IV-14. A Novel Apparatus for the Cyclical Testing Under Simulated Wind Loading of Cavity Walls

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ABSTRACT

The British Ceramic Research Association has for some years been engaged on an extensive programme of research into the performance of masonry walls when subjected to lateral loads arising from wind loads, that is pressure at right angles to the plane of the wall.

The vast majority of these tests have been carried out in a quasi-static manner with pressure applied to the outside of a single leaf wall. A lesser number of two-leaf cavity walls have been tested; most of these have also had the pressure applied to the outside of the wall, but additionally a few had the pressure applied to the inside of the wall, i.e. the face of the inner leaf.

None of these tests applied a tension to the wall ties, which would be the situation where a wall was subjected to external suction. The apparatus described in this paper applies a load alternately to both sides of the outer leaf of a two leaf cavity wall so that the wall ties are subjected to compressive and tensile loads. The cyclical application of the load is controlled automatically so that fatigue testing may be carried out. Full deflection and crack detection instrumentation is applied to the test walls.

Depuis quelques années, la B Ceram RA s'est consacrée à un vaste programme de recherche dans la tenue des murs en maçonnerie lors qu'ils sont soumis à des charges latérales résultant de charges dues au vent, c'est à dire à des pressions perpendiculaires au plan du mur.

La grande majorité des essais a été effectuée d'une manière quasi statique avec la pression appliquée sur l'extérieur d'un mur plein. Des murs à cavité interne ont été essayés en moindre nombre; sur la plupart de ceux-ci la pression fut aussi appliquée sur l'extérieur du mur, mais en addition, la pression fut appliquée sur quelques uns sur l'intérieur du mur, c'est à dire sur la face du pan de mur intérieur.

Pour aucun de ces essais une tension ne fut appliquée sur les agrafes d'ancrage, ce qui aurait été le cas pour un mur soumis à une dépression externe. Les appareils décrits dans ce document appliquent, alternativement, une charge sur les deux côtés du pan extérieur d'un mur à cavité interne, de façon que les agrafes d'ancrage du mur soient soumises à des charges de compression et de traction. L'application cyclique de la charge est automatiquement contrôlée pour permettre à des essais de fatigue d'être effectuès. Des appareils de détection de fléchissement et de fissures sont appliqués sur les murs en essai.

Die B CeramRRA betreibt seit einigen Jahren ein ausgedehntes Untersuchungsprogramm über das Verhalten von Mauerwänden bei in Querrichtung wirkenden Windlasten, d.h. bei einem Druck senkrecht auf die Wandff-äche.

Die meisten Prüfungen wurden sozusagen statisch durchgeführt, indem ein Druck auf die Außenfläche einer einschichtigen Mauer aufgebracht wurde. Eine geringere Anzahl zweischichtiger Hohlwände wurde geprüft; in den meisten Fällen wurde auch die Außenfläche der Wand mit Druck belastet, bei einigen jedoch wurde der Druck auf die Innenfläche der Wand ausgeübt, d.h. die Fläche der inneren Schicht.

In keiner dieser Prüfungen wurde ein Zug auf die Mauerbinder ausgeübt; dies wäre der Fall, wenn die Wand einer Saugwirkung nach außen ausgesetzt würde. Die in diesem Artikel beschriebene Einrichtung dient für das abwechsende Belasten der Außenschicht einer Hohlwand mit zwei Schichten auf beiden Seiten, so daß die Mauerbinder einer Druck- und Zugbelastung ausgesetzt werden. Diese wechselseitige Belastung wird automatisch gesteuert, so daß Dauerversuche durchgeführt werden können. Instrumente für das Messen von Biegungen und Risseprüfgerät werden an den Prüfwänden vorgesehen.

La B Ceram RA è stata impegnata da molti anni in un vasto programma di ricerca nelle reazioni di muri quando soggetti a sollecitazioni laterali causate dal vento, cioè a pressioni applicate perpendicolarmente al piano del muro.

