

## FOCUS

### Basic Human Factors and Nondestructive Testing

by Anas Hassan El Rais

It is important to think about human factors and how they are defined to be able to better understand their effect on inspection results. This definition will affect how an inspector decides which technique should be used to get the best results from nondestructive testing (NDT).

In engineering, human factors normally refer to the study of human capabilities and limitations in the workplace (CAA, 1998). In the past, human factors were referred to mainly in visual testing techniques and the study of human eyes.

Even so, magnetic particle and liquid penetrant testing depend on visual interpretation of the indications developed on the surface of the inspected item, and the only instance human factors have been referred to is when the inspection result is affected by inspector motivation, capabilities, and light conditions at the inspection surface.

In the aviation industry, a study of aircraft accidents was conducted in 1940. It was found that 70% of accidents were attributable to human performance.



Figure 1. Aloha Airlines Flight 243.



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When this study was done again after 35 years, it was found that, surprisingly, there had been no reduction in this percentage, and 12% of that was related to maintenance errors, which included NDT inspection (Sears, 1993).

The accident involving Aloha Airlines Flight 243 on 28 April 1988 involved a 5.5 m (18 ft) section of the upper cabin structure suddenly being ripped away in flight due to structural failure (Figure 1). The jet involved in this accident had been examined, as required by U.S. regulation, by two engineering inspectors. One inspector had 22 years of experience and the other, the chief inspector, had 33 years' experience. Neither found any cracks during the inspection. Accident analysis determined there were over 240 cracks in the skin of the aircraft at the time of the inspection. The ensuing investigation identified many human factor related problems leading to the failed inspection (NTSB, 1989).

After that time, a serious consideration of all human factors was taken into account in the aviation field regarding inspector personnel.

When talking about human factors, the following attributes should be included.

- Human physiology (including health, age, and human body function under different conditions).



Figure 2. SHEL model.

- Psychology (including perception, cognition, memory, social interaction, error, and so on).
- Workplace design.
- Environmental condition.
- Human-machine interface.
- Anthropometrics (the study of measurement of the size and proportions of the human body) (CAA, 2003).
- S is for software (inspection procedures, manuals, standards, checklist layout, and so on).
- H is for hardware (tools and equipment, physical structure of inspected parts, positioning, and operating sense of controls and instruments).
- E is for environment, that is, the physical environment surrounding the inspector (like temperature, noise, and height), and the work environment, including the management structure, work pattern, and so on.
- L is for liveware (the inspector and the people around him or her).

Human factors concentrate on the interface between the human (L) in the center box and the other elements of the SHEL model.

- S: misinterpretation of inspection procedure, badly written instructions, a poorly designed checklist, difficult to use computer software, and non-user friendly inspection equipment.
- H: not enough tools, inappropriate equipment, poor design of the item for inspection.
- E: uncomfortable workplace, inadequate inspection area, extreme high or low temperature, excessive noise, fumes.
- L: relationship with other people, shortage of manpower, lack of supervision and support (Doharty, 1999).

From the accident investigation and using the SHEL model, the following was found.

- There was a shortage of staff.
- Time pressure existed.
- All errors occurred at night.
- Shift or task handover was involved.
- They all involved a supervisor doing longhand on a task (using his power to demand faster inspection or more production due to a tight schedule or to demand the changing of some indication finding due to a lack of spare parts and so on).
- There was an element of “can do” attitude.
- Interruption of inspection occurred.
- There was failure to use the approved procedure.
- Manuals and/or instructions were confusing.
- There was inadequate pre-planning, equipment, or spares (Sears, 1993).

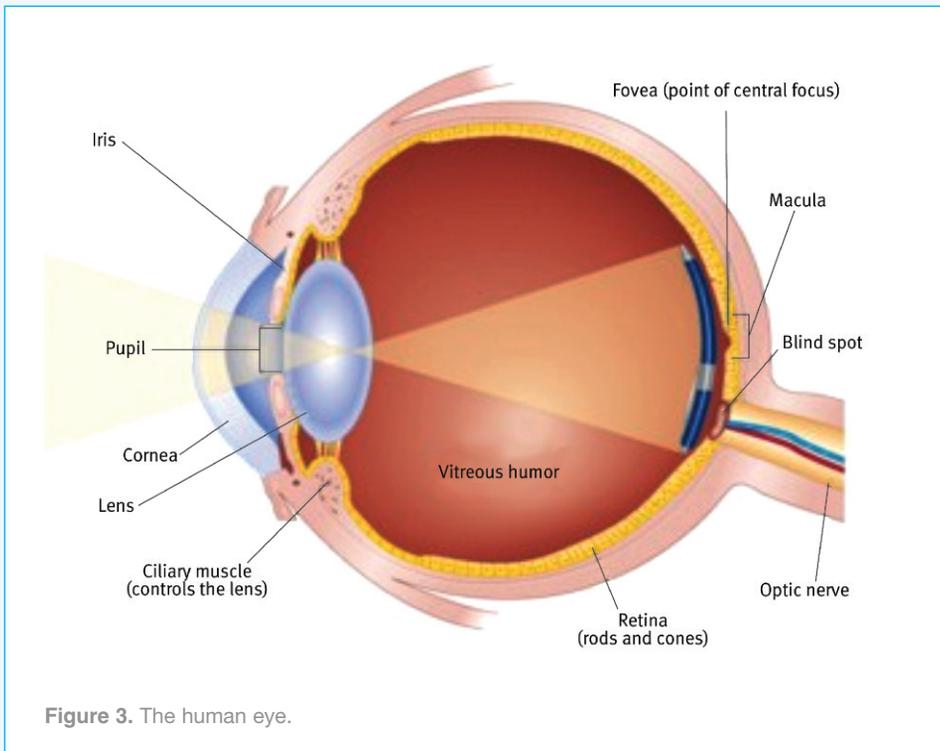
From these findings, NDT personnel should have proper knowledge of human factors that affect their limitations and capabilities. These factors should be included in their training and understood when performing inspections (CAA, 2002).

