CHEMICAL ENGINEERING TRANSACTIONS

VOL. 111, 2024

A publication of AIDIC
The Italian Association
of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Valerio Cozzani, Bruno Fabiano, Genserik Reniers

ISBN 979-12-81206-11-3; **ISSN** 2283-9216

DOI: 10.3303/CET24111002

Human Factors and Interfaces Between Operators, Processes, and Plants in the Italian Technical Standards

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The Seveso III Directive 2012/18/EU imposes an obligation to take into due consideration the human factors and the interfaces between operators, processes, and plants, as part of the implementation of the Safety Management System. The national technical standard UNI 10616:2022 provides guidelines for implementing a safety management system, describing the procedures and technical tools useful for achieving specific objectives for the prevention of major accidents. In the standard, specific attention is paid to the human-machine interface (HMI). In close connection, it is considered the prevention and assessment of human error, a fundamental aspect of process safety management. A good, designed man-machine interface, in the control room of a process plant, allows you to minimize the possibility of operator error on the panel. The assessment of the possibility of human error must be used in the reliability analysis to verify if the procedures and operational controls adopted to improve the behavior of the operator or the instrumental controls give the best contribution to the safety of the system, preparing any corrective actions, also in terms of response times and emergency management of the operators, to reduce the possibility of accidents. The consideration of the human factors and the interfaces between operators, processes, and plants, in the correct implementation of a safety management system must be finally based on the functionality of the operator/process and operator/equipment interfaces to monitor the process, identify any anomalies or emergencies, and implement the planned intervention procedures.

1. Introduction

The Seveso III Directive 2012/18/EU, implemented in Italy by a legislative decree issued in 2015 - D.Lgs. 105/2015 (GU, 2015), is aimed at the prevention of major accidents involving dangerous substances. The D.Lgs. 105/2015 covers establishments where dangerous substances may be present (e.g. during processing or storage) in quantities exceeding certain thresholds. Operators of the establishments are obliged to take all necessary measures to prevent major accidents and to limit their consequences for human health and the environment. Depending on the amount of dangerous substances present, establishments are categorized into lower and upper tier, with different obligations. The requirements include, among others: notification of all concerned establishments; deploying a Major Accident Prevention Policy (MAPP) through the implementation of a Safety Management System for Prevention of Major Accidents (SMS-PMA); producing a Safety Report (SR) for upper-tier establishments; producing an Internal Emergency Plan (IEP) for upper tier establishments; providing information in case of accidents. Safety critical environments – e.g. chemical plants, oil and gas installations, and manufacturing sites (Seveso installations) - typically present a high degree of complexity, especially about the many causal interactions between technical, human, and organizational elements (Carra S. et al., 2020). As part of the implementation of the Safety Management System, the D.Lgs. 105/2015 imposes an obligation to take into due consideration the human factors and the interfaces between operators, processes, and plants. During the control activities, it is, in fact, necessary to verify that training programs and emergency drills are implemented to improve operator behavior. It is therefore fundamental that in the risk analysis the human factor and the conditions in which significant activities for the safety of the establishment must be carried

Paper Received: 1 March 2024; Revised: 11 May 2024; Accepted: 13 August 2024
Please cite this article as: Marrazzo R., Barone D., 2024, Human Factors and Interfaces Between Operators, Processes, and Plants in the Italian Technical Standards, Chemical Engineering Transactions, 111, 7-12 DOI:10.3303/CET24111002

out, giving particular attention to the interfaces between operators and processes in the phase of operational control of the plants.

2. Methods

2.1 Human factors in the control activities

In Italy, the SMS inspection is conducted to verify the suitability of the operator MAPP carrying out a planned and systematic examination of the systems being employed at the establishment, whether of a technical, organizational, or managerial nature.
The human factors and the interfaces between operators, processes, and plants are specific items of interest during the SMS control activity (APAT, 2003). The commission must:

- Verify that training and drill programs exist and are implemented to improve the behavior of the operator.
- Verify that the work shifts and the distribution of tasks have been established considering the psycho-physical stress to which the workers are subjected and that mechanisms are put in place to verify that the appropriate psycho-physical conditions are maintained.

