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DESIGN OF A MAN-MACHINE INTERFACE FOR A PNEUMO - HYDRAULIC CONTROL CONSOLE FOR AN UNDERWATER PLATFORM

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1. Introduction

The control console is an all time attentive system, which is responsible to control and monitor various mechanical subsystems and equipments. The control console is required to ensure satisfactory exploitation and upkeep of these sub-systems and equipments, ensuring safety during all block related operations by means of appropriate interlocks. It is that component of system engineering which seeks to optimise the system by integrating the human performance necessary to operate, maintain, support and control the system in its intended operational environment.

2. Man Machine Interface requirements for control console

The Man Machine Interface is the most important part of the control console system. From the control console of the man machine interface, an operator has to control the various operations of different constituents related to the control console, blocks, shock absorption system and has to continuously monitor, display and transmit to external systems the important parameters, status indications and alarms related to these constituents.

2.1 Operational requirements

The major functions that are required to be performed by the control console include the following:

- Control and monitoring of the sub-systems such as Hydraulic system, Pneumatic system & Water system
- Conduct of Block Preparation for Normal Fly.
- Conduct of Block Preparation for Critical Fly.
- Returning related equipments, blocks and interrelated equipments to initial condition after satisfactory completion of the above operations.
- Periodic testing of the control console with required simulation facilities.
- Periodic operator drill by simulation
- Monitoring and incorporating safety functions
- To communicate with the related systems regarding the operational readiness and system status.
- Communication with the other systems and Main Panel.

3. Mission-Function Analysis

The modes of operation in which the control console is required to work are specified as - Normal, Critical, Maintenance, and Training.

Normal Mode – Mission Phases

1.0 Making the hydraulic system ready
2.0 Making the water system ready
3.0 Supply to the PH system pertaining to that individual block
4.0 Readiness of block for flying of the bird
5.0 Status of shock absorption system
6.0 Checking the initial position of PH system pertaining to that individual block
7.0 Completion of checking initial position
8.0 Checking of operability of PH system
9.0 Completion of operability of PH system
10.0 Opening of door
11.0 Unsealing of the door
12.0 Safe exit of bird
13.0 Closing the door
14.0 Hermetic sealing the door

2.0 Making the water system:
If pressure measured by pressure sensor is<1.5, then it indicates that platform is on surface and various water valves are switched ON. Else If (pressure sensor > 1.5) then Open specific water valves. Water pump should be in recirculatory mode. Assure filling of tanks and monitor pressure continuously. Check the level of the water tanks.
3.0 Supply to the PH system of the individual block:
Check the block top pressure and accordingly take necessary action. Then Flood the top block space by switching on the various respective valves.
Check the hermetic sealing of the door.
Check the hermetic sealing of the door.

Figure 1. Decomposition of a mission analysis in normal mode

Similarly the analysis was carried out for various modes and under different conditions of critical, simulation and training. It is comparatively easy to use, and is generally a low cost activity. It requires few resources, and serves as a very useful means of reaching consensus on *what* and *how* the system is to fulfil its objectives. The analysis comprises details like system description, performance requirements, environmental factors and mission segments.

