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LETTERS TO THE EDITORS

COMMENTS ON 'A SYNTHESIS OF ANALYTICAL RESULTS FOR NATURAL CONVECTION HEAT TRANSFER ACROSS RECTANGULAR ENCLOSURES'

I HAVE read the Shorter Communication of Bejan [1] which gives an excellent review of the analytical work on free convection in rectangular enclosures. In Fig. 1 Bejan summarizes different heat transfer theories for a rectangular cavity filled with Boussinesq-incompressible fluid on which for different Rayleigh numbers Ra_L Nusselt number Nu is plotted against aspect ratio $A = H/L$.

The left-hand side of Fig. 1 shows, according to the theory of Bejan and Tien [2], that at constant Ra_L there exists a well-defined aspect ratio for which the overall heat transfer rate (Nu) is a maximum. This theory was developed in [2] as model (2) for the so-called 'intermediate regime' which lies between the region of vanishing Rayleigh number ($Ra_L < 72\,A^{-2}$) , and the boundary layer regime ($Ra_L > 4.4 \times 10^4\,A^{-5/3}$).

Although the frontiers in the brackets were mentioned to be regarded as diffuse or approximate, the points of maximum Nu for $Ra_L > 10^6$ lie well within the boundary layer regime for which according to equation (47) in [2] Nu is independent of A and much below its maximum on Fig. 1.

Bejan mentions in [1] about the boundary layer regime for the case of tall enclosures ($A > 1$) but ignores its existence for shallow enclosures ($A < 1$). On the other hand in [2] Bejan and Tien demonstrate the existence of this regime also in shallow enclosures when Ra_L is high with the help of the experimental data of Imberger [3] for $A = 0.01$ and 0.02. If we now assume that there exists a boundary layer regime also for shallow enclosures the maximum Nu for a particular Ra_L will now be given by equation (47) in [2], which when plotted on Fig. 1 will be horizontal lines for different Ra_L.

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REFERENCES

1. A. Bejan, A synthesis of analytical results for natural convection heat transfer across rectangular enclosures, *Int. J. Heat Mass Transfer* **23,** 723–726 (1980).
2. A. Bejan and C. L. Tien, Laminar natural convection heat transfer in a horizontal cavity with different end temperatures, *J. Heat Transfer* **100C,** 641–647 (1978).
3. J. Imberger, Natural convection in a shallow cavity with differentially heated end walls — Part 3. Experimental results, *J. Fluid Mech.* **65,** 247–260 (1974).

REPLY TO "COMMENTS ON 'A SYNTHESIS OF ANALYTICAL RESULTS FOR NATURAL CONVECTION HEAT TRANSFER ACROSS RECTANGULAR ENCLOSURES'"

IN HIS Letter to the Editors, Hossain [1] raises the important issue of the engineers' ability to predict heat transfer in horizontal 'end-to-end heated' enclosures in the *boundary layer regime*. He is correct in pointing out that the only theory developed for this domain {Bejan and Tien [2], the 'boundary layer regime', equation (47)} does not appear on the Nusselt number–aspect ratio (Nu–A) chart, which I constructed in order to display all the analytical results on rectangular cavities [3]. However, contrary to Hossain's interpretation, the boundary layer theory [2] does not appear as a horizontal line on the Nu–A chart. Noting the different notations used in references [2] and [3], and using the notation of reference [3], the boundary layer regime heat transfer is

$$Nu = 0.623 Ra_L^{1/5} A^{-2/5}. \qquad (1)$$

This theoretical result is shown plotted on the Nu–A chart for $Ra_L = 10^8$ and $Ra_L = 10^7$. It is evident that the boundary layer theory of [2], equation (1), bridges the 'gap' between the intermediate regime theory [2] and my theory for moderately tall enclosures [4]. This 'gap' develops as the Rayleigh number Ra_L increases.