Among the tools available to the inspection commission during the documentary verification, it is possible to verify directly, also by consulting the documentation relating to the health and safety at work analysis, the compliance with the indications relating to the maintenance of suitable psycho-physical conditions of the workers.
During the "on-site" visit, the possible insights concern interviews with the employees both on the management methods of ordinary and extraordinary management, maintenance, and emergency interventions and on their involvement in the drafting and/or revision of the operating instructions.

2.2 The consideration of the HMI and human error

The national technical standard UNI 10616:2022 (Establishments with major-accident hazard-Safety management systems-Guidelines on implementation of UNI 10617) (UNI, 2022) provides guidelines for implementing a safety management system, describing the procedures and technical tools useful for achieving specific objectives for the prevention of major accidents in industrial establishments (national technical standard UNI 10617:2019) (UNI, 2019).
It deals with most of the hazards and major accident risks present both in simple installations and in more complex installations where the process risks can be preponderantly compared to those connected to the simple loss of containment. The application of the contents of the standard must be commensurate with the specificities of the major accident hazards present in the establishment.
In the standard, specific attention is paid to the human-machine interface (HMI), meaning the system that separates the operator, who is using a machine (i.e. the control panel located in the control room in the case of the process industry), from the machine itself, while ensuring a constant connection.
Among the objectives for the continuous improvement of the SMS-PMA, which arise from the results of the identification of the hazards and the assessment of the risks of a major accident, the improvement of the quality of the interface between the operator and the plant/process can also be included (i.e. promptness, accuracy and punctuality in reporting anomalies).
In close connection with the HMI, it is considered the prevention and assessment of human error, a fundamental aspect of process safety management.
To strengthen and disseminate the culture of safety, the site manager should also operate through the implementation of a company policy that clearly and transparently identifies the criteria for distinguishing acceptable behavior from that which cannot be considered as such, distinguishing situations involving intentional misconduct from human errors attributable to organizational causes.
The awareness of the people who carry out a work activity in the plant, involved in activities relevant to safety, can be verified through knowledge of the potential negative consequences deriving from a failure to comply with the specified procedures, with consequent human error, and the possibility of even a major accident. The need to verify the system procedures, on the other hand, may derive from the possible analysis of the accidents and/or near misses connected to the ascertained human error.

3. Results

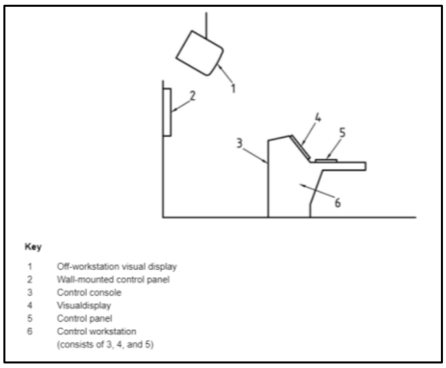
3.1 Design of the man-machine interface

The functionality of the interfaces between operators, process, and systems, consisting of the instrumentation located in the control room with related switchboards/monitors/buttons/optical and acoustic signaling panels, including wireless devices, must be ensured through the periodic check program of the active safety systems,

consisting of toxic and/or flammable gas detectors, fire detectors, alarms and blocks for critical operating parameters. The displays must report process variables, alarms, automatic blocks, recordings, as well as actuators for control actions on the process, such as starting/stopping pumps and compressors, opening/closing valves, and changing the regulation and operating parameters set.
The main functions of an interface are: Presentation of process information; Immediate implementation of control actions; Support for diagnosis, decision making, or planning.
Important elements of an interface are usability, making the HMI easy to use (reducing the possibility of errors), and accessibility by the panel operator. A correct design of the control, alarm, and automatic blocking systems must consider the analysis of the operator's tasks at the switchboard and the optimal ergonomic and specific environmental factors for the correct operation of the systems and plants. A good, designed man-machine interface, in the control room of a process plant, allows you to minimize the possibility of operator error on the panel, both during normal operating conditions and during emergencies, throughout the process life cycle, and in case of plant or process changes. These interfaces must be considered throughout the life cycle of the process and during plant or process changes. Control provisions must be adopted to manage any modifications/changes made, in conditions of necessity and under specific responsibility, to the switchboards or control equipment. These changes must not reduce the ergonomic design characteristics as well as they must take into account other project requirements, such as accessibility for maintenance or periodic checks.