4. Function Allocation

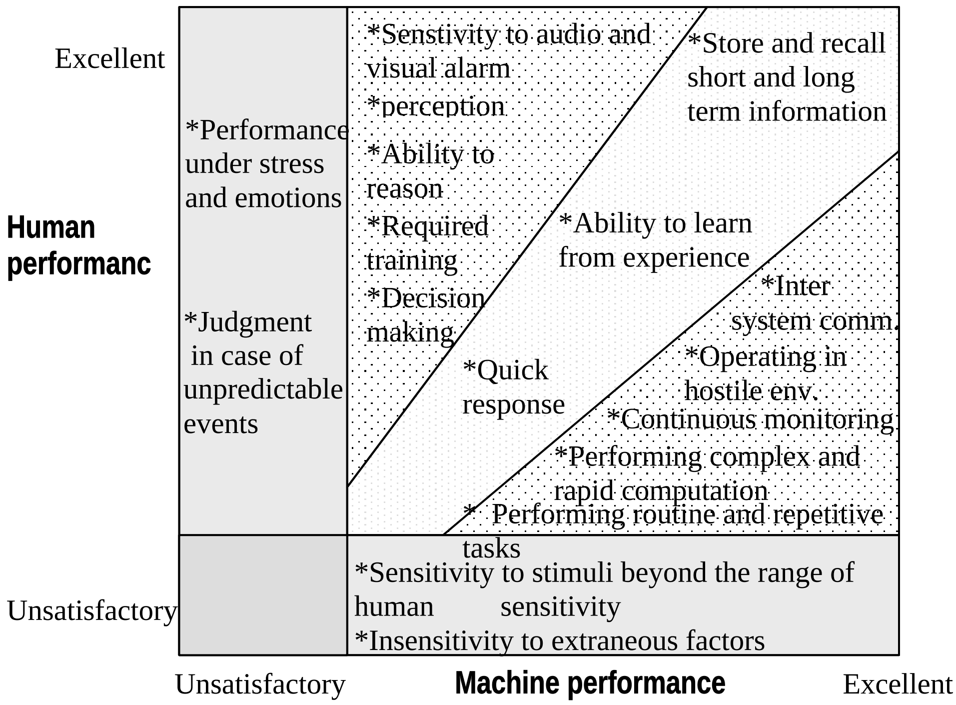


Figure 2. Criteria for allocating functions to human or machine

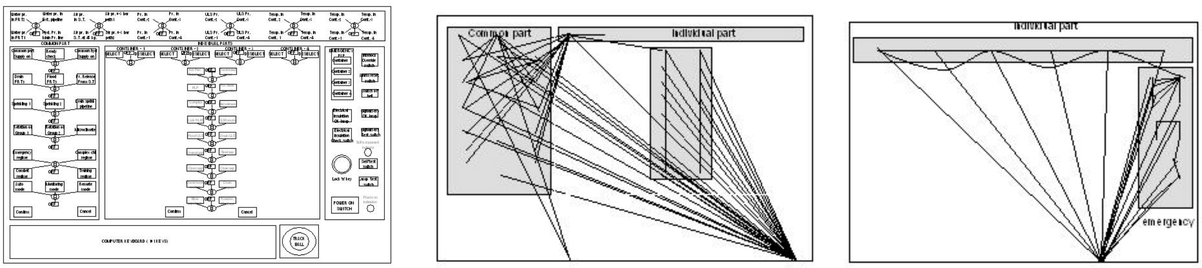
As per Price's approach [Price,1985]on this matrix different functions are allocated to the operator. There on a detailed man-machine interface is developed, which incorporates a Monitor, a Mimic display, and an Operator's Panel. The monitor encompasses the various tasks of storage of manual; help files and simulation tasks favourable to machines.

4.1 Design of Mimic & operator panel

MIMIC design involves a lot of rethinking into the subsystems functional grouping and their corresponding relation and relevance to the operator. Mass scale reduction in number of sensors and valves' display becomes essential due to the space constraint. Thus a graphical display of the plant activities is created containing lamps and indications for hydraulic, pneumatic and water components and sensors. Also the requirement to check critical hydraulic/water/pneumatic components and sensors status forces one to provide the pad switches cum indicators for `healthy', `faulty', `off' and `on' status indications.

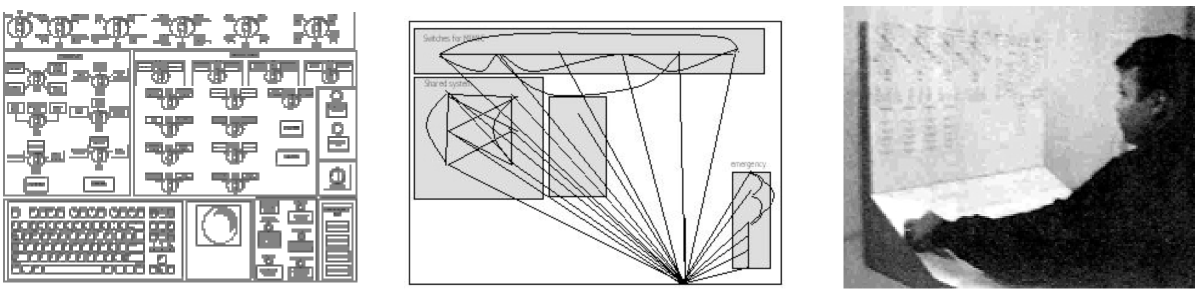
5. Task Analysis

Task analysis is the study of the tasks that have to be undertaken by individuals or groups in order to achieve particular system goals. In order to ensure that all the important task features are considered during this process, a path analysis has been carried out for cues initiating the action, controls used, decisions involved, typical errors, response required, criterion of acceptable performance and feedback of task completion, involved in each of the task element [L.Ainsworth,2001].



