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NEUTRAL PLANES IN STRATIFIED MULTIPLE ROOM ENCLOSURES

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INTRODUCTION

For adjoining rooms in multiple-room enclosures, Emswiler [1] has defined the neutral plane (NP) as the vertical location at which the pressures are equal on both sides of the separating wall such that an opening in the wall at that level would pass no flow. In the simplest case of two rooms connected by one opening, the NP is near to the half height of the opening, with flow passing from the hot room to the cold room through the upper half of the opening, and a reverse flow in the lower half. The velocity distribution was developed by Brown and Solveson [2], and is much like the result for an orifice, except that the driving potential in this case is the temperature difference between the two rooms which results in a kind of "chimney" (or "stack") effect. Their analysis assumed that each room was at a constant temperature (no stratification), and the resulting velocity distribution was given by

$$V = \sqrt{(2gz\Delta\rho/\bar{\rho})} \qquad (1)$$

[1] Member of ISES

In more complex buildings with many interior doors and windows, the NP is usually not centered in the opening, in fact, it may lie above or below the opening so that the flows in some openings are entirely in one direction. Flow patterns of this type are common in passive buildings and have been reported by researchers at Los Alamos National Laboratory (LANL) [3].

If the rooms are stratified, it is possible that more than one neutral plane may exist. This has been pointed out by Hill, Kirkpatrick and Burns [4] who consider the case of linear vertical temperature distributions, and such behavoir has been observed by Burns and Kirkpatrick [5]. They develop an equation for locating the NP's which involves an iterative numerical solution.

The purpose of this note is to define the necessary and sufficient conditions for the existence of multiple NP's, and to give a simple geometric method to locate them relative to each other.

PROOF OF EXISTENCE

First of all, there may be no NP's. Consider two adjoining rooms, but with the connecting door closed. One room could be pressurized (by heating or cooling) with respect to the other to any degree so that they would have no pressures in common. Hence the existence of one NP is entirely within our own control simply depending upon how we choose to pressurize the two rooms.

Let us suppose that two connecting rooms are pressurized so that they do possess a NP. The question then is, "Under what condition(s) can we expect to observe more than one NP?" The situation is illustrated in Fig. 1 for the case of linear stratification, and two NP's are shown schematically.

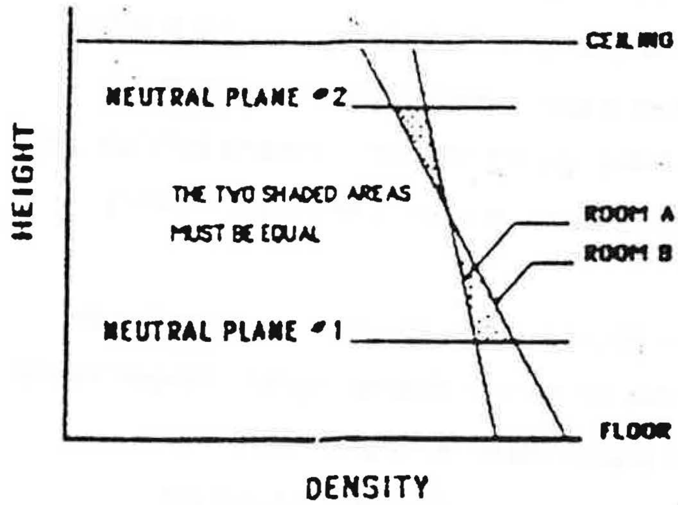

Fig. 1 Density distribution for two linearly stratified rooms with an interecting density distribution

In order that two NP's exist, it is required that the weight of the column of air between the two NP's must be the same in both rooms. The weight of the air column is obtained by the integral

$$\int \rho g dz$$

If one constructs the areas corresponding to this integral for each room in Fig. 1 (not shown in the figure), and requires that those areas be equal, then it will be easily seen that the density curves (temperatures can be used here with almost the same accuracy as density, since density varies inversely with temperature) must have an intersection, and that the shaded triangular areas must be equal. For linear stratification this means that the two neutral planes are spaced evenly above and below the intersection point. The intersection is essential for the existence of a second NP, and there can be no others.

Now consider the more general case of nonlinearly stratified rooms with temperature distributions as shown in Fig 2. This would be

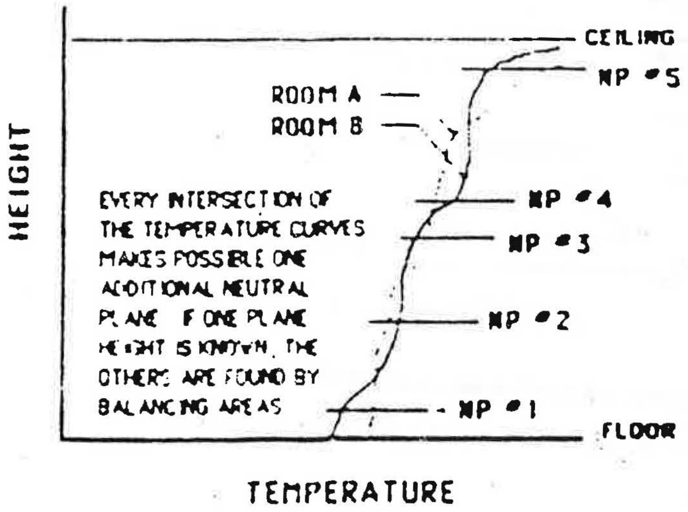

Fig 2. A condition of nonlinear stratification is illustrated with multiple interections of the temperature profiles

somewhat unusual situation, but one which could occur during periods where the flows are not strongly driven (i e in passive buildings, in the morning and evening or where phase differences occur in the rates of solar gain and thermal storage). If one NP is located, then all the others are easily located, since each pair of NP's straddles an intersection of the temperature curves enclosing equal areas above and below the intersection

