CoA Memo M and P No. 44

August, 1964.

THE COLLEGE OF AERONAUTICS

DEPARTMENT OF PRODUCTION AND INDUSTRIAL ADMINISTRATION

Ergonomics and Systems Design Laboratory

P.18. An interface design for a shock-tube system

- by -

D. Beevis
T.B. Leamon
E.J. Lovesey
J.G. Neale
R.H.D. Strank

SUMMARY

A linear display of lights and a mimic diagram arrangement of switches are suggested for the proposed high pressure shock tube control panel to enable the operator to follow a safe and reliable operating procedure.

Contents

Acknowledgments

The members of the project group wish to express their gratitude to Mr. W.T. Singleton, for his help and guidance and to Mr. J.R. Busing and Mr. D. McQue for their co-operation in facilitating the observations which were made.

Duration of project

The project time available was three afternoon sessions of two hours with additional individual work by members of the group.

1. Members of the group

D. Beevis (23)

H.N.C.(Aero.,Mech.,Prod.) Stud.I.Prod.E.
5 year M.o.A. Apprenticeship at the
National Gas Turbine Establishment.

T.B. Leamon (23)

B.Sc.Tech.(Chemistry) Manchester A.M.C.S.T.
Production Management Course and one year
in the Work Study Dept. of Ilford Ltd.

F.J. Lovesey (24)

H.N.C. (Aero.,Mech.) G.I.Mech.E., Grad.
R.Ae.S. 5 year M.o.A. Apprenticeship at
the Royal Aircraft Establishment, Farnborough.

J.G. Neale (25)

Dip. Loughborough College (General Eng.)
Qualified teacher (Oxford University
Institute of Education).

R.H.D. Strank (23)

B.Sc.(Physics), Imperial College, London.
1 year with J. Lyon and Co. Ltd.

2. Introduction

An existing high-pressure shock-tube which forms part of the equipment of the aerodynamics department at the College, was due for major modification and reconstruction. It was felt that this provided an opportunity to redesign to interface in professional Human Factors terms and to this end the Ergonomics Laboratory was approached. The task was allocated to the final year Ergonomics students as one of their minor projects.

At the start of the project, the shock tube site was visited and a brief description, which appears below, was made of the major components. Notes were also made of the differences between the existing and proposed 2 inch shock tube.

General description of present apparatus

The existing apparatus consists of essentially:-

a) A storage chamber containing high pressure hydrogen at 1500 psi.
b) A tube containing the working section and sealed at each end by diaphragms which rupture when the H_2 storage pressure reaches a certain value.
c) A dump chamber evacuated by a rotary pump and a diffusion pump.

Models of the order of 1″ × ¼″ diameter in size may be mounted in the working section. These are viewed through a thick glass wall.

Diaphragms are generally constructed from 4″ diameter .030″ thick copper or aluminium sheet. A 2″ cross is scribed .005″ deep to enable the discs to rupture in the same manner and at approximately the same pressure during different runs (± 5% of nominal bursting pressure). Other materials such as cellophane may be used but these generally shatter producing flying fragments. If diaphragms do not rupture during a run because of insufficient pressure, due to work hardening, they must not be used again. The rupture configuration also determines the shock wave speed and turbulence.

The Dump Chamber is pumped down to .2 mm. of mercury pressure by a rotary pump. An oil vapour diffusion pump then operates to reduce this pressure still further. This pump has to be water cooled. For very low pressures, the oil vapour pump is required to run for 2 to 3 hours. Consequently only 2 or 3 runs can be made per day. (A separate pump is used to evacuate the working section of the tube).

A Shock Wave is produced when the high pressure hydrogen ruptures the diaphragm and rushes into the tube where it meets the low pressure air to form a hot boundary.

The Running Time of the tube is approximately 100 micro-seconds.

An Explosion risk is present due to hydrogen escaping round 'O' rings, etc. Consequently care must be taken during the operating sequence to ensure that valves are not opened to let the gas into areas where an explosive mixture may be formed. Fans are provided to remove any escaping hydrogen at the roof.

Future Shock Tube This will be required to run with a storage pressure of 10,000 psi. which will produce a shock wave of 3,000 psi. at the Air/Hydrogen boundary.

A pump will be required to transfer the hydrogen from the commercial bottles to two high pressure tanks. This operation will be carried out in the early morning before testing.

Because of the extremely short duration of each test, a pressure measuring Langham Thompson device has been modifed to switch on cameras and oscilloscopes as soon as a certain pressure, which is just below the bursting pressure, has been reached.

Because of the danger of explosion with hydrogen at 10,000 psi., an audible system of warning will be required to inform persons to get clear of the working area. The shock tube and accompanying apparatus will be operated from an adjoining room.

