the lever to crash the aircraft. This was not hypothetical; it actually happened at Toronto on 5th July 1970 when the spoilers were deployed at 60 ft. 109 people were killed.

The other factor was the different practices; some pilots armed the spoilers, some deployed them manually. And when you mix the two types of pilot, as occurred here, with a lever with major ergonomic problems, disaster happens

Example 2 Three Mile Island

This was a partial melt-down of a nuclear reactor on 28th March 1979

It involved a relatively minor malfunction in the secondary cooling circuit which caused the temperature in the primary coolant to rise. This in turn caused the reactor to shut down automatically. At this point a relief valve failed to close, but instrumentation did not reveal the fact, and so much of the primary coolant was vented that the heat in the reactor core was not removed. The operators were unable to diagnose or respond properly to the unplanned automatic shutdown of the reactor. Deficient control room instrumentation and inadequate emergency response training proved to be root causes of the accident

During attempts to clean filters, a regular process, a check valve had stuck open and water forced its way into an instrument air line. A sequence of events then caused an emergency shutdown, and venting; because another valve had stuck open, coolant water escaped resulting in the partial melt-down.

There were several control panel interface problems which resulted in the correct action not being taken. The first was not strictly ergonomic; the light indicating the position of the valve (which stuck) did not do that; it indicated the power to the solenoid for the valve. During normal operation, power to the valve's solenoid and its position are the same, but if the valve decides to stick open, then this is no longer true. Operators were used to the light indicating the valve's status, assumed that the valve was closed and no remedial action was taken until the new shift recognised the problem. Until then coolant water had continued to vent.

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The next problem was a temperature indicator which, if consulted, would have indicated that the valve was still open. It was at the back of the desk, effectively out of sight and was not consulted. The fact that the operators were not trained on its use was a factor.

As the cooling water flow decreased, temperatures increased resulting in steam pockets replacing the coolant in the pressuriser; the pressuriser water level indicators showed it was rising whereas it was partially steam.

Because there was no core water level indicator, the operators judged its water level solely on the pressuriser water level. And as this level indicator was high, they assumed the core was safely covered.

And because the water indicators for the pressuriser showed its level to be increasing, the operators reduced the flow of cooling water to avoid overfilling. Hence the runaway situation and the resultant partial melt-down.

So, in summary, we had instrumentation which did not represent the true situation and other instrumentation which could have helped was poorly sited and operators had had no training on its use.

Example 3 Kegworth air crash.

This occurred on 8th January 1989 when a Boeing 737-400 did not quite make the runway at East Midlands Airport, to where it had diverted. The flight from Heathrow to Belfast suffered a blade detachment in the port (left) engine, resulting in noise, vibration and smoke in the cabin. The pilots shut down what they thought to be the failed engine but in fact they had chosen the wrong one.

The first factor was that of the location of the air conditioning packs, which on previous models of the 737 had been different. The presence of smoke in the cabin led the pilots to assume that the starboard engine had failed because that was the one that provided air to the cabin in earlier models; but not on the 737-400. And when the smoke stopped after shutting down the starboard engine, they assumed that they had picked the correct engine, but it was due to them also reverting to manual throttle.

The ergonomic factor was that of the vibration meters. Correct reference to them would have told the pilots which engine had failed. On earlier aircraft, vibration meters had a reputation of being unreliable and were often ignored. On the 737-400, they were in fact very reliable, but the pilots did not know this.

On previous aircraft, the needle was on the inside as is common on most types of meter. On the 737-400, the meter comprised a series of LEDs which went round the outside of the dial. And the meters were very small. So, we have meters which were small and worked in a way opposite to that which pilots were used and were required to be read in a situation where there is a lot of vibration. They got it wrong.

To summarise, instrumentation which would have enabled the pilots to identify the correct engine to shut down was small, worked in a different way to which they were used and was habitually ignored because of previous unreliability. And there were contrary cues due to the fact that cabin smoke stopped when they took (the incorrect) action.

Example 4 MTI Welding Technologies Ltd.

This company had acquired a welding machine which previously had a robot inside an interlocked cage. The machine no longer had the robot and had been modified to allow manual operation. This included providing buttons close to a holding fixture which had hydraulic clamps. On 23rd August 2013, the operator pressed the wrong button and the clamp closed on his hand, causing the loss of two fingers.

Now, there were a string of faults relating to ineffective interlocks and other factors, but the arrangement of the buttons poses ergonomic questions:

- Did critical buttons have tactile feedback, say by having a raised ring around them? This enables you to know that you are pressing a certain button even if you are not looking at it.
- Were buttons grouped in a high risk way? Buttons which cause actions which pose a risk should be grouped away from buttons which do not.

Most of the data in the public domain or ergonomic contributions to accidents are on ships, aircraft and chemical plant, but the last example shows that the types of equipment with which most of us are involved also require careful consideration of the ergonomics of controls in order to reduce risk.