Regarding the parametric domain (Ra_L, A) in which the boundary layer regime [2] prevails, a definite answer can only be anchored on conclusive experimental data. Since I wrote the review paper [3], we have completed the first experimental study of natural convection in a shallow enclosure in the *high Ra_L regime*. The parametric domain covered by these water experiments is $A = 0.0625$, $10^{12} < Ra_L < 10^{13}$. The new flow configuration and the heat transfer picture revealed by these experiments are described in a forthcoming paper [5].

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REFERENCES

1. S. Hossain, Comments on 'A synthesis of analytical results for natural convection heat transfer across rectangular enclosures', *Int. J. Heat Mass Transfer* **24,** 1559 (1981).
2. A. Bejan and C. L. Tien, Laminar natural convection heat transfer in a horizontal cavity with different end temperatures, *J. Heat Transfer* **100,** 641 (1978).
3. A. Bejan, A synthesis of analytical results for natural convection heat transfer across rectangular enclosures, *Int. J. Heat Mass Transfer* **23,** 723–726 (1980).
4. A. Bejan, Note on Gill's solution for free convection in a vertical enclosure, *J. Fluid Mech.* **90,** 561 (1979).
5. A. Bejan, A. A. Al-Homoud and J. Imberger, Experimental study of high Rayleigh number convection in horizontal cavity with different end-temperatures, *J. Fluid Mech.* **109,** (1981).

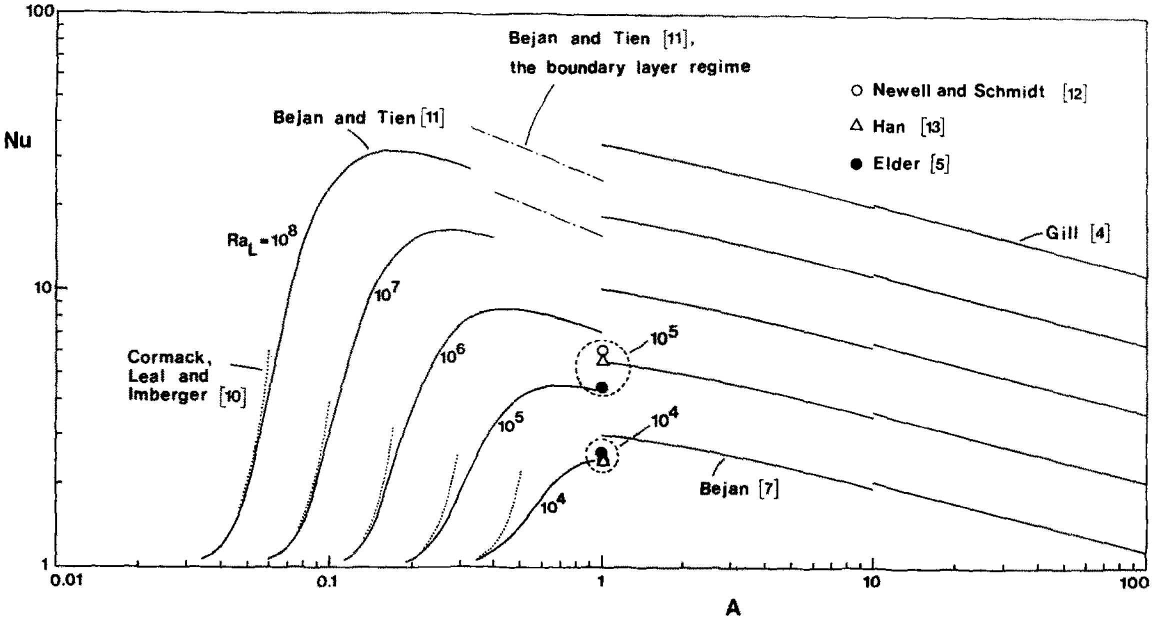

FIG. 1. Summary of heat transfer theories for a rectangular cavity filled with Boussinesq-incompressible fluid (the numbers in square brackets represent references listed in [3]).