CHANNEL TUNNEL:

PASSENGER REACTION TO PRESSURE TRANSIENTS

FINAL REPORT

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EXECUTIVE SUMMARY

This report describes laboratory tests carried out under carefully controlled conditions with volunteers who were subjected to simulations of pressure variations associated with travelling aboard a shuttle train through the Channel Tunnel. Questionnaires were answered with regard to the unpleasantness in comfort terms of the pressure variations experienced at particular intervals during 3 different journeys. Not until after each test was any mention made of Channel Tunnel. Finally, after each test, the subjects were asked to indicate the degree of discouragement they felt with regard to making further journeys. At this point, they were asked to consider the experience to have been part of (i) a BR InterCity journey (ii) a Channel Tunnel journey (iii) an extended express Underground journey (iv) a trans-Alpine Tunnel journey.

On a scale of 1 to 7, with 1 labelled "not at all unpleasant" and 7 labelled "extremely unpleasant", the mean rating of all 30 volunteers was assessed. For the datum journey (Case A), which represented a severe but reasonably likely situation involving the addition of pressures from trains passing in the two running tunnels at the same time as passing beneath the English coastal ventilation shaft, the mean rating assessed at the end of the journey was 2.13. At the most unpleasant phase of the journey (coinciding with actually passing beneath the shaft, the mean rating over all subjects was, however, 3.53. At the time, 3 out of the 30 (i.e. 10%) marked rating '7', and 4 (13%) marked rating '6'. This therefore must constitute a serious event, and subsequent discussion with Mott Hay and Anderson has considered closing the ventilation shaft connection to the main running tunnels during normal operation so as to remove the main component of this pressure transient. This would seem a quite feasible action to take. It is assumed that a similar modification would be made to the French shaft. If such an improvement to the pressure conditions can be made, then the general tenure of the subjective response to the datum Case A journey must be considered acceptable.

Journey Case B was an artificially amplified version of Case A in terms of pressure, and was intended to give an indication of a hypothetical worse case if various design and operating decisions (as yet unknown) summated to give more extreme values of pressure. The corresponding ratings to the Case A values given above were 2.30 for the mean rating taken over all

subjects at the end of the journey, and 4.10 for the mean rating taken over all subjects for the critical Section 2. For Section 2, 5 out of the 30 (17%) marked rating '7', and 3 out of the 30 (10%) marked rating '6'. Thus, the Case B result strongly supports the proposal to close off the coastal shaft connection to the running tunnels during normal operation.

Journey Case C represented a generally less severe case and gave a mean rating over all subjects at the end of the journey of 2.10.

When referred to a Channel Tunnel context for the simulated journeys as well as the three other journey scenarios, the discouragement rating with regard to making a Channel Tunnel journey was higher than for a BR InterCity journey or for a non-stop Underground express, but lower than for a trans-Alpine rail journey. With regard to the latter, it is considered that the high relative rating mainly reflected the fact that the car-carrying wagons on the Alpine route were open-sided and unlit. One person out of 30 (3%) said after Case A that the pressure fluctuations would prevent them from making the journey again.

In overall terms, the conclusion from this work is that the pressure conditions are not unacceptable but that a significant improvement would occur if the coastal ventilation shafts could be closed off from the main running tunnels during normal operation.

1.0 INTRODUCTION

When trains enter and pass through a tunnel, rapid pressure fluctuations are experienced in the tunnel and on board the trains. The amplitude and general character of these pressure transients are strongly dependent on train speed, the blockage ratio of the train cross-section within the tunnel, the interaction of the pressures with those caused by other trains in the tunnel system, and a number of other features concerned with the train and tunnel geometrics.

Passengers on board these trains will experience these pressure changes mainly as sensations in the ear. Previous work on this topic (refs. 1, 2) has shown that individual people vary considerably one to another on the degree of discomfort felt. A small percentage of the public can find such effects really quite unpleasant whilst others will experience very little discomfort at all.

For the Channel Tunnel project, it is clearly important that a minimal number of the travelling public should find the pressure fluctuations unacceptable during their journeys through the tunnel. As a result, Transmanche-Link decided to initiate a subjective test with volunteers exposed to a laboratory simulation of the pressure conditions predicted to occur during tunnel operation. Because of their previous experience in this field, British Rail Research were commissioned through Transmark to undertake the work in their Transient Pressure Chamber at Derby. The Institute for Consumer Ergonomics, affiliated to Loughborough University of Technology, were sub-contracted by BR Research to attend to the ergonomic aspects of the tests, recruitment of the subjects and to the statistical analysis of the results.

The object of the tests was primarily to subject the test volunteers to simulations of the pressure conditions existing during three types of tunnel journey. These would cover both typical and severe pressure situations. The subjects would be asked to respond to a questionnaire concerning the degree of unpleasantness of the pressure transients and the degree of discouragement they caused with regard to making further journeys.

The pressure histories for the three simulated journeys through the Tunnel were determined by a sophisticated computer-based prediction method by Mott Hay and Anderson.

This report describes the study in detail. Section 2 contains a description of the Pressure Chamber and its operation and the test procedure adopted.

Section 3 describes the results of the tests and includes discussion and interpretation of the results in the context of the Channel Tunnel project.

Section 4 provides the conclusions.

2.0 EXPERIMENTAL METHOD

2.1 The Pressure Chamber

The British Rail Transient Pressure Chamber, located in the Structures Laboratory of the Research Division, was constructed in 1971 and has been subsequently developed specifically to investigate human response to transient air pressures. It is a rectangular steel-framed box approximately 2 m high and 1.4 m square with large windows and has seating for two test subjects (Fig 1). Above a perforated ceiling, the roof of the chamber comprises a set of bellows which is operated by a vertically mounted hydraulic ram. The ram is powered from the laboratory hydraulic circuit and is controlled via a servo-controller with either ram position or chamber pressure feed-back by electrical signals from a tape recorder. The fast response of the ram displacement, together with a linked variable pressure ventilation air outlet valve, allows a faithful reproduction of the specified pressure changes to be generated in the chamber after appropriate adjustment of the gain in the signal conditioning equipment.

Various safety devices are built into the chamber and control system to prevent excessive pressure changes and rates of pressure change being experienced inside.

A relatively high impedance fan and choke arrangement is used to ventilate the chamber with filtered air at a nominal flow rate of 6 l/s which varies by only ± 15% throughout the range of pressure transients reproduced in these tests.

A loudspeaker and microphone in the chamber enables communication between the subjects and the tester outside. Two emergency stop buttons are provided, one within the chamber and one outside close to the operator. Pressing either button isolates the hydraulic control system preventing further pressure changes, but does not release the door which has to be manually opened from the outside. As a precaution, therefore, at least two competent people are always present within the area when tests with subjects are in progress.

FIG. 1.