Nella maggior parte dei casi queste prove sono state effettuate in maniera quasi statica, con pressioni applicate alla superficie esterna di muri ad un solo strato. Un numero minore di muri doppi con intercapedine è stato assoggettato a prove; molte di queste prove sono state con pressione applicata alla superficie esterna del muro, ma ci sono anche state alcune prove con pressione applicata alla superficie interna, cioè allo strato interno del muro doppio.

In nessuna di queste prove è stata applicata una tensione ai collegamenti murari, come avverrebbe nel caso in cui un muro viene assoggettato ad aspirazione esterna. L'apparecchiatura descritta in questo articolo applica una sollecitazione ciclicamente ad entrambe le superfici del muro esterno di un muro doppio con intercapedine,

in modo da assoggettare i collegamenti murari a sollecitazioni di compressione e di trazione. L'applicazione ciclica della sollecitazione è controllata automaticamente, in modo da poter effettuare la prova di fatica. Una serie completa di strumenti per la misura di inflessioni e per la rivelazione di incrinature è applicata ai muri sotto prova.

INTRODUCTION

The British Ceramic Research Association has, for the last seven years, been engaged upon an extensive and wide-ranging investigation into the resistance of brick and block walls to lateral forces arising from wind loads, that is pressures applied at right angles to the plane of the wall. The results of this work up to 1978 were used to form the basis of the new limit state British Standard Code of Practice for Structural Use of Masonry.[1] A number of papers and reports have been published[2] describing various aspects of the work as it progressed and four more papers are being presented at this Conference covering other facets of the investigation. The test walls in the programme, which have been up to 5.5 m long and 5.2 m high, both single leaf and cavity, have been built in steel frames which represented one bay of a multibay framed structure constructed either of steel or reinforced concrete. Uniformly distributed loads were applied to the infill walls using a system of lightweight airbags.

In a real building, pressures from wind loads may be applied to the walls in several ways; as a positive pressure on the outside of the wall, as a negative (suction) pressure outside the wall or as a positive pressure inside the wall. Most of the test walls in the programme have been tested in the first of these three ways. During a test, pressure is applied to the wall steadily by inflating the airbags at a constant rate. No attempt was made to simulate the effects of gusting because in the design of walls to B.S. Codes of Practice, the effect of gusting is taken into account in the design wind load which is derived from CP.3 Chapter V[3], which allows for the topographical location, the ground roughness, the building height and shape, the assumed wind direction and the building life. Moreover, none of the tests applied a tension to the wall ties, which would be the situation where a cavity wall was subjected to external suction.

The apparatus described below applied a load alternately to both faces of the outer leaf cavity wall so that the wall ties are subjected in turn to compressive and tensile loads. The cyclical application of the load is controlled automatically so that fatigue testing may be carried out.

GENERAL ARRANGEMENT OF THE TEST SPECIMENS

The general arrangement of a test wall in the rig is shown in Figures 1 and 2.

The cavity wall is built into and tied to a steel frame which simulates a panel wall in one bay of a multi-bay steel or reinforced concrete framed structure. The method and degree of peripheral restraint is arranged to be appropriate to the circumstances of the test panel and is immaterial to the conduct of the test, except that to a certain extent it governs the disposition of the test equipment.

Three-quarter-inch plywood sheets are positioned in the cavity in such a manner that they do not touch either of the leaves and are restrained by horizontal struts which pass through holes in the inner leaf and are attached to a convenient rigid abutment. A set of lightweight inflatable bags are situated between the plywood and the cavity side of the outer leaf so that when they are inflated they apply a uniformity distributed pressure to the inner face of the outer leaf; the reaction is transmitted from the plywood boards back through the struts to the rigid abutment. The width of the airbags is such that they thread between the wall ties.

A steel frame clad in plywood is fixed about 1 inch in front of and parallel to the outer face of the wall. A series of airbags are situated between the face of the wall and the reaction board in order to apply a uniformly distributed pressure to the face of the wall.