Helium may not be used in place of hydrogen to overcome the explosion problem since the shock wave velocity would be decreased from Mach 18 to Mach 8. (The shock wave velocity is a function of both the high pressure and the driven gas).

3. Procedure

Initially a flow diagram was prepared for the proposed operating procedure which had been set down by Aero. Dept. staff. However, it was soon realised that many minor but essential operations had been omitted from this and an analysis would have to be made of the present procedure. This was subsequently carried out during a run and a 'Decision' chart was constructed consisting of inputs, decisions, and outputs.

4. Results

Decision analysis of operating procedure

	Input	Decision	Output
		Experimental variables:- pressure, working section gas, diaphragm strength, instruments required.	Select suitable diaphragm
2.	Fans are running, there has been no system malfunction.	Charging room is safe to enter	Enter room
3.	Exhaust valve is open	Tube is at atmospheric pressure	Release the end of the shock tube (at present a capstan screw, to be replaced by two hydraulic jacks and wedges). Remove burst diaphragm. Insert new diaphragm. Reconnect tube end and do up tightly.
4.	'Feel' of the capstan or jacks, click of micro switch (shows a light only in the control room).	Tube end properly reconnected, diaphragm is properly sealed.	Insert 2nd diaphragm if required. Switch on instruments and allow to warm up.
5.	Diff. pump cooling water valve position.	Cooling water flow is adequate. (An interlock is to be fitted to this).	
6.			Pirani vacuum gauge switched on and warming up.
7.	Position of Dump Chamber air inlet valve.	Tube is isolated from atmosphere.	Check Roughing Valve, Backing valve, Isolator Valve, Baffle valve, closed Switch on Rotary Pump.
8.	Reading of Pirani Gauge	O.K. to evacuate Diffusion Pump.	Open Isolator and Backing valve.
9.	Reading of Pirani Gauge	O.K. to heat Diff. pump oil.	Switch on heater to Diff. pump.

	Input	Decision	Output
10.	Working section pressure	Tube ctr. section pressure too high	Switch on Leybold (working section) pump. Check tube gas inlet valve is closed. Open small valve to evacuate plunger valve reservoir.
11.	Time lapse of 10 sec.	Plunger valve is open	Open valve above Leybold pump and tube inlet valve.
12.	Vacuum rise in tube is normal.	Plunger valve is open (check)	
13.	Temperature of Diff. Pump (by touch)	Pump is being effectively cooled.	No action necessary.
14.	Working section pressure dropping.	Evacuate Dump Chamber to (assist Leybold Pump (or (prevent 2nd diaphragm rupturing.	Close Backing valve. Open Roughing valve.
15.	Pressure differential across 2nd diaphragm	Differential is acceptable.	Pumping continued, no adjustment necessary to Roughing or Tube Inlet valves.
16.	Suitable time lapse (10 min.)		Vacuum reservoir valve to Leybold pump closed.
17.	Vacuum in ctr. section not falling at the required rate.	Condensation present in Leybold pump.	Flush through the pump with dry air (oetails uncertain, D.B.)
18.	Working section and Dump Chamber pressure .2 mm. mercury.	Pressure low enough for Diff. pump to function	Close Tube Inlet valve. Roughing valve closed. Backing valve) Baffle valve) opened
19.	Pressure in Dump Chamber is that required (Pirani gauge reading).	Tube is ready to receive gas charge to working section.	Close Baffle valve, leave Diff. Pump running. Select scale on working sectn. pressure meter. Open gas bottle valve, open tube inlet valve, blow thro' rubber tube and convect it to up-stream end of the dryer. Open gas inlet valve. Monitor pressure of gas allowed into tube using small hand operated valve.

	Input	Decision	Output
20.	Working section pressure is that required.		Close (Gas Inlet valve (Gas bottle valve Close Tube Inlet valve. Close pump stop valve. Switch off Leybold pump. Turn on air supply to plunger valve.
21.		Plunger valve is closed and shock tube isolated	Turn on power supplies to Models. Check Instruments.
22.	All previous procedure	Tube is ready for test.	Press button to open charge valve to high press H_2. After short pause to flush thro' tube below 1st diaphragm press button to close Vent valve. Keep both buttons pressed.
23.	Sound of shock wave	Diaphragms have ruptured.	Release buttons, venting tube to atmosphere. Read all instruments. Turn off power supplies to all models.
24.		Tube required for another run.	Switch on Leybold pump, open stop valve and tube inlet valve. Open valve to plunger valve vacuum reservoir to open plunger valve. Possibly flush the tube thro' with dry air.

5. Discussion

When the proposed operating sequence had been determined it was necessary to discuss the form in which the interface or control panel should be presented.