3.2 Practical schemes of control rooms

The human factors are aspects of the ‘control room system’ of great importance to ensure that the operating crew can safely operate in all possible operating conditions using the tools available (Leitner R. et al., 2022).
To represent some practical examples of a control room (ISO, 1999), with the relative representation of process parameters and data on the screen of a DCS (Distributed Control System), the case of a typical process industry was investigated. In the following, schemes of correct design and distribution of spaces in a control room, with the relative minimum requirements are presented (T. Naito et al., 2011), about: illustrations of definitions associated with workstation visual display (Figure 1a) and visibility of large screens and the widths of corridors (Figure 1b); travel routes and collaborative operation among units (Figure 2).



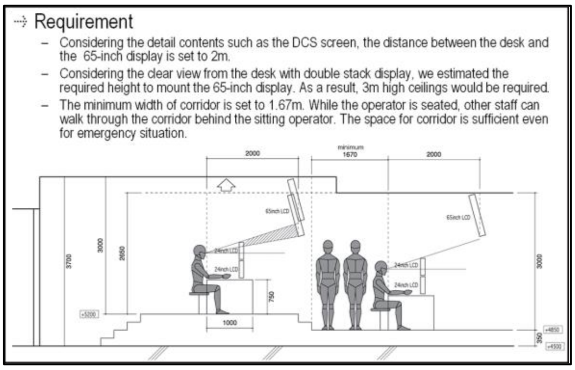


Figure 1a: Workstation visual display

Figure 1b: Visibility of large screens and the widths of corridors

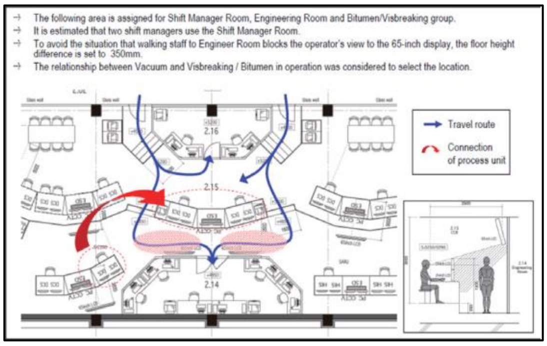


Figure 2: Travel routes and collaborative operation among units

The key points for the adequate representation of data and information on a screen, to improve the man-machine graphic interfaces (ANSI/ISA, 2015; B. Hollifield et al., 2008; Bullemer et al., 2008), are: color graphic representation (Figure 3); device status display (Figure 4a) and representation of data values (Figure 4b).

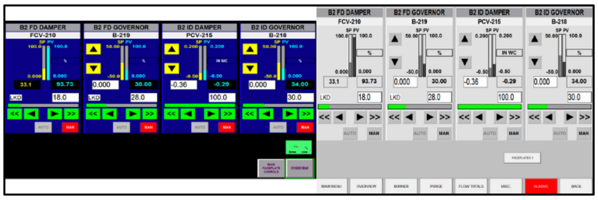
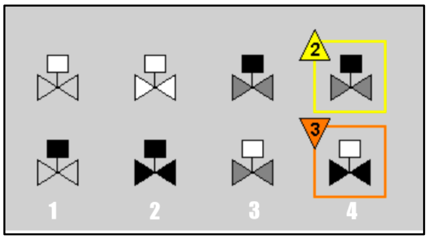