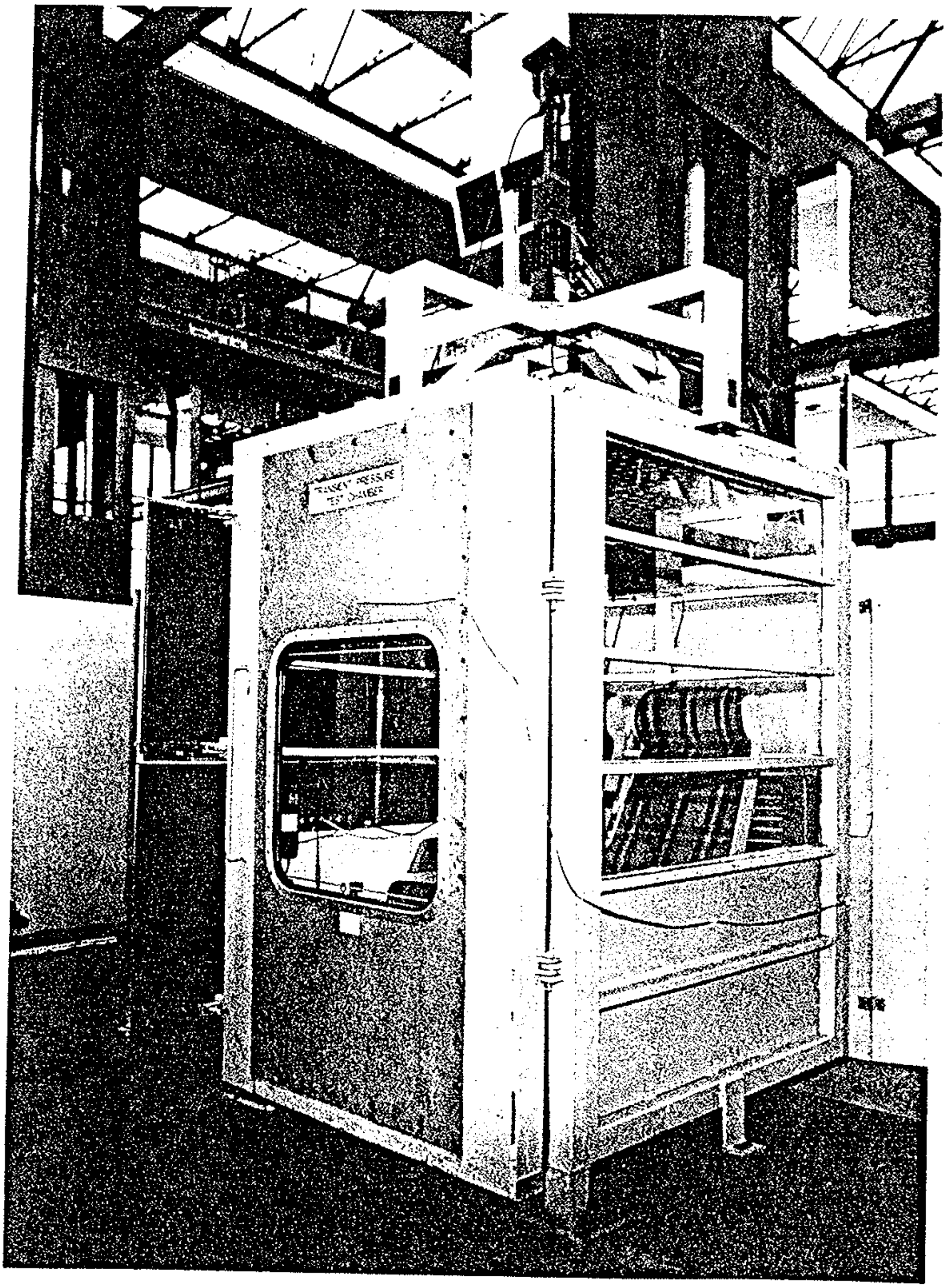

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FIG. 1. DERBY TRANSIENT PRESSURE TEST CHAMBER

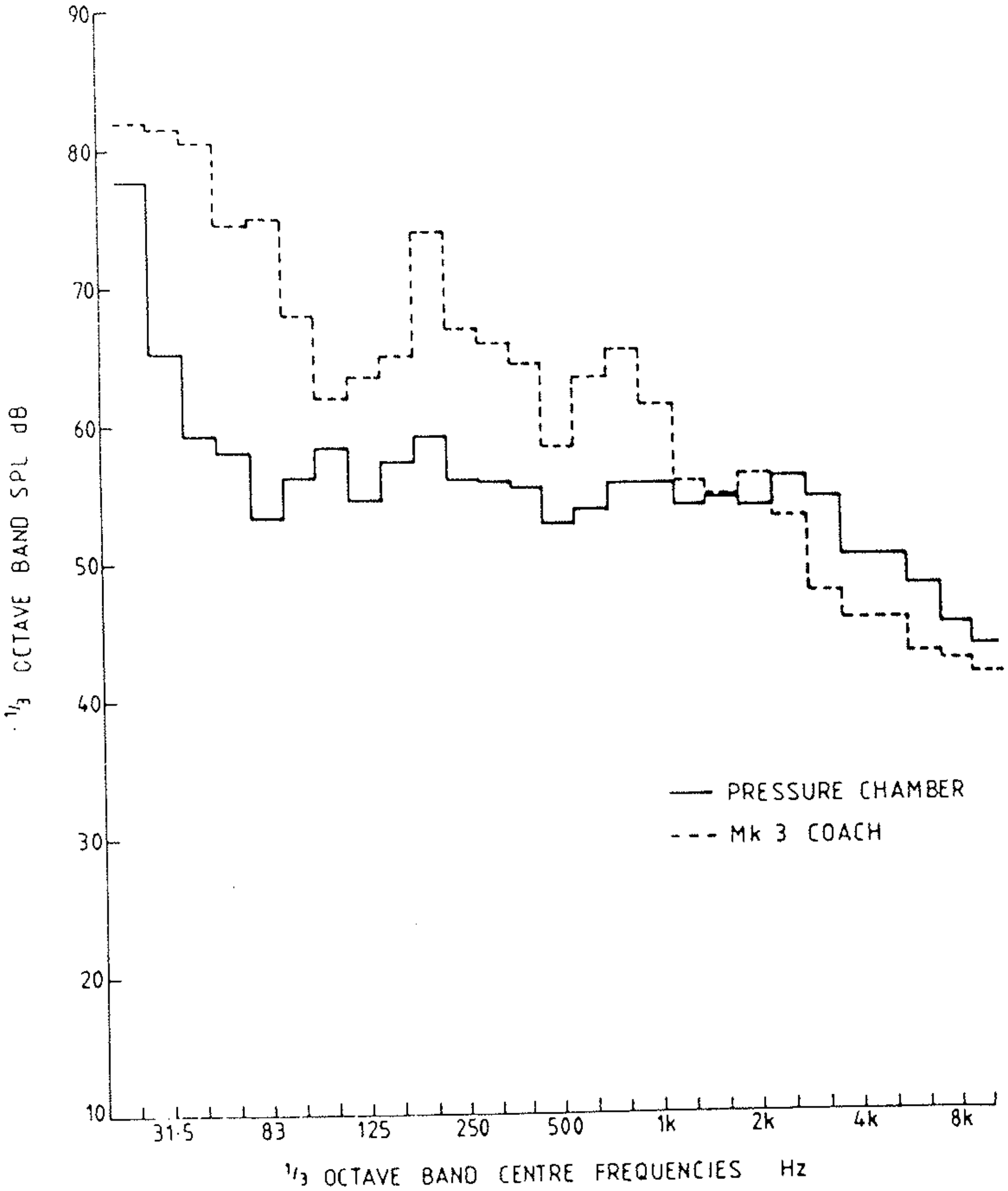
2.2 Chamber Operation

The chamber was well ventilated. Nonetheless, out of consideration for their fellow subjects in such a confined space, subjects were asked to refrain from smoking during the trials.