Display alternatives

Three different types of displays were suggested. The first type, known as a 'Christmas tree', since it consists of a vertical line of lights with horizontal branches which flash on as parts of the operating procedure are completed, was discarded as it was thought this system is essentially a linear one with no separate sub-routines.

The second proposal was for a pictorial representation by a 'minic' diagram where lights are mounted on a line diagram of the system. When, for instance, a valve is open, a light will show at the corresponding valve on the diagram. Unfortunately this method does not inform the operator of the next action to be taken and consequently previous knowledge is required of the apparatus and its operating sequence.

The third possibility was of a linear display consisting of a row of switches under a line of red and yellow lights. At the start of a run, all of the lights would be on. As the operating sequence progressed, starting at the left and moving along one by one, each switch in the line would be depressed cancelling its corresponding light. The switches on the control panel would be of one of two forms. Either control switches which when depressed, besides extinguishing the red light above, also operate a relay or start a pump, etc., or they would merely serve as a check reminder. For example, the operator would see that the next light (which is yellow) is on, read the check instructions beneath it, check that a valve is closed, say, then depress the switch to remove the light and move on to the next operation.

The display finally chosen is a combination of both the Minic diagram and the linear display (see fig. 1).

All of the controls which may be operated from the control panel will be mounted on the minic diagram while three rows of eight lights each will be mounted behind the diagram to enable the operator to carry out the required operating sequence. As each control is used, the corresponding light will appear, enabling the operator to see just where he is in the sequence and by looking at the instructions mounted above the next unlit light to the right he will be able to determine the next action to be performed. (See fig. 2).

Instead of mounting action or check instructions above each light, the light glass itself may carry the wording. This method would however, require all lights to be on initially and to be extinguished as the sequence proceeds.

The three pressure indicators should be mounted on the right hand side of the control panel. These will be duplicated since it will also be necessary to read them in the room where they are situated. There will be one instrument for measuring the pressure in the changing chamber an alphatron to record the vacuum in the working section and thirdly, a pirani gauge for measuring pressure in the dump chamber. To aid the operator to obtain the correct pressures, it is recommended that at the commencement of a run, he presets all of the dials to the required values.

Many of the check lights will be controlled by microswitches mounted on the manual controls. For instance, microswitches can be mounted on the hydraulic jacks and wedges to indicate whether the tube is properly reconnected after having a new diaphragm inserted.

Where doors have to be closed manually, it is recommended that yale locks should be installed which can be opened from the inside of the danger area. In the event of an accident or when the tunnel operator requires urgent assistance, a key can be obtained by breaking the glass front of a box mounted outside of the area.

Type of switch

The switch should be of the toggle type. If controlling a value, the toggle switch should be mounted so that when in the down position, the value will be open. Thus if a light fails it will still be possible to see the state of the system by the switch position.

The toggle switch should have a lever tip diameter of $^1/_4''$, lever arm length of 1 inch and a displacement of approximately 90°. The horizontal spacing between lever arms should be not less than 1 inch. The switches should be mounted in four rows of twelve with a vertical separation of $1\frac{1}{2}$ inches. The rear of each switch should be accessible for rewiring in case the operating sequence requires to be modified at some future date. This may be achieved by bringing all electrical outputs and inputs to a plug board which is separate from the switchboard, and then connecting by detachable wires.

Interlocks

All the switches could be fitted with mechanical interlocks so that the n^{th} switch could not be depressed until the $(n - 1)$ switch had been operated. However, with the system of lights it was not thought necessary to include interlocks for every stage, but only where, if the sequence is incorrect, a human operator may be endangered.

The five following cases were thought to require interlocks:-

1. Fans must be running and the H.P. pump room door must be locked before the H.P. cylinders are filled.

2. The fans should be in the same circuit as either the control room lights, or in the same circuit as the Control panel master switch.

3. Valve B2 cannot be opened and valve B3 cannot be closed unless the diaphragm clamps are closed and their microswitches are tripped. These micro-switches should also operate 'CLAMPS ON' light at the diaphragm clamps when they are tripped.

4. Dump chamber, Air Inlet, Working section Isolator, Air Inlet and Plunger Valves must be open before a red 'DO NOT RELEASE' notice is cancelled on the diaphragm clamps.

5. Charging Chamber Room and Working Section Room Door locks should operate green O.K. lights on the display panel.

Charging Sequence

Switch on lights. (Fans in same circuit, or if too expensive wire through to master switch on control desk which switches on all lights, relays, etc.).

Decide on experimental parameters, 1 or 2 diaphragms and strength; pressure in Charging Cylinder, Working Section pressure and gas. Air Inlet Valve open check. (i.e. Run to atmosphere variation).

1. Check preset indicator needles on working section, dump chambers and charging chamber dials. Switch on gauges. Press button below dials to switch on light.