Each of the sets of airbags are connected in parallel to manifolds. The source of air pressure is a high-pressure high volume blower feeding a reservoir fitted with an adjustable pressure control valve. The air is fed to the manifolds through solenoid-operated valves and exhausted by other solenoid-operated valves. The operation of the valves is controlled by a synchronous event timer and associated pressure switches in the airbags. The test sequence is thus: Pressure is applied to one side of the outer leaf steadily up to a predetermined value, maintained for a period and then exhausted. The sequence is then repeated on the outer leaf steadily up to a predetermined value, maintained for a period and then exhausted. The sequence is then repeated on the other side of the outer leaf. This cycling sequence is continuous and the number of cycles is recorded. The frequency is determined by the speed of the cam timer, and the rate of increase in pressure controlled by varying the pressure in the reservoir. The upper level of frequency of the cycle is governed by the speed at which the air bags can be filled and exhausted. Stripes of electrically-conducting paint are applied to both faces of the wall; each strip is fed from a constant voltage source through a relay.

When a crack occurs in the brickwork, a discontinuity occurs in a paint stripe and the associated relay opens. All the relays are connected to the timer control circuit in such a manner that any crack in the brickwork stops the cycling and exhausts the pressure. The number of cycles completed at the time of shut-down is recorded. Subsequently the broken paint stripe may be electrically isolated and the control circuit reset, enabling the cycling to be restarted.

The horizontal deflections of the inner and outer leaves are recorded by means of suitable linear transducers which

are connected to a data logger and on occasions to a rapid response chart recorder.

THE PNEUMATIC CIRCUIT

The pneumatic circuit is shown in Figure 3. The source of compressed air is a high-volume, high pressure fan feeding a ½ cu m air receiver. The pressure in the receiver is controlled by a damped vane type pressure relief valve which continuously leaks a proportion of the delivered air so as to keep the receiver at a non-pulsating pressure which is appreciably constant. Each of the two sets of air bags are connected to two separate manifolds, which are fed from the receiver by solenoid operated valves. Air is exhausted from the air bags via the manifolds and similar solenoid controlled exhaust valves. The manifolds and connecting pipes are kept as short as is practicable and they and the solenoid operated valves are of large bore, all to facilitate rapid filling and exhausting of the air bags. Sensitive pressure gauges and pressure switches are connected to selected air bags at points remote from the entry point of the air.

THE ELECTRICAL CONTROL CIRCUIT

The electrical control circuit is shown in Figure 4, The cycle of operations is controlled by a cam type timer driven at constant speed by a synchronous motor. There is the facility of varying the cycle frequency by changing the gearing of the driving motor. The sequence of operations is as follows:

The closing of the cam contacts C1 energises and the solenoid to one inlet valve through the relay contact a1 and the pressure switch contact P1. When the pressure in the air bags attains the preset value the pressure switch contact P1 opens, causing the inlet valve to close. The pressure in the air bags then remains constant. The purpose of relay A is to inhibit a double pressure pulse in the event of a small leak in the pneumatic system or bounce of the pressure switch contacts. Upon the operation of the pressure switch at the preset value the coil of the relay A is energised through pressure switch contact P2. Relay contact a1 opens, preventing the undesired reclosing of the solenoid valve; relay contact a2 merely serves to maintain the supply to relay A. The whole sub-circuit resets when the cam contact C1 opens. The closing of the cam contacts C2 energises the solenoid of the corresponding exhaust valve, and this remains open until the contacts reopen. Neon lights indicate the status of the solenoid valves and the pressure switches.

The air supply to the other set of air bags is similarly controlled by the cam contacts C3 and C4, which are set 180° (one half-cycle) out of phase with the corresponding contacts C1 and C2, Figure 5. Cam contact C5 controls an electro-magnetic counter which records the number of cycles completed. The complete sequence of events for the first half cycle is shown in tabular form in Table 1.

