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LETTERS TO THE EDITORS

COMMENT ON THE PAPER "AN EVALUATION OF BULEEV'S MODEL OF TURBULENT EXCHANGE"

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QUARMBY's paper [1] requires a comment relative to a number of statements directed to our results which we obtained with an improved version of Buleev's model and have been published previously. We will restrict ourselves to those statements which are related to our result for the ratio of the eddy diffusivity in the tangential direction $\varepsilon_{h,w}$ to that in the radial direction $\varepsilon_{h,r}$ in a circular tube [2].

Quarmby states that he could not achieve our result revealing for the ratio $\varepsilon_{h,w}/\varepsilon_{h,r}$ values greater than unity by direct application of Buleev's method. Further, after examining the mathematical properties of Buleev's solution, he finally arrives at the following conclusion: "It is clear that the result claimed by Ramm and Johannsen [2], that the ratio $\varepsilon_{h,w}$ to $\varepsilon_{h,r}$ is greater than unity and in agreement with experiment, Fig. 5, is impossible." This statement clearly implies that we published incorrect results either by purpose or by obvious incompetence in applying Buleev's model adequately. In view of the fact that we never published any results obtained by direct application of Buleev's original model but always stated that we removed "certain deficiencies (as also evaluated in Quarmby's paper) which become apparent on physical grounds and with respect to empirical evidence in predicting turbulent transport properties" [2] Quarmby's statement is completely unjustified and must be considered unfair if not malicious.

The "impossible" result that $\varepsilon_{h,w}$ to $\varepsilon_{h,r}$ is greater than unity is the immediate consequence of introducing length scales which are dependent on direction. This essential extension of Buleev's model (as well as others) is most elaborately described in [3] but was also clearly discussed in references 4, 5 and 7 cited by Quarmby in his paper.

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REJOINDER'

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QUITE often, progress in science and engineering has been made by recognising that an established idea is wrong, that some concept is false or some claim overstated; though the production of "negative" results is not highly regarded. Only the French remember who corrected Newton's mistaken idea that sound travels *isothermally*.

Ramm and Johannsen make the particular point that they modified the method of calculating the length scale and also made it a function of direction, thereby, supposedly, re-establishing the credibility of Buleev's model and the results obtained from it.

Examining equations (12), (13) and (16) of [1] it is clear that altering the definition of length scale and the method of calculating it from one configuration to the next is equivalent to changing the coefficients from one configuration to the next. Ramm and Johannsen [7] of [1] say that the choice of the method appropriate to each case is the result of "intuition". It is not surprising that they concluded that there was no need to alter the coefficients also.

Further, in Buleev's model the length scale is a function of position and in principle an eddy diffusivity could be calculated for any direction from a particular point of interest. The choice of the usual co-ordinate directions r, ω is for convenience. Making the length scale a function of the direction of the line along which the integration is being performed, means that the length scale can have an infinity of different values at the same one point. Consequently, the "mole" at that point has an infinity of different diameters, means, free paths and velocity fluctuations, all at the same time. This is not a convincing physical picture.

However, maybe Ramm and Johannsen's modifications could have been justified heuristically. Their proposals for the length scale in the tangential direction, L_ω, are that: (i) in [4] of [1], it decreases linearly to zero as the wall is approached; whereas: (ii) in [7] of [1] they used two options which become identical for the case of a plain tube or parallel plate channel and which in the notation of [1] can be written:

$$L_\omega = L_r(y_0^+)\left(\frac{y^+}{y_0^+}\right)^m \tag{1}$$

where

$$m = 0.01/\ln(y_0^+/25).$$

Clearly for all practical values of y_0^+ this becomes $L_\omega = L_r(y_0^+)$. That is, the tangential length scale is everywhere equal to the value of the radial (or Buleev) length scale at the axis of the tube or centre plane of the parallel plate channel.

The two proposals for the tangential length scale are thus very different. The first is the same as an unmodified application of Buleev's theory since as pointed out by [1] the length scale calculated according to the Buleev definition reduces linearly to zero near the wall anyway, whatever the shape of the duct. This modification thus does not lead to a correct prediction of the ratio the tangential and radial eddy diffusivities of heat or mass in a plain tube.

On the other hand with the second modification it can be seen, from examining the relevant equations, especially equation (16) of [1], that if L_ω has a constant value then with du^+/dy^+ about unity near the wall and for practical values of y_0^+, the arguments of the functions f_0 and f_2 become very small and the integral for calculating the tangential eddy diffusivity contains only the weighting function G. In particular if we take the case of a parallel plate channel where velocity, L_0 and modified tangential length scale are constant on any plane parallel to the wall, we get, in the notation of [1]

$$\varepsilon_{h,z} = c\mu\alpha r_0^+ L_0'^2\left(\frac{L'}{L_0'}\right)\int_{-1/\alpha}^{+1/\alpha} \tfrac{1}{2}m^2\zeta\exp(-m\zeta)\,d\zeta \qquad (2)$$

which is identically zero since the attenuation function under the integral sign arises from the neutron flux analogy used in the basic turbulence model, both original and modified, and the *modulus* of ζ must be taken. This modification leads to a zero value of $\varepsilon_{h,z}$ near the wall. The ratio of $\varepsilon_{h,z}$ to $\varepsilon_{h,y}$ would accordingly also approach zero at the wall since as explained in [1] $\varepsilon_{h,y}$ (or $\varepsilon_{h,r}$) does not approach zero near the wall as quickly as $\varepsilon_{h,z}$ (or $\varepsilon_{h,\omega}$).

Neither of the modifications used by Ramm and Johannsen re-establishes the claims made for the Buleev theory.

Buleev's theories seemed to provide the answer to problems of considerable importance and long standing. Indeed, they seemed to go further than many research efforts being made at present world wide in that they claimed to show how to calculate from a single model not only the Reynolds stresses but also the turbulent Prandtl or Schmidt number. This together with a claim for universality of application, both claims supported by Ramm and Johannsen, made the theory very worthy of critical assessment. It is a pity to find the claims overstated but there is nothing of malicious intent in that.

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