If there is an opening between the two rooms, as illustrated in Fig. 3, then there will be multiple flow streams of alternating direction This was observed by Lin and Bejan [6] A similar kind of behavior has been observed [3] for flow in a weakly driven passive building having a sunspace In this instance, a one-way velocity profile in a doorway exibited two maxima and two zero points The peak flow speeds were small

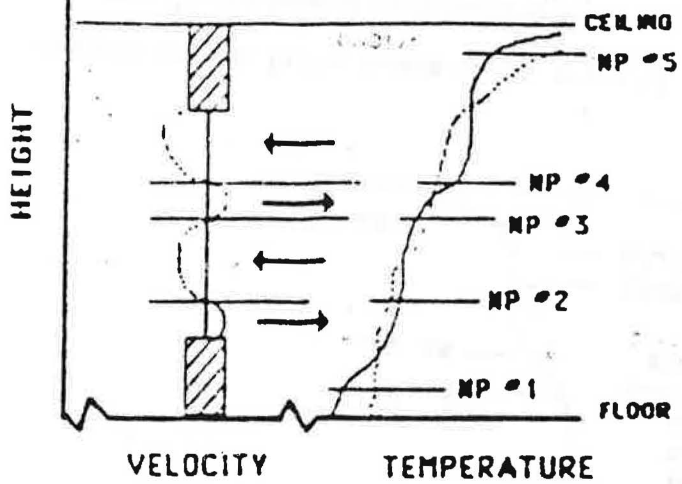

Fig. 3 The openings connecting rooms A and B have multiple flow streams of alternating direction and with zero velocity on the neutral planes

(<0.1 m/s) and the convective energy transported by the streams was less than 10% of the total sunspace-to-building energy flux

EXAMPLE

We consider an enclosure with an adiabatic partition separating two air-filled rooms each with height/length = 2 and height/breadth = 1 An opening centered in the partition is half the height and breadth of the room. The room temperatures are fixed as shown in Fig. 4, and the predicted airflows in the opening are also shown there. The predictions are based on a numerical aperture-flow model developed earlier [7] which follows that of Brown and Solvason [2] except that the effects of stratification on both flow and heat transfer are included Two-way airflow and the existence of two NP's are clearly seen in Fig. 4. As discussed above, the two NP's are a consequence of the intersecting

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REFERENCES

1 J E Emswiler, "The Neutral Zone in Ventilation," Presented at the Annual Meeting of American Society of Heating and Ventilating Engineers, Buffalo, NY, January, 1926

2 W G Brown and K R Solvason, "Natural Convection Through Rectangular Openings in Partitions, Part 1 Vertical Partitions," Int J Ht & Mass Trans., v 5, 1962, pp 859-868

3 J D Balcomb, "Heat Distribution by Natural Convection Interim Report," Los Alamos National Laboratory report in preparation

4 D Hill, A Kirkpatrick, and P Burns, "Interzonal Natural Convection Heat Transfer in a Passive Solar Building," To be presented at the 23rd National Ht Trans Conf, Denver, Colorado, August 1985

5 P Burns and A Kirkpatrick, Personal Communication, October, 1984

6. N. N Lin and A. Bejan, "Natural Convection in a Partially Divided Enclosure," Int J Heat Mass Transfer, v. 26, pp 1867-1878, 1983

7. G F. Jones, J. D Balcomb and D R. Otis, "A Model for Thermally Driven Heat and Air Transport in Passive Solar Buildings," to be presented at the ASME Winter Annual Meeting, Nov. 1985, Miami Beach, Florida

temperature profiles

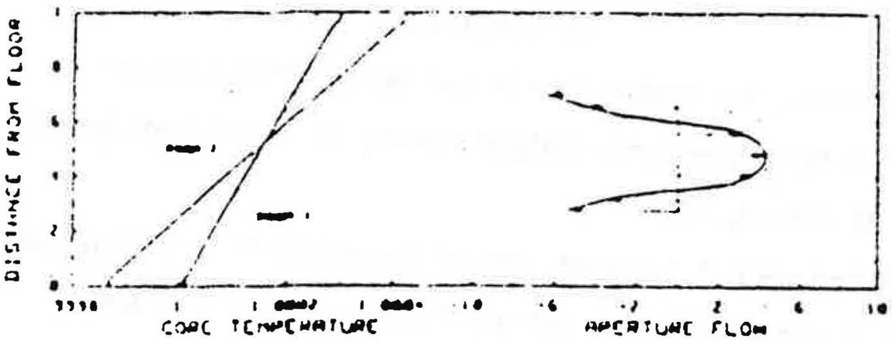

Fig. 4 Room-core temperatures and corresponding airflow in an opening separating the two rooms. Distance is normalized by room height, temperature by 1325 R, and flow by $5.7 \times 10^{-5}\ m^3/s$

CONCLUSION

It is demonstrated by a simple argument that multiple neutral planes can exist in a building of several rooms (a partitioned enclosure) only if (1) there exists one NP, and (2) if the vertical temperature distributions in the two adjoining rooms have an intersection. Further, if a NP exists, then the total number of NP's is one greater than the number of intersections in the temperature distributions for the two rooms. If the room is connected by a door or other opening, each neutral plane that intersects the opening represents a plane of zero velocity which separates oppositely flowing streams of air. Such phenomena have been observed in passive buildings.

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