Each conducting paint stripe is connected in series with the coil of its associated relay and all are fed from a constant low voltage supply. Each relay has one contact which is closed when the coil is energised. All these relay contacts are connected in series with the coil of the master contactor, so that the fracture of any one conducting stripe due to a crack in the masonry opens the master contactor and thus shuts down the whole apparatus. The number of cycles completed at shut-down is of course indicated by the counter. A broken paint stripe may be shorted out to enable the experiment to be continued with partially cracked masonry. The switch S1 is a starter switch, necessary to override the 'fail-safe' device during the starting-up procedure. The time-delay relay is connected in parallel with the 'maintaining' contacts of the master contactor coil, so that a momentary interruption in the mains electricity supply does not undesirably shut-down the experiment. By the incorporation of these various features in the circuitry the whole experiment may be left to run safely unattended.

THE PERFORMANCE OF THE APPARATUS

The tests are usually carried out to represent the statistically determined wind-loading regime of a particular location. In general, for example, a large number of cycles would be completed at several low air pressures, with the number of cycles being progressively reduced at each of the higher pressures. A typical regime is shown in Figure 6. The deflections of one zone of a wall over this range of pressures is shown in Figure 7, and Figure 8 depicts the cyclical deflections of a wall during a typical cycle. After the build-up of pressure, (A to B) the pressure and deflection remain constant for a period (B to C) and then upon the opening of the exhaust valve (C) there is an exponential decay (C to D) until the pressure is applied in the opposite direction (D).

REFERENCES

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3. British Standards Institution. Wind Loads, CP.3: Ch. V: Part 2: 1972.

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TABLE 1—Sequence of Events for 1st Half Cycle

Cam 1	Cam2	Pressure	P1	Inlet Solenoid	Inlet Valve	P2	Relay A	a1	a2	Exhaust Solenoid	Exhaust Valve	Cam 3	Cam 4
Open	Open	Zero	Closed	Dead	Closed	Open	Dead	Closed	Open	Dead	Closed	Open	Open
Closes	Open	Increases	Closed	Energised	Opens	Open	Dead	Closed	Open	Dead	Closed	Open	Open
Closed	Open	Max	Open	Dead	Closed	Closed	Energised	Open	Closed	Dead	Closed	Open	Open
Closed	Open	Holding	Closed	Dead	Closed	Open	Energised	Open	Closed	Dead	Closed	Open	Open
Opens	Open	Holding	Closed	Dead	Closed	Open	Dead	Closed	Open	Dead	Closed	Open	Open
Open	Closes	Falls to Zero	Closed	Dead	Closed	Open	Dead	Closed	Open	Energised	Opens	Open	Open

N.B. Sequence of events for second half cycle is identical for Cams 3 and 4.