For these tests the communications loudspeaker was also used to feed white noise of a particular intensity to the chamber to mix with the inherent noise of the laboratory and of the chamber operation and thus simulate the intensity of noise within a train carriage over the important range of audible frequencies. It was felt preferable to provide broad band noise rather than to attempt (perhaps inaccurately) to simulate the likely train sound. Figure 2 shows the mean of the 1/3 octave band sound pressure levels measured in the chamber during the simulation of a 15 minute section of a journey with two people sat inside. Also shown is a typical sound level measurement inside a BR Mark III coach travelling at 200 km/h in the open air.

At the beginning of each test the ventilation system was used to slowly raise the pressure in the chamber, over a period of 4 minutes, to 3 kPa above atmospheric pressure. This improves the performance of the bellows and eliminates the noise which would be generated by their flapping when passing between positive and negative pressure differentials. A test proceeded only after the subjects had become acclimatized to the new datum pressure level about which the simulated journey transients were then generated. Before opening the door at the end of the test, but only after the subjects had completed their questionnaires, the chamber pressure was slowly reduced to atmospheric pressure.

For these tests, Mott, Hay and Anderson specified three pressure histories to simulate three different types of journey through the Channel Tunnel. The data for the pressure histories was supplied to BR as digital magnetic tape recordings which were used to produce analogue signals for recording on the chamber control magnetic tape.



NOISE LEVELS INSIDE THE PRESSURE CHAMBER OPERATING WITH TWO OCCUPANTS COMPARED WITH TYPICAL NOISE INSIDE A Mk 3 COACH TRAVELLING AT 200 km/h IN OPEN AIR

FIG.2. SOUND PRESSURE LEVELS MEASURED IN CHAMBER

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In the chamber a digital counter showed the subjects the number of the section of the tunnel through which they were travelling. This was also the number of the question which they should answer at the end of that section. A description of how each journey was assessed as ten consecutive sections is given in 2.3, Simulated Journeys, below. The loudspeaker in the chamber was used to provide an auditory cue for answering the question at the end of each tunnel section.

The command signals for the number indicator and the auditory cues were recorded alongside those for the pressure variations of the simulated journeys on a four track magnetic tape. This tape was played back through a Store-4 tape recorder to control the tests. A pressure transducer in the chamber was used to provide a feed-back signal for the servo-controller. The chamber pressure signal was also continuously fed to a pen recorder to give a permanent record of the pressure history experienced by each of the subjects.

2.3 Specification of Simulated Journeys

The three journeys chosen for simulation in the tests represented firstly (Case A) a typical journey in busy traffic conditions with a mixture of shuttle and through trains operating in both running tunnels. The pressures represented those felt by a passenger positioned near the front of a shuttle train, travelling from England to France. The speed profile of the train was that corresponding to a constant traction power output, and a maximum speed of approximately 160 km/h was reached for part of the journey. Though a typical journey, the phasing of the timings of the trains in each running tunnel was chosen in Case A to produce a severe superpositioning of pressure waves from the trains coinciding with the large pressure variation caused when the train passes beneath the first coastal ventilation shaft.

The second chosen journey (Case B) is a hypothetically worse case than Case A assuming that various contingencies, involving increased train drag and hence pressure, materialize and summate to produce a worst case. The same speed profile and superposition situation is assumed as in Case A so as to give a pressure history for Case B that is a 25% augmented version of Case A.

The third journey (Case C) assumes a constant train speed throughout of 130 km/h. It is considered to operate as before in a busy traffic situation with other trains also travelling at 130 km/h constant speed in the other running tunnel. Case C constitutes a less severe case in pressure terms than the datum Case A.

All journeys simulated the England to France direction as a higher pressure is reached at the coastal shaft position for this case. Each tunnel transit time was approximately 25 mins. Figures 3 to 5 show the pressure histories experienced for the three cases.

An auditory cue fed into the chamber marked the division of the journey into ten sections for separate assessment. The occurrence of these cues is marked on the Figures 3 to 5 as a heavy vertical line, through the pressure plot. The subjects assessed each of the ten sections individually and also each journey as a whole at the end. The section numbers appeared on a digital display inside the chamber as the journey progressed. The sequence of presentation of the three journeys was varied so as to minimize order effects.

FIGURE 3:
Case A.

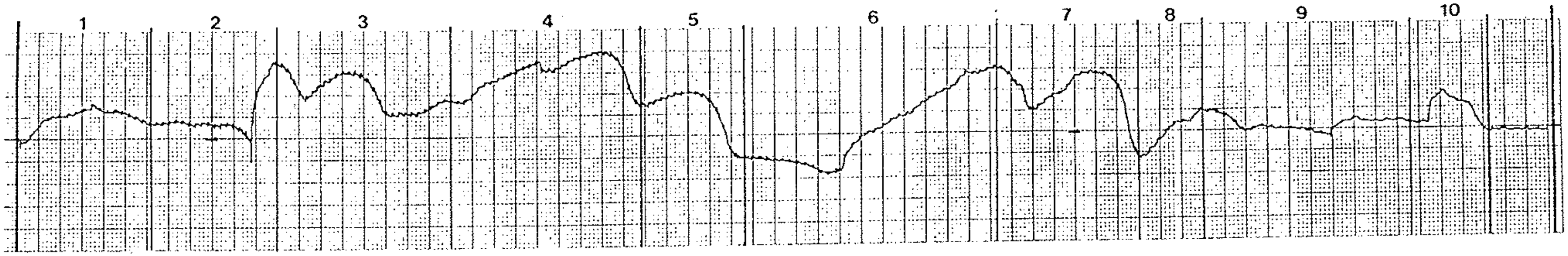


FIGURE 4:
Case B.

