AIVC 12,541

COMPUTATIONAL FLUID DYNAMICS MODELLING FOR INDUSTRIAL VENTILATION APPLICATIONS

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ABSTRACT

Computational Fluid Dynamics (CFD) modelling techniques have been used extensively and with considerable success for many years in providing environmental and physiological flow conditions in applications as diverse as -

- Aerospace
- Biomedical
- Chemical Processing
- Electronics
- Materials Processing
- Metallurgy
- Nuclear Energy/Power Generation

The same basic modelling techniques have also found acceptance, and have been utilised to good effect, in Architectural and Engineering applications to evaluate -

> airflow around buildings, wind load on buildings, pollution modelling and toxin dispersion, and air and heat circulation patterns within buildings.

HH Robertson, in conjunction with a number of research bodies, has employed these techniques to provide finite **natural ventilation** solutions to high heat load and environmentally sensitive applications in a number of industrial metal processing plants around the world.

INTRODUCTION

Traditionally, natural ventilation systems for industrial applications have been designed using empirical mathematical models. The basis for this form of calculation was generally founded on extensive field testing of completed installations and, at best, provided a **limited** degree of accuracy in determining the exhaust airflow to be provided.

While these techniques have adequately served industry for many generations, to achieve a "guaranteed" level of ventilation performance, a designer generally had to "over-engineer" his design to get the required outcome. That is, the end results that were achieved were confined to producing a "big picture" solution.

Yes, we can provide you, Mr Client, with an **average** maximum temperature rise above ambient within your building of 10 ^{0}C, and **Yes,** we will ensure that the SO_2 emissions are maintained within your nominated **average** Threshold Limit Values, but **No,** we cannot guarantee that the operator working an 8 hour shift, permanently located on the platform at RL 18.50 between Grid Lines 7 and 8, will not be subjected to conditions which could well be outside these parameters.

This being the case, why should the Client be expected to approve capital expenditure, of, say, several hundreds of thousands of dollars, to provide a result which may require significant modification at a later date?

We at HH Robertson have now proven, that by employing the capabilities of CFD modelling now available, in conjunction with our over 90 years of international field experience, we can in fact provide the level of accuracy needed in our system design and product selection to produce effective **natural** ventilation system designs. We therefore can ensure that our clients receive the level of comfort necessary to meet their increasingly stringent physiological and financial demands.

METHODOLOGY

CFD modelling is a simulation tool used to model fluid flow situations in engineering equipment, living systems and the environment. The ability to rapidly and inexpensively create desktop models of large, complex industrial buildings and processes has greatly enhanced the engineer's capability to provide natural ventilation system designs for projects such as Aluminium Smelters, Steel Mills, Copper Smelters, etc.

Prior to commencing any modelling, it would still be usual to undertake empirical calculations to broadly establish the extent of the problem and provide a basic understanding of the project requirements. An extension of this phase of the work would be a building envelope thermal analysis, which would then provide a ventilation flow rate analysis and act as a prelude to the establishment of the CFD model.

For a CFD model to be constructed, the first requirement is that detailed geometry of the building, both externally and internally, be established. Consideration needs to be given to any other structures adjacent to the building under evaluation, as these can have significant influence on wind airflow patterns impacting on the subject structure. Wind-borne process contamination from these other buildings can also be an important consideration when assessing internal environmental conditions.

With this form of modelling, a major result component is the airflow and heat flow patterns within the occupied space of the building. It is essential that major heat sources, sources of pollution emission, significant structural objects, working platforms, etc. be geometrically modelled in their correct locations as accurately as possible.

A prime requirement of the end result of the study is that (apart from any process requirements) we provide environmentally acceptable conditions for the process operators.The normal working location of these people needs to be clearly identified.

With software now available, it is probable that a significant proportion of this data can be integrated into the model directly from AutoCAD or other similar building design packages.

The final level of accuracy achieved will, to a large degree, be determined by the number of individual grid points, or sub volumes, selected for the interior of the building. The number can vary from 100,000 for a very simple structure to 700,000 for a more complex structure. As an individual calculation is then undertaken for each of the grid points for the required parameters ie, air velocity, temperature, pressure, etc. this factor will have a significant bearing on the computer to be utilised to run the model, the speed of producing the results, and, of course, the cost involved in running the model.

The results would then be produced graphically to provide pictorial representation of the various parameters required. These can include -

- Velocity Vectors
- Temperature Contours
- Fume Concentration Levels
- Pressure Contours, etc

Refer attached diagrams for examples relating to a Furnace Building project;

12. Air and Temperature Flows between Zones
13. Temperature Contour Plots (These would normally be in colour to provide greater detail of the temperature gradients within the building)
14. Velocity vectors

Having established one model situation it is then relatively easy to alter any of the variable conditions, eg heat load, allowable temperature rise, external wind conditions, process emissions, etc, to allow alternative solutions to be evaluated.