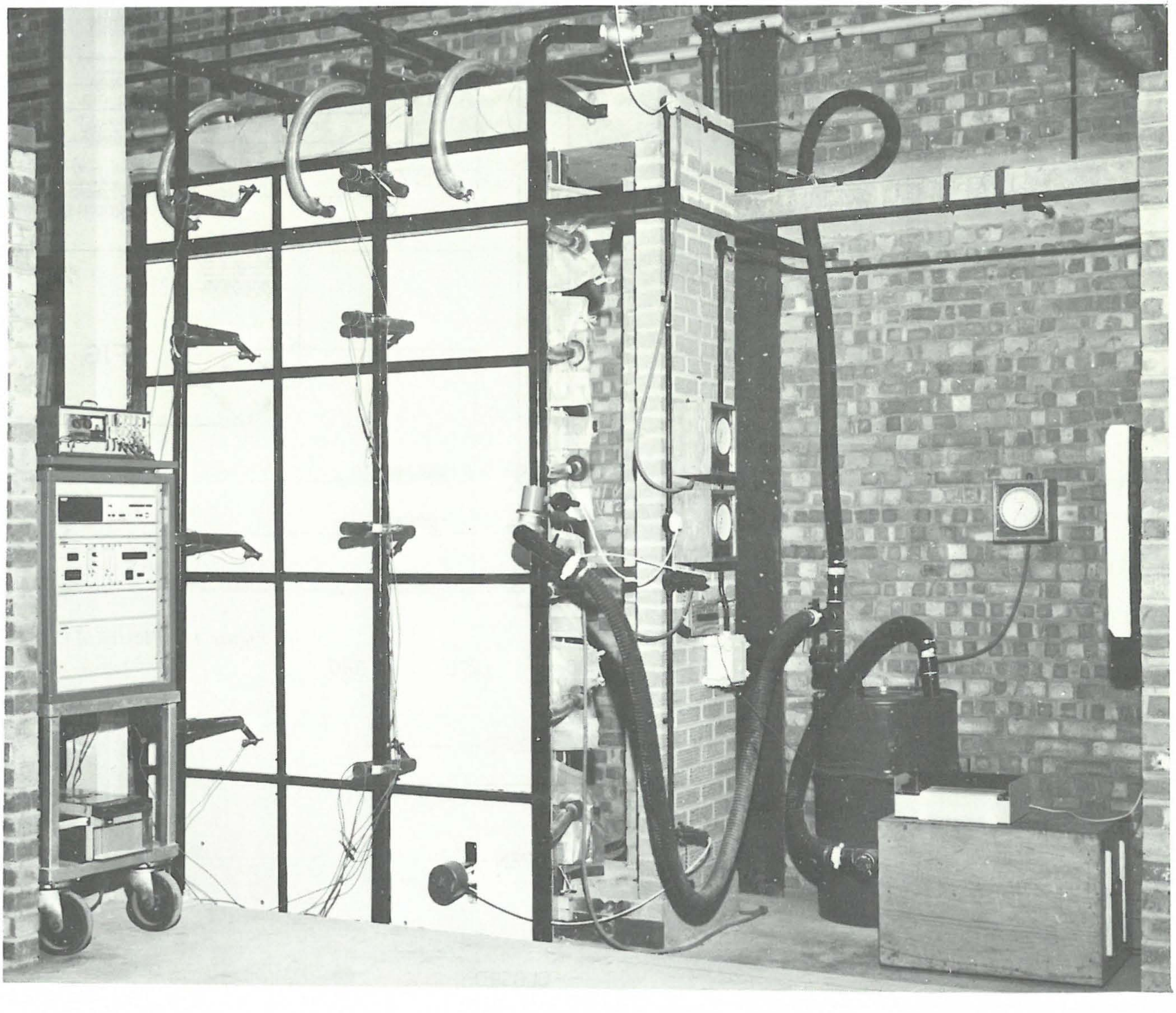

Figure 2. Test in Progress

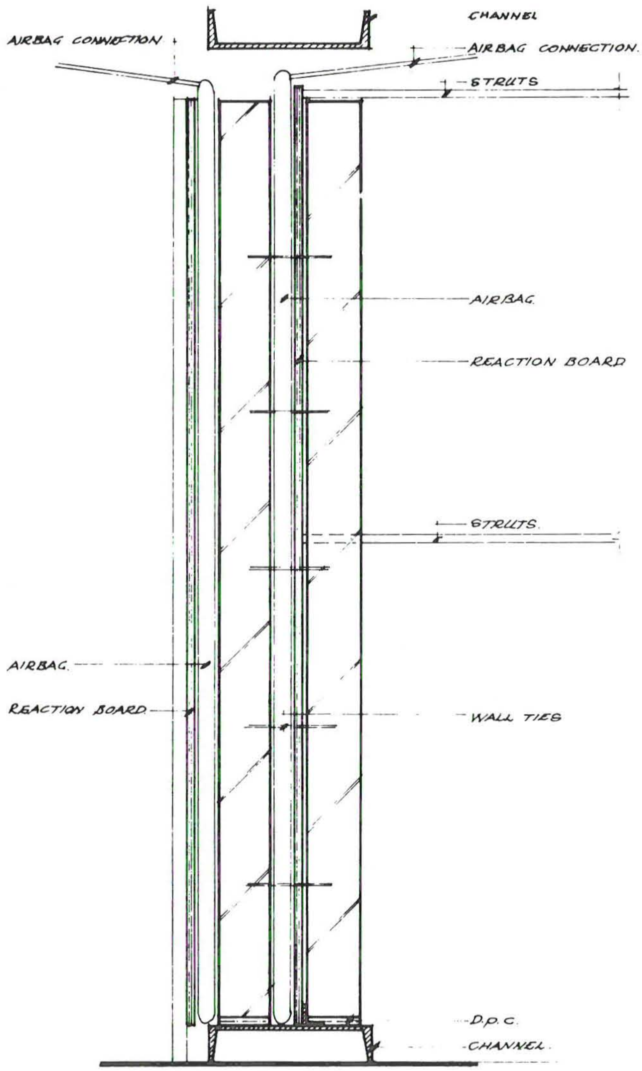

Figure 1. General Arrangement of Test Wall