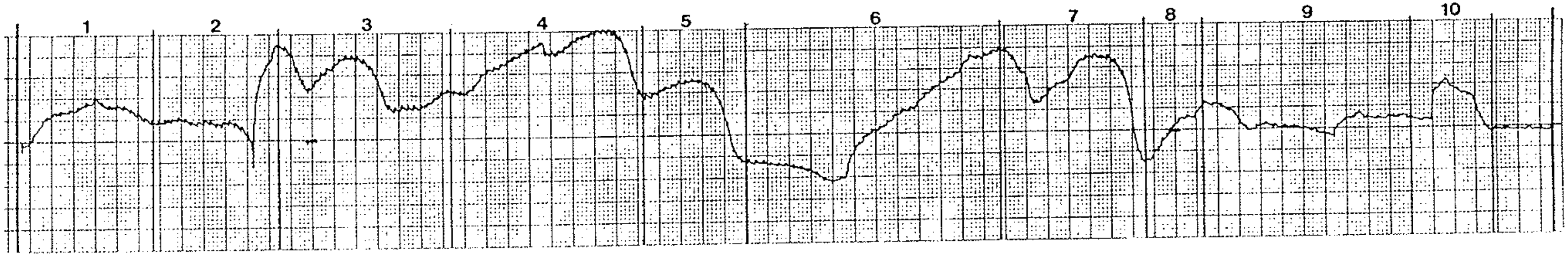
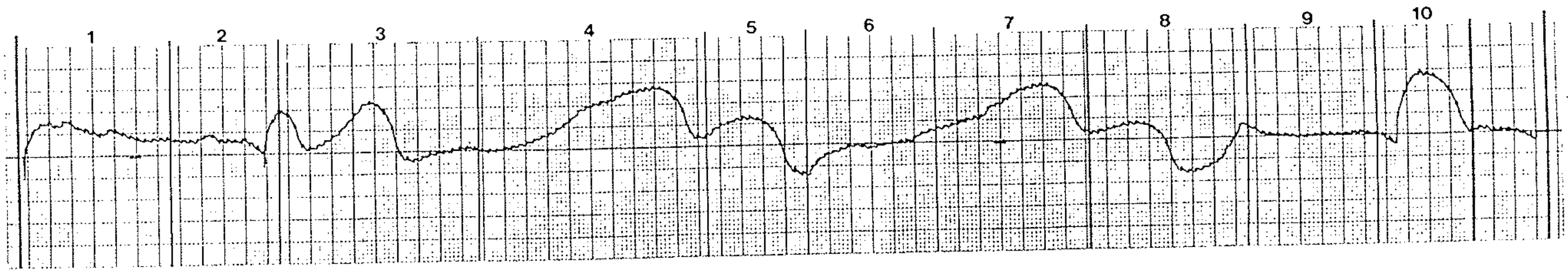


FIGURE 5:
Case C.



SCALE: Vertical 5mm = 1 kPa.
Horizontal 5mm = 20 seconds.

2.4 Questionnaire

The response of subjects was gathered using a questionnaire with questions after each of the 10 sections in a journey and then after the whole journey.

The question immediately after each section was:

How unpleasant, if at all, did you find that section of the journey?

Not at all unpleasant								Extremely unpleasant

The subjects responded by ticking the box on the scale appropriate to their experience.

A similar question was also asked after the journey:

Give an overall rating for the whole of that journey

Not at all unpleasant								Extremely unpleasant

The subjects were not told up to this point that the test had anything to do with Channel Tunnel, so as to avoid any pre-conceived bias being registered in the results. However, it was clearly important at some stage afterwards to obtain an assessment from the subjects of their response in the specific context of Channel Tunnel in case this modified their general feeling of how acceptable the conditions were. So as to put the Channel Tunnel scenario into perspective, the subjects were also asked to imagine three other scenarios, at least one of which was likely to be one that they had actually experienced. They were then asked how discouraged they would be from making the journey had it been like the simulation they had just experienced.

The questions were set out as below:-

We would like you to consider that the simulated journey you have just experienced was an actual train journey made by you and your family on holiday. Please complete the questions for the four such holiday journeys outlined below.

You and your family sitting in a BR InterCity train travelling on a main-line route.

(i) To what extent, if any would the pressure fluctuations experienced discourage you from making this journey again?

Not at all discouraged								Extremely discouraged

(ii) Would the pressure fluctuations you experienced prevent you from making this journey again?

Yes	
No	

You and your family sitting in your car in a fully enclosed rail vehicle travelling through the Channel Tunnel from France to England.

(i) To what extent, if any, would the pressure fluctuations experienced discourage you from making this journey again?

Not at all discouraged								Extremely discouraged

(ii) Would the pressure fluctuations you experienced prevent you from making this journey again?

Yes	
No	

You and your family sitting in a metro train travelling on a non-stop underground express journey.

(i) To what extent, if any, would the pressure fluctuations experienced discourage you from making this journey again?

Not at all discouraged								Extremely discouraged

(ii) Would the pressure fluctuations you experienced prevent you from making this journey again?

Yes	
No	

You and your family sitting in your car secured to an open-sided and unlit railway wagon travelling under the Alps from Switzerland to Italy.

(i) To what extent, if any, would the pressure fluctuations experienced discourage you from making this journey again?

Not at all discouraged								Extremely discouraged

(ii) Would the pressure fluctuations you experienced prevent you from making this journey again?

Yes	
No	

2.5 Test Procedure

Thirty subjects successfully completed the trial, both males and females aged between 18 and 65 years.

Prior to the tests the subjects were questioned on their medical history relating to the ears, nose and throat to ensure they had no chronic ear ailments. Then a visual inspection of the eardrums and an audiometry test was carried out by a qualified nurse to ensure that there were no defects in the eardrums.

The subjects were then seated in the chamber and the experimental procedure and questionnaire described. Subjects were particularly discouraged from discussing between themselves their reactions to the journey so that they would not influence each other's responses.

If there were no questions at that point the pressure chamber door was shut and the internal pressure slowly raised to the operational datum of 3kPa above atmospheric pressure. After ensuring the subjects were ready, a short practice was given to familiarize them with the test procedure and answering the questionnaire. The first five minutes of Case C was used, with five audio cues and section numbers superimposed. Following the familiarization run their first case was presented. Afterwards, the subjects were allowed out of the chamber for a refreshment break before re-entering to experience their second case. The third case was presented after a similar break.

During the trial the subjects were allowed to read magazines and talk to each other, but were asked not to discuss their reactions to the test conditions so that they did not affect each other's judgement.

At the end of the experimental session the subjects had a second audiometry test before departing.

3.0 RESULTS AND DISCUSSION

Table 1 on the following page presents the results of the unpleasantness ratings for all sections of the three cases studied and also for the overall assessments. As well as presenting the frequencies of scores within each assessment, values for the mean, standard deviation and median are also given.

The rating distributions for all sections are shown in cumulative bar form in Figures 6a and b which follow after Table 1. The median line is shown and its value is that between the 15th and 16th score.

Differences in journey pattern and sectioning between Cases A/B and Case C means that some sections in Case C (6, 7 and 8) cannot be meaningfully compared with those in either Case A or Case B. However, although some other sections in Case C are of a different time interval to the comparable section in A and B the pressure histories are considered sufficiently similar in character, to allow comparison. All sections in Cases A and B are directly comparable between cases as the only difference is in the amplitude of pressure changes.