A COMPARISON OF VARIOUS FORMS OF MODELLING

HH Robertson has had the opportunity to participate in a study to develop and design a natural ventilation system for a Copper Smelter project in South Australia.

The forms of modelling undertaken over a period of some 5 years were -

- Initially empirical calculations (based on ASHRAE formulae)
- Physical scale model tests
- Thermal computer model

Limited field testing was then undertaken to enable comparisons to be drawn with regards to the accuracy of the theoretical evaluations against the field results, and also a comparison of the physical scale model against the computer model.

In summary, the first two models above produced similar results, while the computer model indicated that the results for temperature conditions within the building were much more closely aligned to the field measurements.

The result of these studies showed that the empirical and physical scale models produced a more conservative result, which in real terms indicated that the exhaust ventilators were somewhat oversized, albeit they provided site conditions within the Client's specified requirements.

Had we been able to produce the computer-generated model instead of the physical model, we would have been able to reduce the ventilator sizing and offer a comparable reduction in the cost of the products supplied to the Client.

BENEFITS OF CFD MODELLING

It is clearly evident to us that the selected use of CFD modelling can produce significant benefits on major Industrial Ventilation projects. These include -

- **Accuracy** of results
- Flexibility in being able to **quickly** undertake several study options for a particular building under a range of conditions, to produce an optimum result
- Client comfort in knowing significant **capital expenditure** can produce a **"guaranteed"** result
- **Cost-effective** design solutions
- **Proof** that Natural Ventilation solutions work.

Our experience to-date is that the reasonably significant cost and time involved in undertaking CFD modelling is outweighed by the real benefits achieved by:

- Locating the inlet and exhaust ventilation equipment in the optimum position to **achieve maximum ventilation effect.**

- Through accuracy of design ensuring that the "right" sized and most aerodynamically efficient ventilation products have been utilised, so as to provide the required ventilation performance at the **cheapest cost.**

I believe CFD modelling to be an excellent example of what was initially a research tool now being of significant benefit to Industry. This form of modelling clearly allows us to **show** our prospective client exactly what will happen inside his building **before** he commits his capital.

ACKNOWLEDGEMENTS

The Author acknowledges the excellent assistance in undertaking CFD Modelling for HH Robertson by the following organisations:

- CSIRO, Division of Building Construction and Engineering, Victoria, Australia

- Lincolne Scott, Australia

- University of Pretoria, South Africa

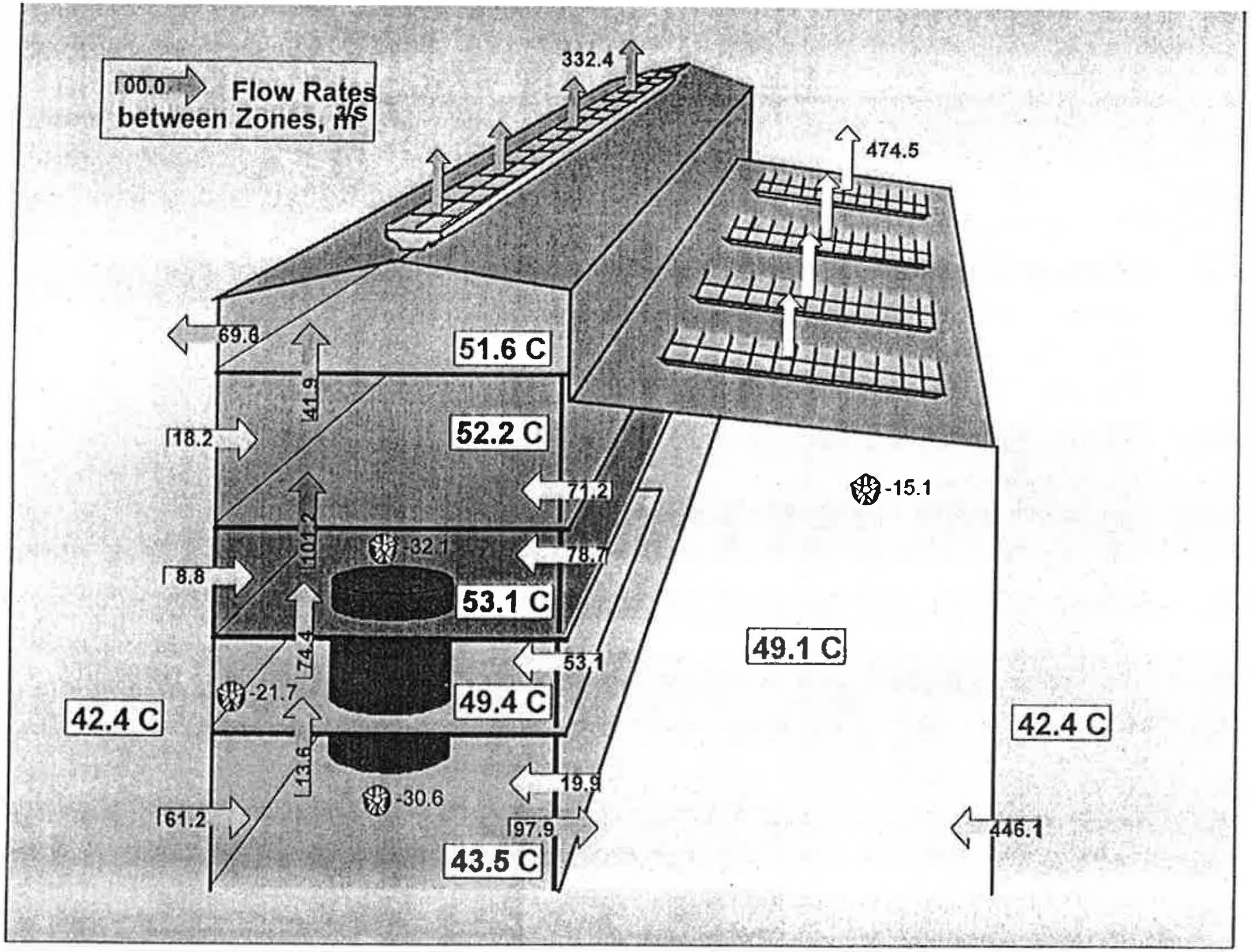

Diagram No. 1 FURNACE BUILDING : Air & Temperature Flows Between Zones
(CSIRO, DBCE, Australia)