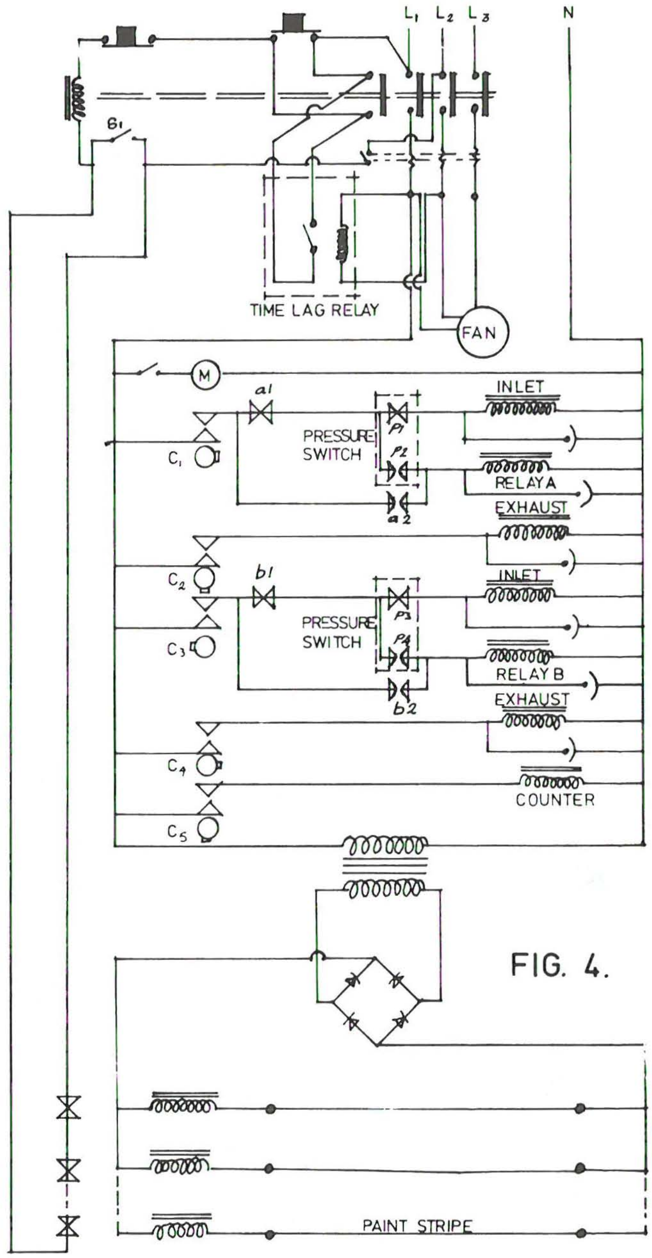

Figure 4. Electrical Circuit

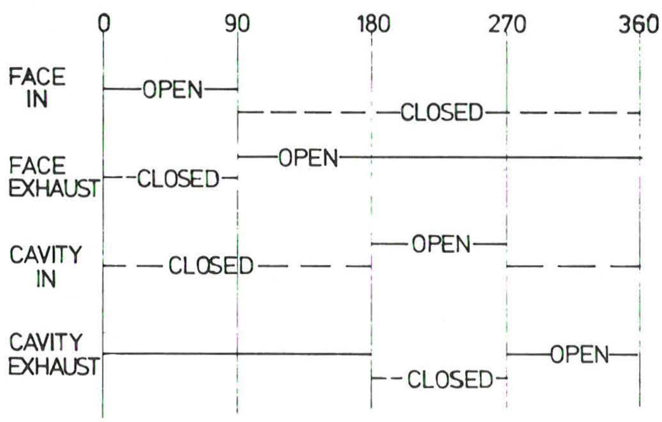

Figure 5. Sequence of Events