TABLE 1: The Mean (average,) Standard Deviation and Median values for the ratings of unpleasantness.

Section		Mean	Standard deviation	Median values	Rating Frequency 1	2	3	4	5	6	7
Case A	1	1.50	1.04	1	21	6	2	0	0	1	0
	2	3.53	1.83	3	2	9	7	5	0	4	3
	3	1.66	1.27	1	19	7	2	1	0	0	1
	4	1.57	0.94	1	19	7	3	0	1	0	0
	5	2.17	1.34	2	12	9	4	3	1	1	0
	6	2.23	1.50	2	13	8	3	2	3	1	0
	7	2.50	1.57	2	11	7	4	3	4	1	0
	8	1.57	1.10	1	22	3	2	2	1	0	0
	9	1.43	0.94	1	22	6	0	1	1	0	0
	10	1.97	1.25	2	14	8	6	0	1	1	0
Overall		2.13	1.33	2	10	13	4	1	1	0	1
Case B	1	1.57	1.04	1	20	7	0	2	1	0	0
	2	4.10	1.79	3.5	0	6	9	4	3	3	5
	3	2.07	1.14	2	11	12	2	4	1	0	0
	4	2.17	1.29	2	12	9	3	4	2	0	0
	5	2.13	1.36	2	14	6	4	5	0	1	0
	6	2.17	1.12	2	9	13	3	4	1	0	0
	7	2.60	1.22	2	3	15	8	0	3	1	0
	8	1.33	0.66	1	22	7	0	1	0	0	0
	9	1.30	0.65	1	23	6	0	1	0	0	0
	10	1.73	0.64	2	11	16	3	0	0	0	0
Overall		2.30	0.95	2	6	13	7	4	0	0	0
Case C	1	1.83	1.09	2	14	10	5	0	0	1	0
	2	2.17	1.77	2	8	15	4	1	1	1	0
	3	1.80	1.13	1	16	8	4	0	2	0	0
	4	1.57	0.77	1	17	10	2	1	0	0	0
	5	1.53	0.82	1	19	7	3	1	0	0	0
	6	1.40	0.67	1	21	6	3	0	0	0	0
	7	1.57	0.97	1	19	8	1	1	1	0	0
	8	2.50	1.22	2.5	7	8	11	2	1	1	0
	9	1.27	0.58	1	24	4	2	0	0	0	0
	10	2.63	1.50	2	8	8	7	3	2	2	0
Overall		2.10	1.12	2	11	10	5	3	1	0	0

FIGURE 6a: RATING DISTRIBUTIONS
Cases A & B

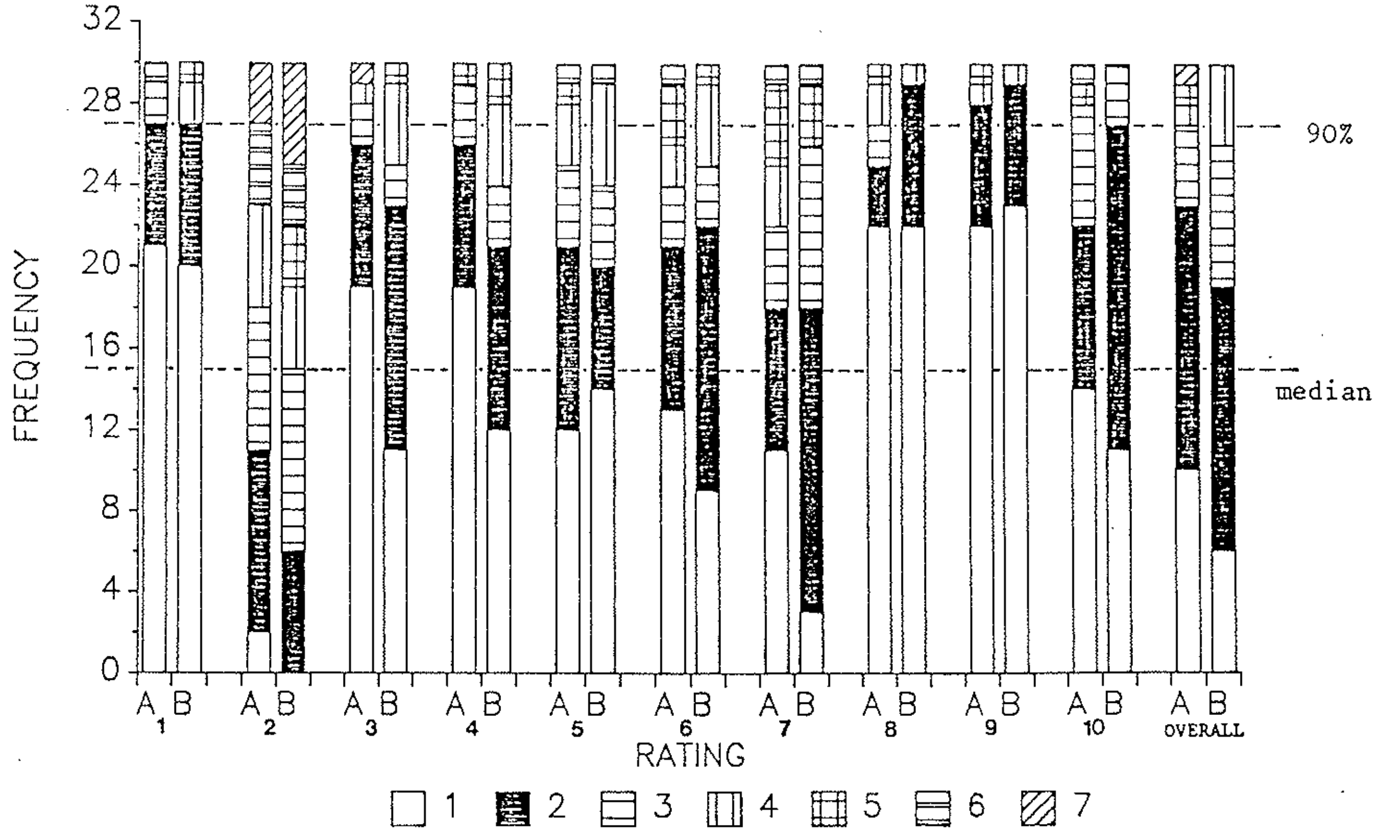
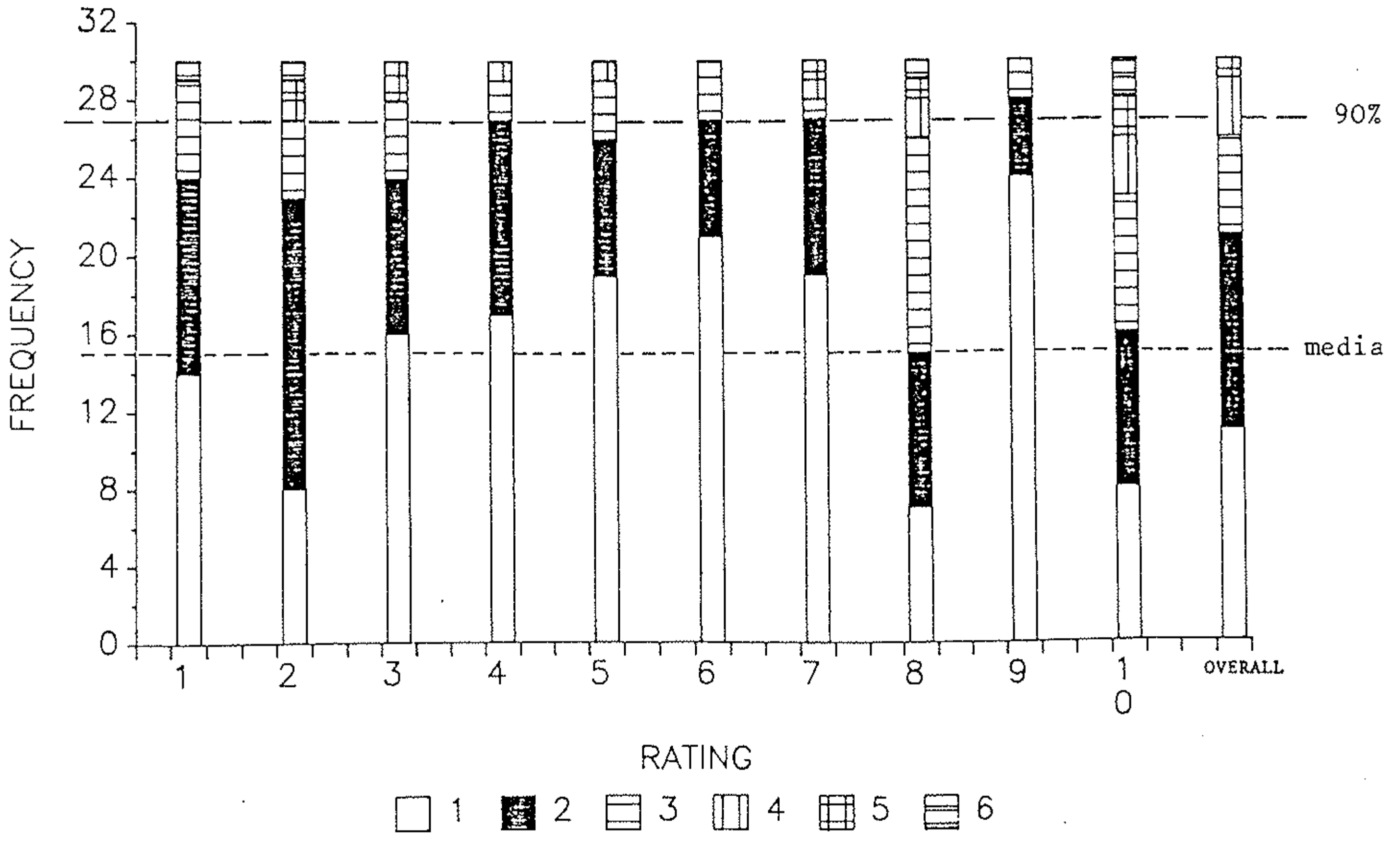