2. Open dump chamber air inlet valve, working section isolator, air inlet and plunger valves - green light comes on and 'DO NOT RELEASE' light on diaphragm clamp is cancelled.

3. Fit diaphragms. Press light switch by each diaphragm clamp - green lights appear on panel.

4. Diffusion pump cooling water on - press switch on mimic diagram - green light will appear.

5. If running to atmosphere, close plunger valve, tube isolator valve, and baffle valve. Green light appears on panel. By pass sequence to item No. 23.

6. If running to vacuum, check air inlet, roughing, backing, isolator and baffle valves are closed - green light appears on panel.

7. Switch on rotary pump - green light on panel.

8. Check dump chamber pressure and then open isolator and backing valves - green light on panel.

9. Check dump chamber pressure, switch on diffusion pump heater - green light on panel.

10. Check working section pressure and manually close gas inlet valve. The switch on leybold pump - green light on panel.

11. Open stop valve and vacuum reservoir valve - check by position switch or hand switch by valve to get green light to come on to mimic diagram to show that the plunger valve is open.

12. Check plunger valve is open. Then open tube inlet valve - green light on panel.

13. Check working section vacuum rise, close backing valve, open roughing valve - green light on panel.

14. Monitor pressure differentials of working section and dump chamber. Positional control is required for stop valve and rotary pump isolator valve. Close vacuum reservoir valve - green light on panel.

15. Check working section and dump chamber pressures are down to .2 mm of mercury. Close tube inlet and roughing valves - green light on panel.

16. Open backing and baffle valves - green light on panel.

17. Check dump chamber pressure is correct. Close baffle valve and charge working section - green light on panel.

18. Close tube isolator and stop valves - green light on panel.

19. Turn on air supply close to plunger valve - plunger valve off on mimic diagram - green light on panel.

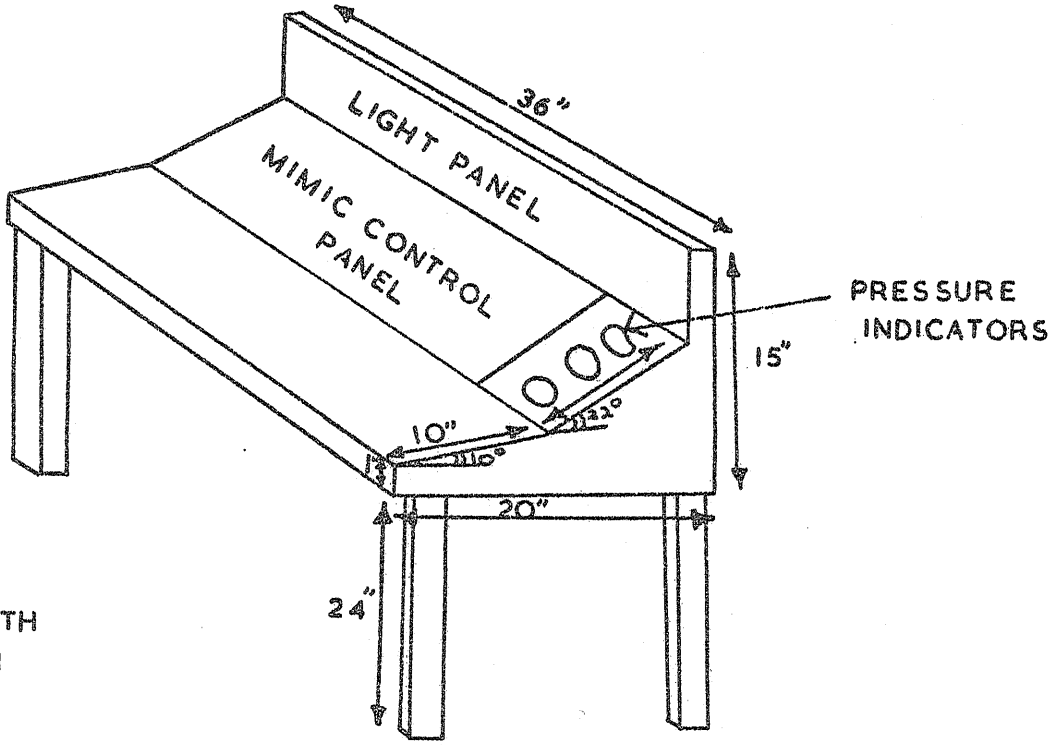
20. Switch off Leybold pump - green light on panel.

21. Switch on warning lights - which also sound audible warning - green light on panel.

22. Lock Charging room and Control room doors - green light on panel.

23. Switch on power supplies to models - green light on panel.

24. Press switch (1) to open valves B1 and B2, wait 4 seconds and press switch (2) to close valve B3.



FOR USE WITH
17" CHAIN

LIGHT DISPLAY PANEL