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IEA ANNEX 23

MULTIZONE AIR FLOW AND POLLUTANT TRANSPORT MODELLING

GENERAL PRESENTATION

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IEA-Energy Conservation in Buildings and Community Systems

Annex 23
Multizone Air Flow and Pollutant Transport Modelling

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Annex 23, general presentation.

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The Annex 23, on Multizone Air Flow and Pollutant Transport Modelling, was adopted in June 1990. This Annex was scheduled to operate on a task-shared basis for a period of 54 months.

Till now, six countries have officially committed to the Annex (Canada, France, Italy, Japan, The Netherlands, USA); LBL has been appointed to operate the Annex; France has officially committed to lead subtask 1; Sweden and Switzerland act as subtask leaders of, respectively, subtasks 2 and 3. Belgium has still the status of an observer. AIVC cooperates with Annex 23.

After an 18 months of preparation phase, the working phase started in March 1992 for a period of 24 months; the working phase will be followed by a one year of reporting phase. Till now four Expert Meetings have been held (Nice, F, October 1990; Aachen, D, March 1991; Ottawa, CND, September 1991 and Lausanne, CH, March 1992). On the average, 20 to 24 participants attend each meeting. It was decided to distribute an Annex 23 Newsletter and the two first issues of this Newsletter have already been distributed to 60 of our colleagues.

The objective of Annex 23 is to study physical phenomena causing air flow and pollutant transport in multizone buildings and to develop modules to be integrated in a multizone air flow modelling system.

The Annex is shared in three subtasks:

- subtask 1; System Development;
- subtask 2; Data Acquisition;
- subtask 3; Evaluation.

The goal of subtask 1 is to develop modules to be integrated in a multizone air flow modelling system, to store the physical knowledge associated to each module in a standard format in order to ease the reuse of this knowledge in various contexts, to develop a prototype of an Intelligent Simulation Environment in order to facilitate access to the modelling system, and to demonstrate the coupling of a multizone air flow modelling system with Building Energy Performance Simulation codes.

The goal of subtask 2 is to provide validated data, necessary to use the system (e.g., wind pressure distribution, default values for leakage of building components).

The goal of subtask 3 is to assess the relevance of the modelling system; to reach this goal, comparisons between computed and experimental results will be performed together with a sensitivity analysis and an error propagation study. The result of this subtask will be a report on application limits.

The simulation code developed in the frame of Annex 23 is based on the existing COMIS program; the structure of this program is described below:

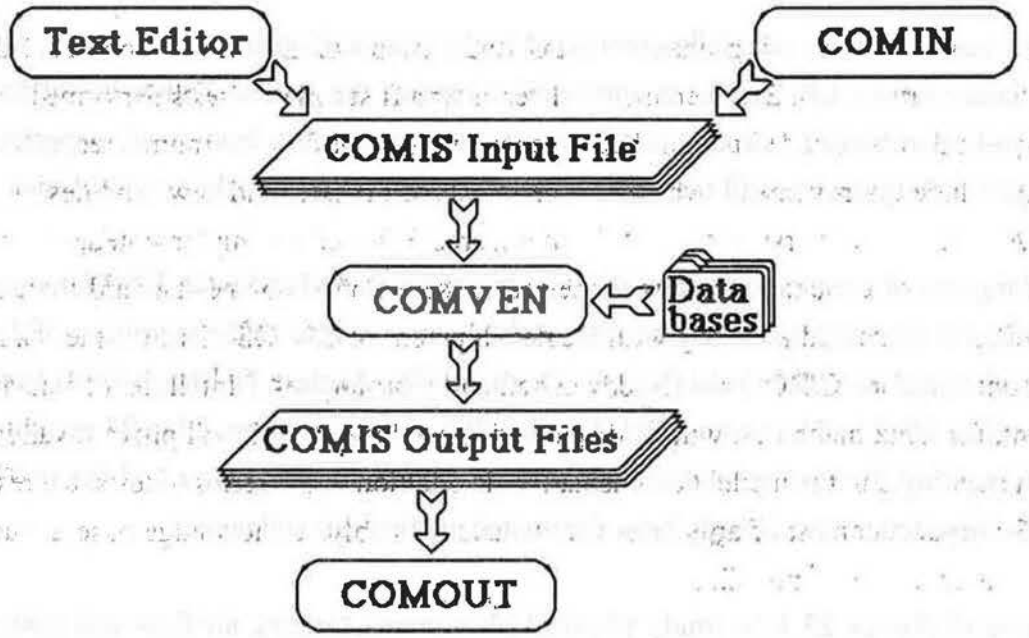

Fig.1 : Structure of COMIS.

COMIS consists of three main parts: COMIN, COMVEN and COMOUT. COMIN is used to describe the building under investigation. It consists of a straightforward menu system that conducts a dialogue with the user, using a line-terminal.

The result of a session with COMIN is a file called "COMIS Input File" which contains the description of the building in a kind of simple description language, using keywords to identify the respective parameters and so-called "headers" to make the file more legible. Since this file consists of pure ASCII text, it is possible to edit it with an arbitrary text editor. COMVEN is the calculation part of COMIS. It takes a COMIS Input File as input and creates a system of non-linear differential equations from the network of zones interconnected by links described in the COMIS Input File. Using an appropriate solver (of which several are build into COMVEN), the program then tries to solve the system of equations, yielding, for instance, the pressure distribution in the building and the air flows entering in or out-coming from the zones. The data which have been specified as outputs in the COMIS Input File are dumped into various files which can be used by several back-end programs referred to as COMOUT (for instance, in a PC environment, the user can have COMVEN create tables that can be used to visualize and further process the numerical outputs with the spreadsheet program LOTUS 1-2-3™).