## Human Performance and Limitations

The following is a description of how the senses and brain function under different conditions.

### Vision

Figure 3 shows parts of the eye. The cornea acts as a fixed focusing device, with between 70 to 80% of total focus ability. The iris controls the amount of light entering the eye by varying the size of the pupil. The shape of the lens is changed by the ciliary muscle, resulting in the final focusing adjustment. This process is called accommodation. The retina consists of light sensitive cells of two types, cones and rods. Cones function in good light, are capable of detecting fine details, and are color sensitive. Rods cannot detect colors and they are poor at distinguishing fine details, but they are good at detecting movement and sensitive at lower light levels. The tiny area known as the fovea is



**Figure 3.** The human eye.

responsible for the central, sharpest vision. A healthy fovea is key for reading, driving, and other activities that require the ability to see detail. It has a very high concentration of cones (photoreceptors responsible for color vision), allowing one to appreciate colors. The blind spot area has no photosensitive cells at all. An image that falls in this area cannot be seen.

The following factors affect sight clarity.

- Physical imperfection in one or both eyes, temporary eye disease, aging, exhaustion, fatigue, and fever.
- Influence of ingested foreign substances such as: drugs, medication, alcohol, and cigarettes.
- Environmental factors: the amount of light, clarity of air (dust and mist), fumes, gasses, and extreme temperature and oxygen levels.
- Factors associated with the object: size and contours, contrast with surrounding areas, relevant motion of the object, distance of the object from the viewer, and the angle of the object from the viewer.

All these factors affect how long the inspector can do the inspection and the

number of items the inspector can inspect before the ciliary muscles become fatigued. With this ability to focus on near items weakened, even if the inspector has received satisfactory eye exams (the visual acuity test) as scheduled, he or she will fail to concentrate on near items and see them clearly.

In some conditions where viewing accessibility is limited, a discontinuity indication image may fall out of the fovea area. The inspector may not notice the discontinuity image because it is out of the area of focused vision. It may fall in the blind spot, especially if he/she cannot look at the item with both eyes. If this is the case the inspector may not see it at all (Campbell, 1999).

In addition to the light intensity or direction of illumination to avoid glaring of the inspector's eyes (with either direct or a reflected light source), many human factors can make the test with visual-based techniques unreliable.

## Information Processing

The NDT inspector depends on his/her senses to gather information and this information is then processed by the brain. The limitations of the human information processing system should also be considered.

- Attention can be thought of as the concentration of mental effort on sensory or mental events.
- Perception can be defined as the organization, identification, and interpretation of sensory information in order to represent and understand the environment (Coon, 1983).
- Memory can be considered to be the storage and retention of information, which depends on three processes: registration, storage, and retrieval (Solso, 1995).
- Situational awareness is when the process of attention, perception, and judgment should result in awareness (Endsley 1988). The types of memory are as follows.
- Ultra short-term memory: its sensory stores can be up to 2 s (0.5 s for visual, 2 s for audio).
- Short-term memory: receives a proportion of the information received into sensory stores and allows one to store it long enough to use (from 5 to 20 s).
- Long-term memory: is used to store information that is not currently being used, like knowledge, personal experience, beliefs, social norms, values, motor programs, problem solving skills, and abilities.

The basic elements of human information processing have now been explored. It is important to appreciate that these elements have limitations, for example, doing complex jobs or multiple tasks (like climbing towers and doing an inspection at the same time). This results in divided attention, which will reduce information being used in the decision making process of the brain regarding discontinuity evaluation. This can also reduce awareness, which will affect judgment of indications.

Also, environmental conditions affect brain function. Temperature, oxygen levels, fumes and gasses, and unsafe environments that require extra care all contribute. Physical conditions like health, fitness, sickness, lack of sleep, influence of drugs /alcohol, and uncomfortable conditions all affect the psychological state of the inspectors (especially if he/she has claustrophobia or a fear of heights).

## Motivation and Stress

Motivation is what drives humans to do their job in the best way possible (and increase their mental performance).

Motivation is affected by the following.

- Level of arousal (which refers to a person's readiness for performing work. All factors that been discussed here contribute to the level of arousal for a person).
- Stress (can be social stress like financial problems, work load, or anything that can be considered as a psychological load on the inspector).

Both of these can be called stimulants, and the right amount of stimulant will result in optimum performance of a person. If there is a low level or very high level of stimulation, this may result in bad performance and can increase error (Hawkins, 1993).

Environmental, psychological, and physical conditions directly affect the level of stimulation by altering the level of arousal and stress. For each individual there is an optimum stimulation level. The team leader or supervisor (who is usually a Level III) should know each inspector's capabilities and limitations and provide him/her with the right amount of stimulation (arousal and stress) according to each job variable and condition. This requires a good knowledge and study of human factors in more detail. ●

## Author

**Anas Hassan El Rais:** Kuwait Airways, NDT workshop.

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