Figure 3: Colour graphic representation



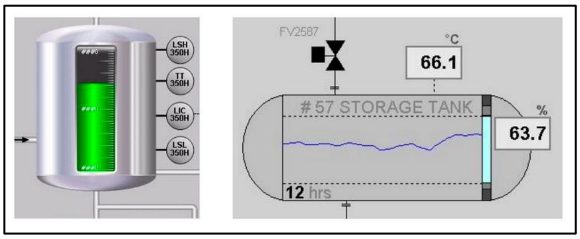


Figure 4a: Device status display *Figure 4b: Representation of data values*

Typical examples of control panels are finally given in the following, as taken from the DCS (Distributed Control System) in the control room (R. Kowalski et al., 2016):

- Figure 5: Plant overview
- Figure 6: Process Air Unit Section

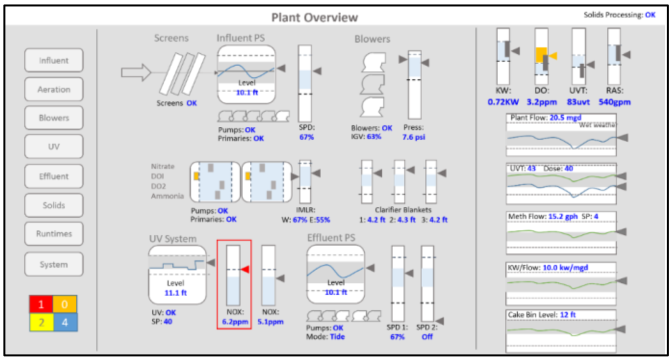


Figure 5: Plant overview

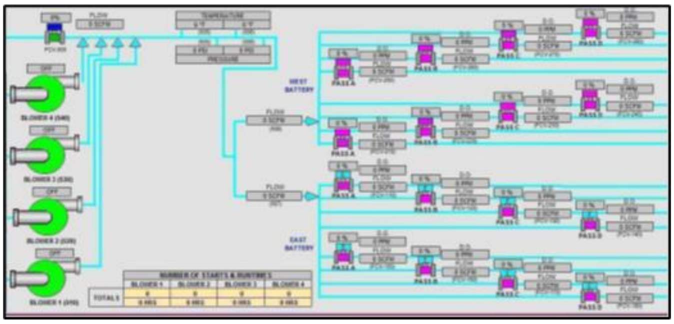


Figure 6: Process Air Unit Process

3.3 The prevention of human error in a process plant

Human behavior and performance are cited as causal factors in most accidents on process plants (Gambetti F. et al., 2012). The prevention of human error cannot ignore the knowledge of the potential negative consequences deriving from non-compliance with system procedures, with the possibility of a major accident. The assessment of the possibility of human error must be used in the reliability analysis to verify if the procedures and operational controls adopted to improve the behavior of the operator or the instrumental controls give the best contribution to the safety of the system.

The management by the workers of operating anomalies and/or emergency situations must be verified both in the actual conditions of occurrence of the events and in the simulations, to highlight any deficiencies connected to the human factor. The analysis of non-conformities relating to procedures, regulations, and operating instructions, detected as a result of inspections and/or accidents/near-accidents, generally linked to human error, can highlight deficiencies related to the behavior of people, the organization, and the work environment. Such deficiencies must be subject to appropriate corrective actions. Emergency drills are an important element of evaluation. They must be carried out according to a specific path that goes from planning to the critical analysis of the results, to prepare any corrective actions, also in terms of response times and emergency management of the operators to reduce the possibility of accidents related to human error.

4. Discussions

Based on the experience coming from the control activities conducted on some Seveso Italian establishments, in the following the discussion about examples and indications of particular or recurring situations are given about the consideration of the human factor in the SMS. The inspections must mainly be aimed at evaluating how much the company policy, and therefore the management system, require that human factors be taken into consideration in the conduct of the plant's activities, identifying any deficiencies. The aspects that must be taken into consideration are the organizational elements, the policy, and standards followed in the design and modification phases of the plants, the operating conditions, problems related to process management, and the working environments.