FIGURE 6b: RATING DISTRIBUTIONS
Case C



There are a number of ways in which these data can be considered, the principal ones being in terms of the central tendancy (means, median) and extreme values (upper centiles).

The calculated mean rating scores are plotted for the three cases on Figures 7a and b following this page. (Since Cases A and B are directly comparable by section they are shown on the same figure to allow easy visual comparison). Probably the most striking features are the high scores given to section 2 of Cases A and B (passing the coastal shaft). The scores attributed to the same section (2) of Case C have resulted in a much less severe rating. A statistical test applied to these results showed the differences to be highly significant. The same test (Wilcoxon matched pairs, Ref.3) was applied to all comparable pairs of sections and the significance results are presented in Table 2.

TABLE 2: <u>Statistical Significance of Differences Between Mean Rating Values (Wilcoxon Matched Pairs Test).</u>

Section	A v B	A v C	B v C
1	ns	ns	ns
2	0.01	0.01	0.01
3	0.05	ns	ns
4	0.05	ns	0.01
5	ns	0.01	0.01
6	ns	-	-
7	ns	-	-
8	ns	-	-
9	ns	ns	ns
10	ns	0.05	0.01
Overall	ns	ns	ns

The value given in the Table is the probability of the result occurring purely by chance.

ns = not significant (>0.05)

\- = sections not comparable

FIGURE 7 a: MEAN RATINGS FOR ALL SECTIONS
Cases A & B

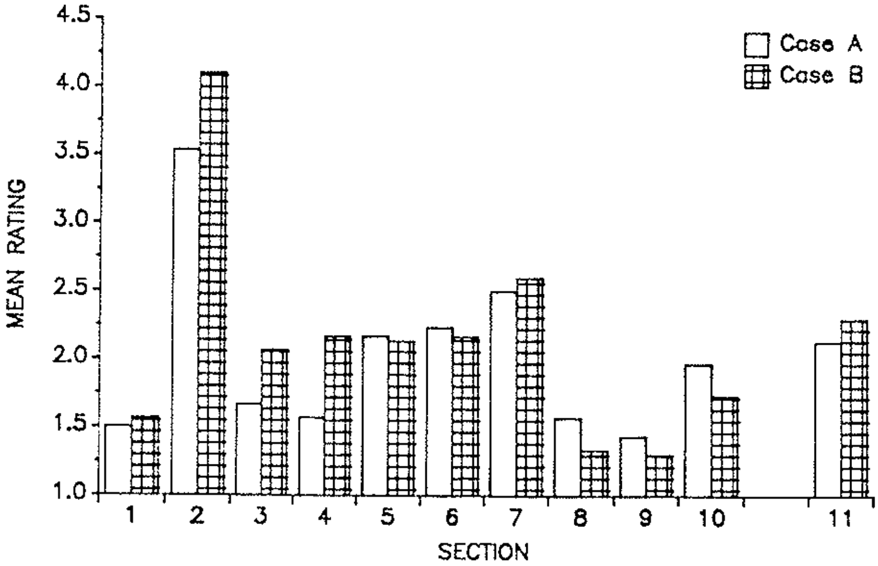
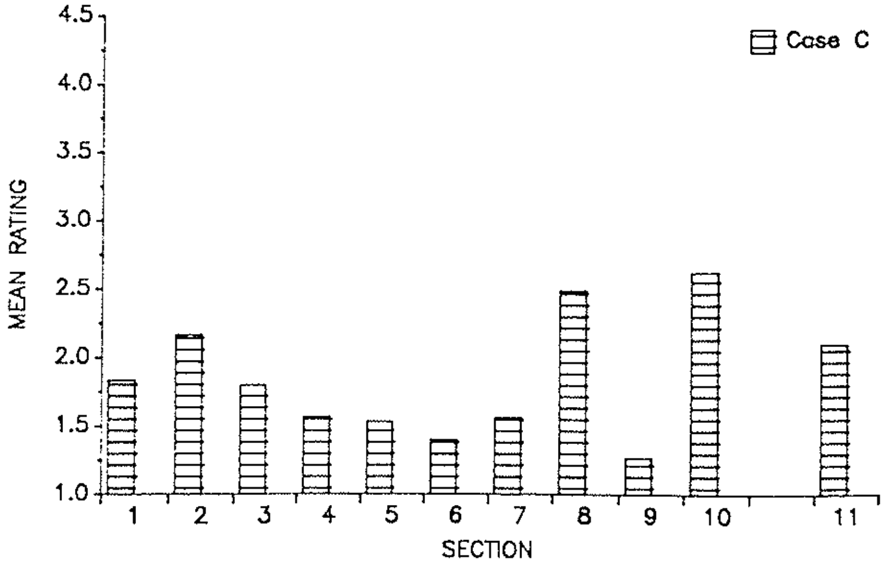