(a) conceptual operator panel (b) path analysis during normal mode (c) path analysis in critical mode

Figure 3. Task analysis carried out by analysing the path followed during two different missions of the operator's panel in normal mode and in critical mode



(a) redesigned operator panel (b) path analysis during normal and critical mode (c) path analysis on a mock up model

Figure 4. Improved path analysis followed during two different missions of the redesigned operator's panel in normal mode and in critical mode

6. Display & Control design

It is important, therefore, that a criterion to be ranked or prioritized in a given application and that specific control selection is based on the prioritised criteria. As many functions and controls are involved in control panel design, controls are grouped according to function and arranged in sequential order of their use, when used sequentially, from left to right and from top to bottom. Importance and frequency of use are used to decide which functional group are located within the central visual and forearm reach areas and which ones are located peripherally. Since due to the constraint, a single plane

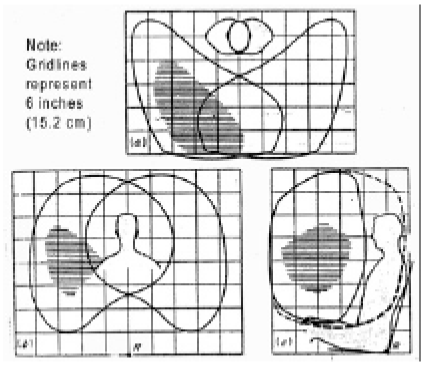


Figure 5. Optimization of control's reach and location

of motion in front of the operator is required for control panels, therefore the relative positions, orientations and directions of control movement have been made a little different as per the functional grouping for ease of visual identification and to avoid likelihood of accidental activation [Sanders & McCormick,1992].

In this design aspect, control serves as a tactile display indicating the status of operator commands to the system. Information from a control is the result of several design features including its location, shape, size, mode of operation, labeling and color. Simplification and standardization of controls and their operation are taken into consideration so that the errors can be minimized.

6.1 Controls

The direction of control movement is made consistent with the related movement of an associated display, equipment component, or the platform. In general movement of a control forward, clockwise, to the right, or up, shall turn the system on, cause the quantity to increase, or cause movement forward, clockwise, to the right, or up. All controls which function in sequential operation for a particular task, or which operate together, are grouped together, along with their associated displays. Where sequential operations follow a fixed pattern, controls are arranged to facilitate operation (e.g., in a pattern left to right or top to bottom. The most important and frequently used controls are in the most favourable position with respect to ease of reaching and grasping. No more than three different sizes of controls are used in coding controls for discrimination by absolute size. When knob diameter is used as the coding parameter, a difference between diameters is not made less than 13mm (0.5 in). When knob thickness is the coding parameter, difference between thicknesses is not less than 10mm (0.4 in). Any method of protecting a control from inadvertent operation does not preclude operation within the time required, especially for immediate action (critical) controls [Sanders & McCormick,1992]. For situations in which control must be protected from accidental activation, design takes care by:

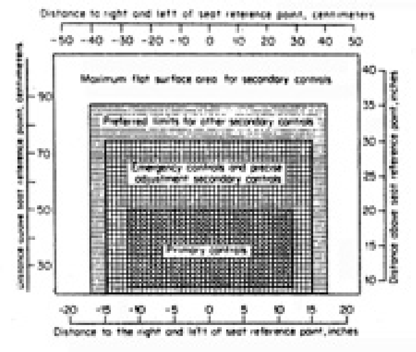


Figure 6. Criteria for placement of controls/display

- Locating and orienting the controls so that the operator is not likely to strike or move them accidentally in the normal sequence of control movements.
- Providing the controls with interlocks, so that extra movement or then prior operation of a related or locking control is required.
- Providing detent controls with resistance that is elastic, building up then decreasing as each position is approached, so that the control snaps into position without stopping between adjacent positions.

6.2 Visual Displays

Visual displays are provided to the operator for a clear indication of equipment or system conditions. The information displayed to an operator is made limited to that which aids the performance of specific actions and the making of decisions and is presented to the operator in a directly usable form. Failure of a display or its circuit is immediately apparent to the operator.

Display is located and designed so that they are read to the degree of accuracy required without requiring the operator to assume an uncomfortable, awkward, or unsafe position. Display faces are made perpendicular to the operator's normal line of sight whenever feasible and shall not be less than 45 degrees from the normal line of sight. The ideal maximum viewing distance from the design eye position to displays located close to their associated controls is 635mm (25 in).