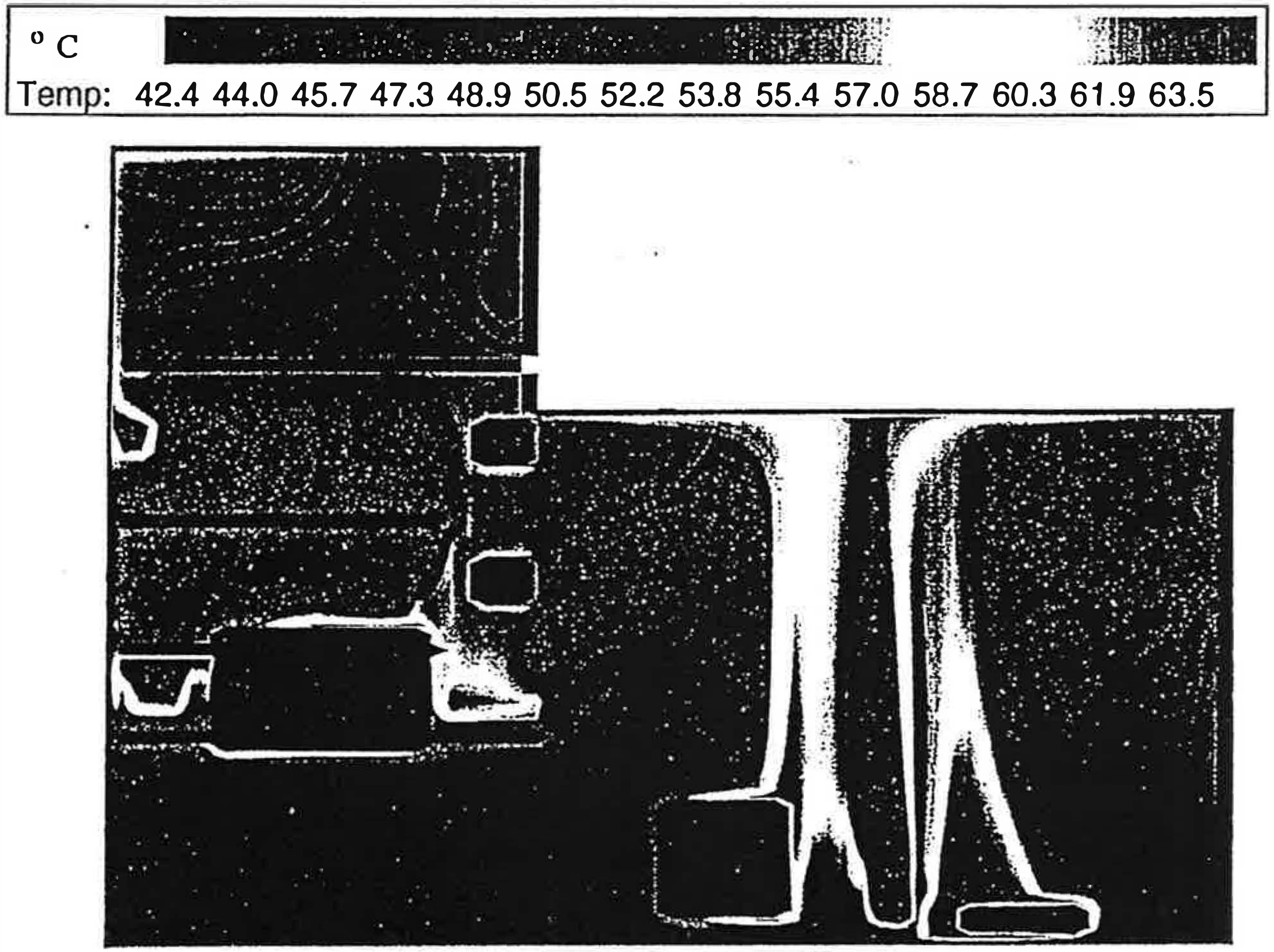

Diagram No. 2 FURNACE BUILDING : Temperature Contour Plot
(CSIRO, DBCE, Australia)

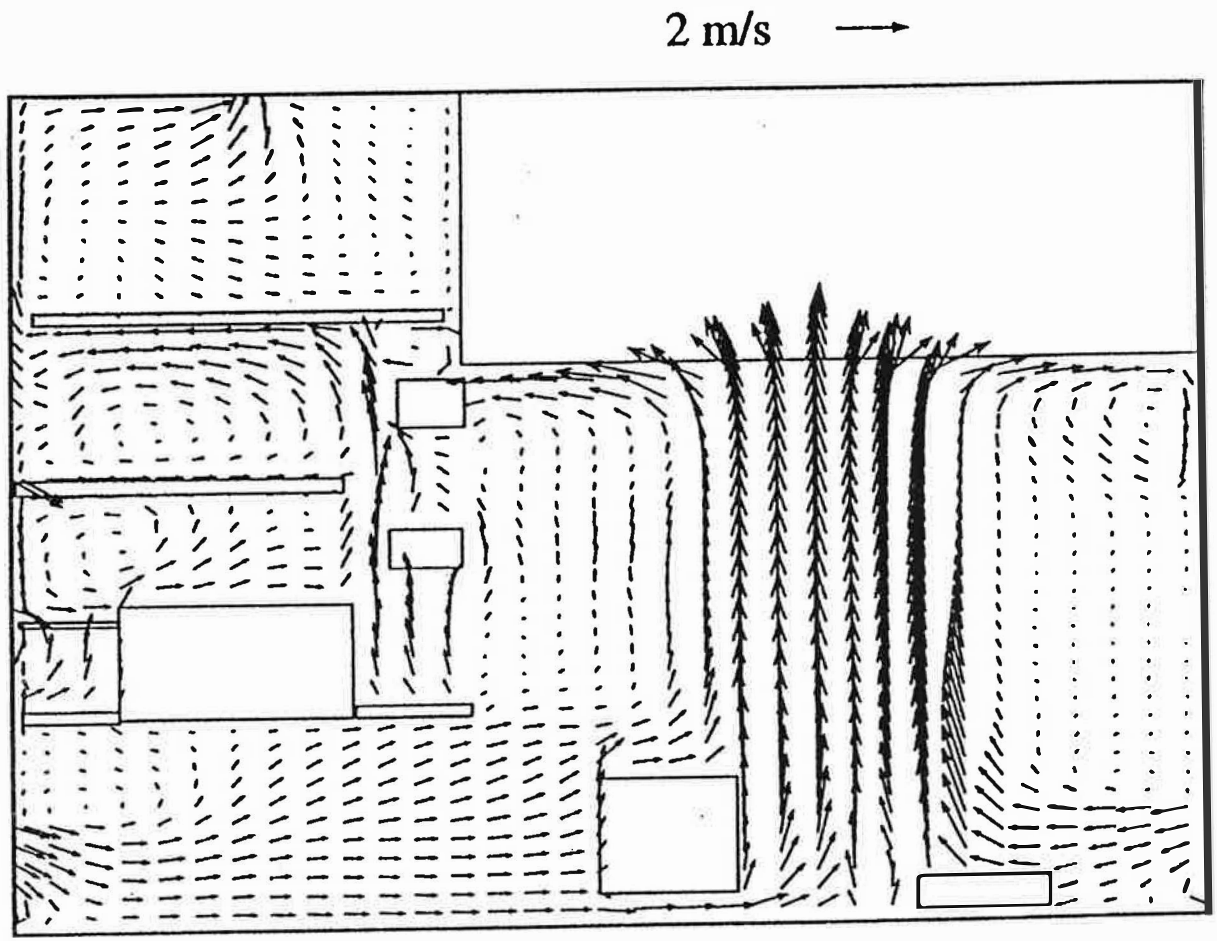

Diagram No. 3 FURNACE BUILDING : Velocity Vector Plot
(CSIRO, DBCE, Australia)