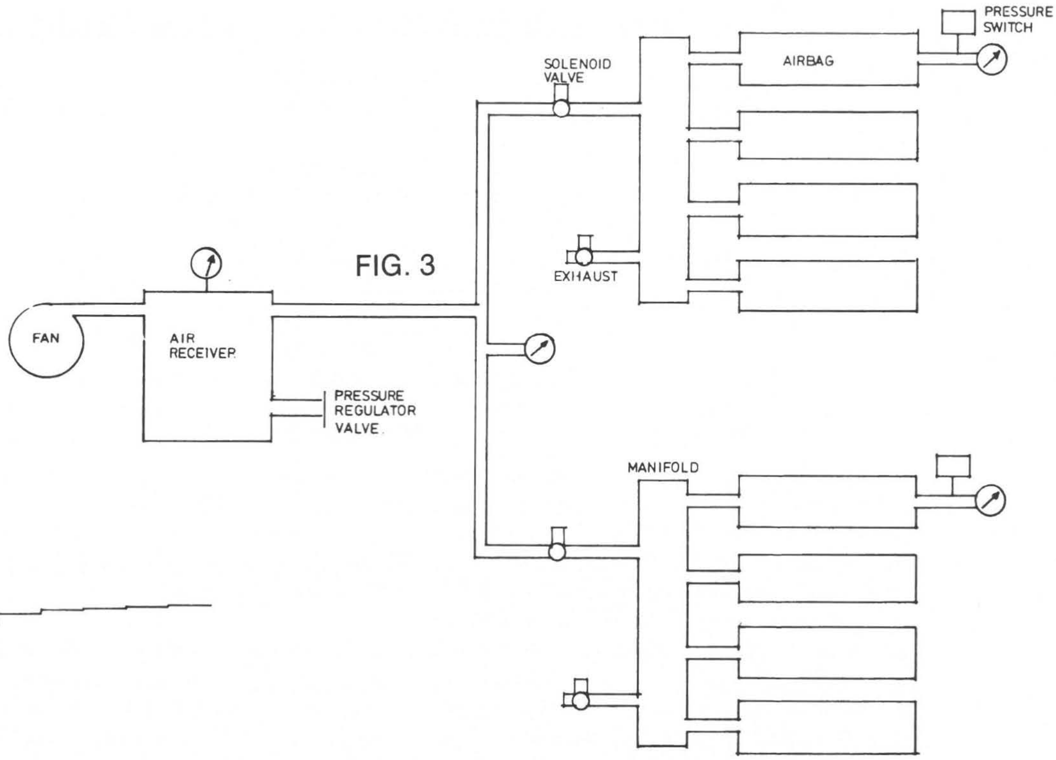

Figure 3. Pneumatic Circuit

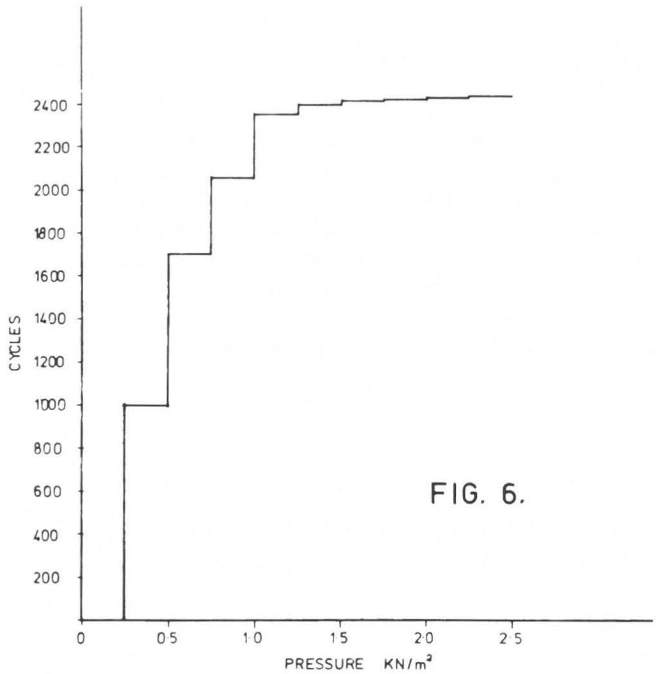

Figure 6. Typical Pressure and Cycles Regime