FIGURE 7 b: MEAN RATINGS FOR ALL SECTIONS
Case C

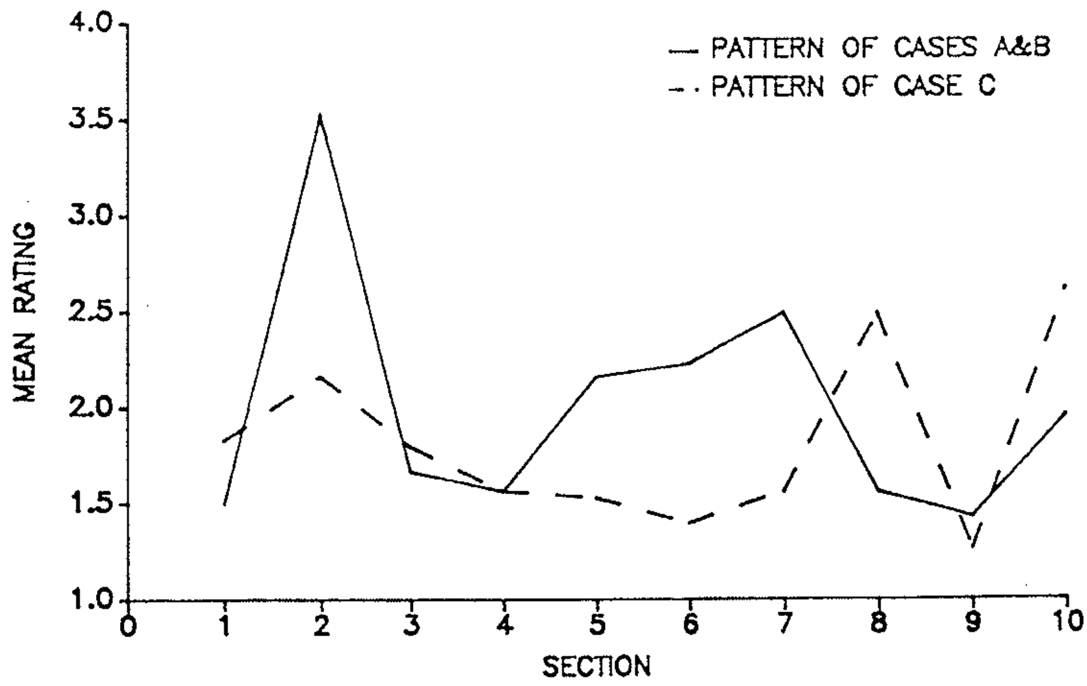


The significance tests largely confirm the impressions that may be drawn by inspection. In terms of the comparison of Case A with Case B the 25% increase in pressure amplitude has resulted in significantly more unpleasant sensations for sections 2, 3 and 4. A priori, one may have expected an increase in unpleasantness ratings across all sections for Case B (increased pressure amplitude). This has not occurred, at least to a significant extent, in terms of the mean values. This is logical for those sections which have little pressure change as they will have only marginally greater pressure effect (in an absolute sense) in Case B than in Case A.

Comparison of Case C with Cases A and B shows that it was significantly less unpleasant than A and B in sections 2 and 5 and 2, 3 and 5 respectively. However, it was considered to be significantly <u>more</u> unpleasant than A and B in section 10. As already noted, the comparison of the individual sections of Case C with those of the other cases is not altogether meaningful.

Nevertheless, the general pattern of the mean rating values for all cases has some similarities and is sketched in Figure 8 heading the following page. Upon entering the tunnel, a generally acceptable pressure transient is produced (although Case C is marginally worse than either A or B) and there is a sharp increase in rated 'unpleasantness' as the train passes the coastal shaft (Case C clearly much more acceptable than either A or B). The ratings then drop during sections 3 to 6 with a sharp rise at 7 (A and B) and 8(C). Following this peak, the ratings plunge to the journey minima values (section 9) before rising for section 10.

FIGURE 8: PATTERN OF MEAN RATINGS ACROSS THE THREE CASES



The mean values calculated from the overall ratings given for the whole journey showed no significant differences, although Case B was marginally 'worse' than A and C. Such 'overall' assessments are often susceptible to influence by the more recent events. In this instance, the relatively severe sections of Case C (8 and 10), occurring immediately before the overall assessment was made, may have resulted in a slightly higher rating. Conversely, the occurrence of the less severe sections 8, 9 and 10 (Cases A and B) just before the overall judgement may have resulted in slightly lower ratings than may have been expected given the responses to the earlier sections (in particular section 2).

The foregoing discussion has been concerned with the calculated mean ratings but a rail operator may be more concerned with the responses of the upper centiles. There are two ways in which this aspect may be best considered; the responses of a stated percentage of subjects, say the top 10%, or the number of people who record above a selected level of 'unpleasantness'. The particular cut-off level is something which will be dependant upon many operational factors, including the quality of service that it is wished to offer the passengers. For instance, the design level of comfort for a prestige service would be higher than that fôr a suburban commuter transport system.

If the three (10%) highest scores for each section are summed and compared between cases the following table is formed (Table 3).

TABLE 3: Summed Top 10% Scores

Case	Section 1	2	3	4	5	6	7	8	9	10	Overall
A	12	21	14	11	15	16	16	13	11	14	16
B	13	21	13	14	14	13	16	8	8	9	12
C	12	15	13	10	10	9	12	15	8	17	13

By inspection of these data a similar pattern to that created by the mean ratings emerges. Of specific interest is section 2 where Cases A and B return maximum scores with three people rating it 'extremely unpleasant'. A total of 5 people (17%) rated Case B as 'extremely unpleasant'. Other sections with high scores are 7 (A and B) and 10 (Case C).

If one considers the number of ratings above a certain level, say 5 or higher, then again, in general terms, a similar picture emerges in terms of relative comfort.