All displays necessary to support an operator activity or sequence of activities are grouped together. Displays are arranged in relation to on another according to their sequence of use or relations of the components they represent. Displays used most frequently are grouped together and placed in the optimal visual zone. Important or critical displays such as for temperature and pressure are looked in privileged position in the optimal projected visual. Flashing lights are used only when it is necessary to call the operator's attention to some condition requiring immediate attention . The flash rate is made from three to five flashes per second and relates to the urgency of the indication.

Figure 7. A temp. gauge

Scale indicators are used to display quantitative information is combination with qualitative information, or when information must be obtained from the display. Except where system requirements clearly dictate non-linearity to satisfy operator information requirements, linear scales are used in preference to non-linear scales. Scale graduations progress by 1, 2, or 5 units or decimal multiples thereof. Except for measurements that are normally expressed in decimals, whole numbers are used for major graduation marks. The display scale starts at zero, except where this would be inappropriate for the function involved. The control of display pointer extends to, but not overlap, the shortest scale graduation marks [DoD-HDBK-763]. Numerals are placed on the side of the graduation marks away from the pointer to avoid having numbers covered by the pointer. If space is limited, numerals are placed inside of graduation marks to avoid undue constriction of the scale.

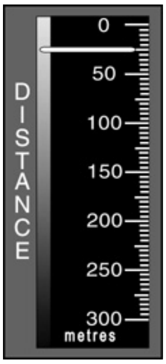


Figure 8. A depth gauge

7. Interface & workspace design

In the workstation design an attempt is made to achieve an optimum compromise between the variable anthropometrics of the targeted operator/user, and the physical size and the layout of the workstation components. An ergonomic analysis for a workstation design is carried out which concerns with spatial accommodation, posture, reaching abilities, clearance and interference of the body segments, field of vision, available strength of the operator, and biomechanical stress. The appropriate anthropometrical data regarding body size, strength, segment masses and inertial properties from the established databases are typically used in the analysis. For the physical design of this workstation, the four essential design dimensions taken are work height, normal and maximum reaches, lateral clearance and angle of vision and eye height.

A well known approach is taken to design the reach requirements of the workstation corresponding to the measurements of the 5th percentile of the representative group and the clearance corresponding to the 95th percentile measurements, so as to make the workstation compatible for both small and large persons [B.Das,2001]. Following shows the salient features present in the design of console:

- Primary controls are located between shoulder level and waist height.
- Controls are located so that simultaneous operation of two controls does not necessitate crossing hands.

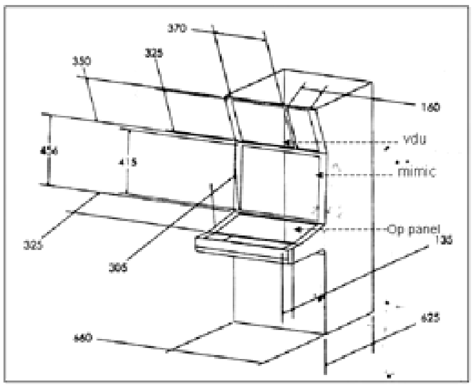


Figure 9. Design of workspace

- Frequently used controls are placed within a radius of 400 mm from the normal working position.
- Occasionally used controls are placed with a radius of 500 mm.
- Infrequently used controls are within a radius of 700 mm.
- All controls are placed within the maximum reach of the seated operator. [Sanders & McCormick,1992]
- Controls requiring fine adjustments are located closer to the operator's line of sight than controls requiring gross positioning.
- When the operator has to manipulate controls while monitoring a display, the controls are placed close to, and directly below, that display.
- Controls that are used infrequently are placed to one side to prevent inadvertent activation.

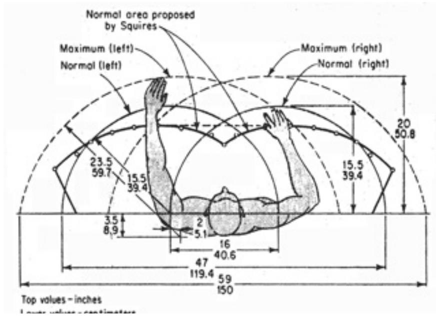


Figure 10. Max.,min. ,optimum reach of the operator

8. Conclusion

Efforts are on being made to conduct operational simulation using ergonomic human operator software and/or conducting user testing in a mock up to reveal potential operating problems. If warranted by technological complexity, time and cost limitations and designer/user agreement, all efforts will be made to develop and build a dynamic simulator for critical control situations to investigate time dependent human–machine control functions and relationships and then accordingly modify system hardware and software as needed to solve problems encountered in using the simulator.

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