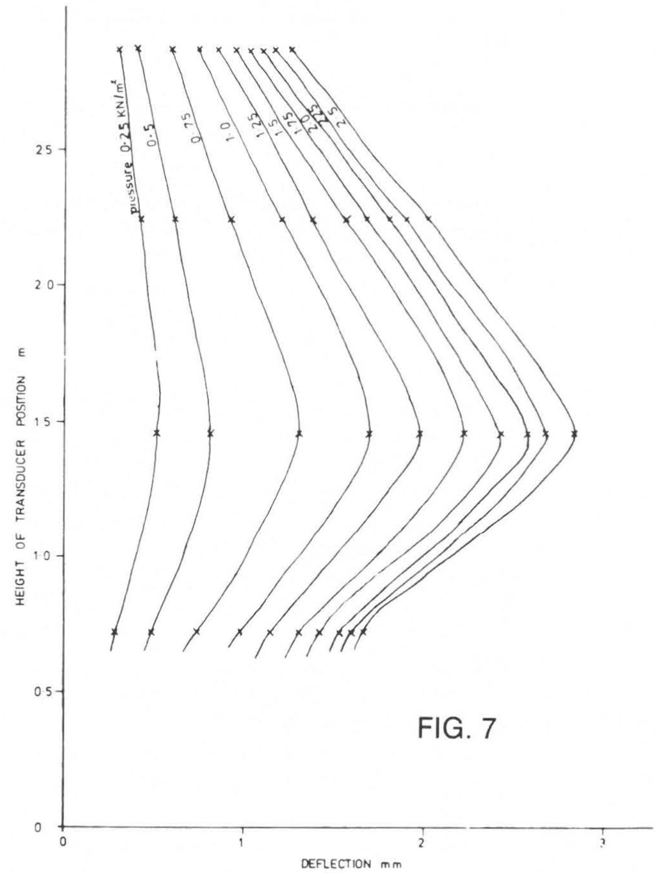

Figure 7. Wall Deflection Diagram

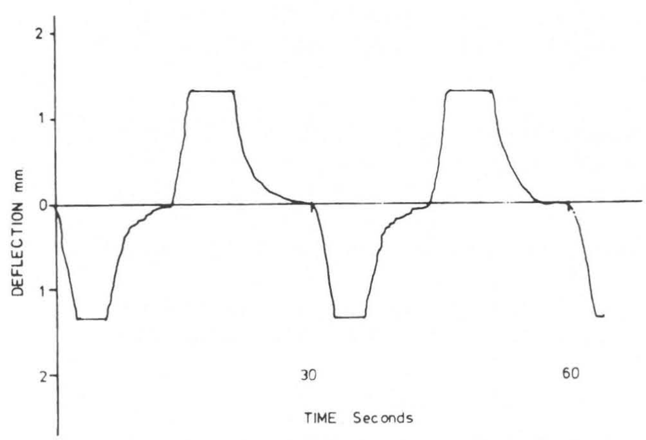

Figure 8. Cyclic Deflection Diagram