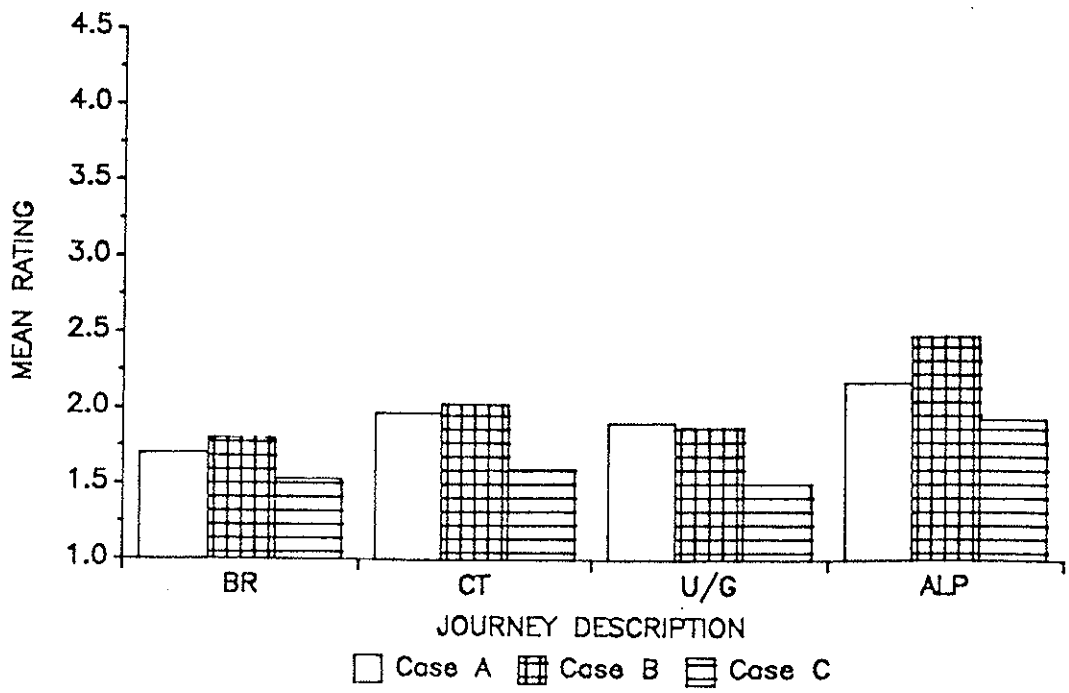
As described in Section 2.4, after a journey was completed, the subjects rated how discouraged they would be from making each of four described journeys if the pressure changes were similar to the case they had just experienced. The ratings were given on a seven point scale, similar to that used for unpleasantness earlier in the questionnaire, such that:

1 = not at all discouraged

7 = extremely discouraged

The results for each case can be compared to each other and the mean ratings are shown in Figure 9 below.

FIGURE 9: MEAN DISCOURAGEMENT FROM TRAVELLING



By inspection it can be seen that Case C is consistently more acceptable than either of Cases A or B across all the scenarios. Similarly it can be seen that the Alpine tunnel is the only scenario for which the mean ratings for Cases A and B appear to differ significantly. Otherwise there is very little difference between the mean rating for these two cases.

A Wilcoxon Matched Pairs Test (Ref. 3) was carried out to check if differences between Cases were statistically significant. The results are shown in Table 4.

TABLE 4: Statistical Significance of Differences Between Cases in Discouragement Ratings of Scenarios

Scenario	Cases Compared		
	A v B	A v C	B v C
InterCity	No Sig.	No Sig.	No Sig.
Channel Tunnel	No Sig.	No Sig.	0.005*
Underground	No Sig.	0.05*	No Sig.
Alpine Tunnel	0.025*	No Sig.	0.025*

* Only four of the differences prove to be statistically significant:

Between Cases B and C for the Channel Tunnel
Between Cases A and C for the underground journey
Between Cases A and B, B and C for the Alpine Tunnel

Table 5: Frequency of subjects claiming that the pressure histories would prevent them from undertaking the journeys described.

	Journey Type			
Case	Inter-City	Channel Tunnel	Underground	Alpine Tunnel
A	1	1	1	4
B	0	0	1	4
C	0	0	1	1

It could be deduced from the above table (Table 5) that Case A was the most severe option as it appears to result in the most people refusing to make the journey. However, it should be noted that there was a single subject who claimed he would not make any of the journeys with this pressure history. He is the same subject who gave an overall rating for Case A of 7. It may be significant that Case A was the first full case he experienced and that his overall rating for Case B (his second journey) was 4. It would be wrong, however, to assume, from this single sample that the first experience of transient pressure waves is considered more unpleasant than when the same history is experienced later in the series. Indeed, the subject who rated Case A as 5 overall experienced this journey as the third case. Detailed analyses of the raw data would be required to determine such an hypothesis.

It should be noted that the experimental design controlled the order of presentation of cases to minimize the order effect and a large number of subjects were used to minimize the effects of any extreme responses from individuals.

From these results Case C gives the least discouraging response to the transient pressure waves. It is interesting to note that there is no significant difference in the ratings at all for the British Rail InterCity journey. This was the most familiar scenario to the subjects, most of them being likely to have travelled on the InterCity service at some time.

There is a difference between the means of the ratings for each scenario as a whole. If this were due to familiarity alone then it would be expected that the InterCity and underground journeys would be similarly rated, as would be the Channel Tunnel and Alpine Tunnel. However, the latter pair are dissimilar with subjects rating a higher level of discouragement from travelling through the Alpine Tunnel than through the Channel Tunnel.

The most obvious differences in the two scenarios is the immediate environment in which the journey is made, i.e. open or enclosed coaches. This difference is perhaps indicative of the importance of the environment to the acceptability of any journey for the traveller.

The environment for the traveller is not purely just a product of the surroundings for the journey itself, but events leading up to it affect the expectations and psychological frame of mind of the traveller. Thus, factors such as the ease of embarking on the journey and even impressions gained when purchasing the ticket become important.

4.0 CONCLUSIONS

The study involved simulations of three possible pressure histories appropriate to Channel Tunnel journeys. The results of subjective response indicated that the pressure conditions were not unacceptable. However, the tests did identify certain areas of concern:

Section 2 for Cases A and B
Section 7 for Cases A and B
Section 8 for Case C
Section 10 for Case C

Clearly, the most severe of these was Section 2 for Cases A and B, for which 10% and 17%, respectively, of subjects rated as '7'. Subsequent consideration has been given to the alleviation of the particular offending transient and it appears practicable to achieve this by closing off under normal operation (ie. normal ventilation mode) the connection of the coastal ventilation shafts to the main running tunnels. It was felt that the other Sections did not produce effects sufficiently severe to require remedial action.

As was expected, Cases B and C were found to be the most and the least unpleasant journeys, respectively, of the three.

The question of putting the experienced pressures into a journey context has suggested that people may be more apprehensive about such pressure conditions when on a Channel Tunnel journey (or a trans-Alpine journey) than on a BR InterCity journey, or on an express underground journey. This suggests that a great deal of attention to the design of the shuttle vehicles and to the Channel Tunnel infrastructure in general should be directed at providing a familiar, relaxed environment.

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