As regards the design phases of new processes or operating systems, it must be evident that the company policy or the standards adopted foresee the consideration of human factors. Indicative of the fact that human factors have been considered is, for example, the evidence of the analysis of the aspects related to the spaces available to the operators, the accessibility of the equipment, the correct construction and location of the control panels, and the use of prototypes and pilot plants also for the analysis and revision of the operator-plant interface.

At an operational level, information on work shifts must be acquired, for example by verifying that the available resources are distributed homogeneously, or in any case congruent with the workload, that the responsibilities have been identified and are commensurate with the experience and ability of the employee to identify the cause of an error which may also cause a major accident. It must be considered that stress and fatigue can be the result of incorrect personnel management. To identify a possible deficiency in this sense, one could, for example, analyze the criteria for allocating resources within the various operational areas, verifying whether both the physical and aptitude characteristics and the degree of experience, which must be possessed by the person responsible for the critical tasks of the plant, have been specified. It should be noted that major-risk establishments are generally single-error-proof, as it is also possible, for greater safety, to apply the “two-person control” system in the control room (R. D. Pedersen, 2017).

Regarding the operating procedures available to operators, the main aspects to consider are that these are clear and complete, written in a language that operators can understand, that their involvement in drafting and revision has been envisaged, and, most importantly, that these procedures provide employees with all the elements that enable them to identify and manage unforeseen situations. It should be remembered that the conditions of the working environment (lighting, temperature, exposure to noise, vibrations or chemical agents, etc.) also play a fundamental role in the employee's ability to interact with the systems and equipment. In this regard, it will be important to verify not so much that the values of these parameters are compatible with the activity carried out, but rather that national and international standards have been considered in the organization of the activity for the definition of optimal conditions in the workplace, providing, in the procedures, the analyses to establish what are the levels that allow to guarantee efficiency and safety. Finally, it should be considered that the system must provide for the periodic measurement of these parameters, to verify that the pre-established limits are respected, adopting compensatory measures in case it is not possible to respect the limit.

5. Conclusions

The consideration of the human factors and the interfaces between operators, processes, and plants, in the correct implementation of a safety management system must be based on:

- The detection of any problems at the interfaces, thanks to the feedback information coming from both the operators and the maintenance technicians.
- Monitoring the status of equipment and systems. Equipment must be visually inspected throughout the work shift. Reading the instruments placed on the equipment makes it possible to verify the reliability of the parameters reported by the remote-control systems in the control room. Furthermore, only through visual inspections, anomalous situations can be promptly identified. The information found must be recorded on special checklists which must be reviewed periodically by the supervisors so that what is reported is consistent with other data and that any anomalous situations are promptly resolved. In addition, it is good practice to have equipment checks integrated with normal operations.
- Adequate maintenance of work tools and equipment, including maintaining good conditions of cleanliness and order in the workplace (s.c. housekeeping).
- The use of correct labeling and signaling of containers, pipes, equipment, etc., also through appropriate color codes, to allow immediate knowledge of the risks and the identification of systems and components. Of specific importance, for example, are the methods for signaling automatic blocks to the switchboard, especially in the event of a bypass due to contingent plant requirements, with the relative operating management procedure.
- The maintenance of good lighting conditions, essential for identifying the equipment, reading the instruments, and identifying possible problems.
- The improvement of the reliability of the operators' performances. Particular attention should be paid to the procedures for handing over deliveries between shift managers and/or switchboard operators during shift changes in the plant and the control room, keeping adequate traces in the system documentation.
- The implementation of an effective system of operational controls based on procedures, permits, inspections, etc., that allows to prevent or promptly identify any human errors before they cause accidents.
- The functionality of the operator/process and operator/equipment interfaces make it easier for the operator to monitor the process, identify any anomalies or emergencies, and implement the foreseen intervention methods. Consider, for example, the problem of managing a maximum number of alarms on screen in the event of a generalized emergency, or the problem of assessing reliability/redundancy for critical alarms (in the event of a power failure).

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