To help participants in requesting information about Annex 23 or the COMIS modelling program, an information server is in use; it works via electronic mail (its e-mail address is: annex23-info@epbl.lbl.gov).

At the beginning of the working phase, the existing version of COMIS, numbered 1.0, is distributed to the participants. Eighteen months later, after a first series of tests performed in the frame of subtask 3, it is intended to distribute a second version of COMIS (numbered 2.0); this version will include improvements which will be results of the tests and new modules. At the end of the Annex, a final version of COMIS, numbered 3.0, will be implemented; this final version will take into account the results of the second series of tests. The standard front-end, COMIN, will be maintained all along with the development of COMIS. On the other hand, a graphical front-end for PC/DOS will be developed and a prototype of Intelligent Simulation Environment, for Unix machines, will be developed as well. Subtask 2 will provide validated data to be incorporated in the model documentation. In addition to the series of tests, the results of subtask 3 will also consist of application limits and, possibly, a knowledge base about air flow and pollutant transport modelling.

The results of this Annex will be documented models* about air flow components, pollutant transport or related utilities (e.g., computation of ventilation effectiveness, mean age of air in a multizone building, automatic sizing of ducts), a software to model and simulate air flows in multizone buildings, a graphical front-end for PC/DOS, a prototype of an Intelligent Simulation Environment together with a report about advantages and inconveniences, feasibility and relevance of such an approach, a report on application limits, a report on coupling with Building Energy Performance Simulation codes.

During the preparation phase, the participants have worked on a planning for which a PERT diagram has been made. Thirty-eight tasks have been identified, the main tasks are:

- in subtask 1;
  - development of models;
  - use of COMIS for Building Energy performance computations;
  - development of a prototype of an Intelligent Simulation Environment;
- in subtask 2;
  - procurement and improvement of input data;
- in subtask 3;
  - sensitivity analysis;
  - error propagation study;
  - experimental comparisons;
  - user tests.

This planning is enclosed to this document (see appendix 1).

In addition to the planning, provisional documents have been produced and distributed (see appendix 2).

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* To document the models, the Annex 23 participants agreed to use the "PROFORMA" format.

Appendix 1

Planning of Annex 23

0. General Tasks

0.01. Start Annex 23

The kick-off meeting (October 1990) is considered as the start of Annex 23.

0.02. Preparation phase

The preparation phase has been completed by the end of March 1992. During this phase, working plans has been formalized and the detailed structuring of the Annex has been finalized.

0.03. COMIS 1.0

A running version of COMIS and a user guide are distributed to the participants at the beginning of the working phase of Annex 23 (March 1992). The programs involved are COMIN, COMVEN and COMOUT. The software runs on PC/DOS (COMVEN runs on any computer with a FORTRAN compiler).

On PCs, COMIN and COMVEN need Windows.
COMOUT uses LOTUS 1,2,3 release 3 and needs at least 1 Mb of RAM.

0.04. Understanding of COMIS

All participants should be familiar with the workings of COMIS 1.0, including the possibilities and limitation of the programme.

0.05 General report

The general report will be the final product of Annex 23 and should be completed in March 1995.

0.06 Final user guide *(H. Feustel)*

The user guide, continuously updated during the Annex work, is edited as an Annex report, together with the final version of COMIS.

1. Subtask 1 - Modelling

1.01 Understanding of ISE (Intelligent Simulation Environment)

All participants are expected to have good knowledge of the ISE concepts in order to facilitate the future work (exchange of information, model documentation, need for expert rules, etc).

1.02. Modelling of COMIS

The ISE developers should have a full understanding of the structuring of COMIS, the "entities" (objects) handled by COMIS and how these objects are structured. The goal is to develop a data model of COMIS with an Object Oriented approach. This implies to define :

- the entities used in the COMIS structure;
- their contents (slots);
- their relations (exchange of messages in the O.O. representation).

A document, describing with an Object Oriented approach the various components used in COMIS, was sent to participants.

1.03 Development of models *(R. Pelletret)*

The goal is to review the existing models and to suggest improvements or to develop new modules. Better information and definition of input parameters would be studied. Improvement of the existing models can consist of either increasing the accuracy of the parameters or modifying the existing algorithms. The existing models would have to be documented with PROFORMA files. The new modules which are expected to be incorporated in COMIS are:

Components	
HVAC components	Some HVAC components have already been developed (INSA Lyon) and will be incorporated in COMIS.
Demand control ventilation	To simulate the devices controlling air flows as a function of pressure differences, humidity or other parameters.
Large vertical openings	To incorporate in COMIS the model developed within Annex 20.
Large horizontal openings	To incorporate in COMIS the model developed by Roger Pelletret.
Behavior of inhabitants	To incorporate in COMIS the models developed within Annex 20.
Zonal models	To use the outputs of COMVEN as inputs to a zonal model which computes the air flow pattern in each zone.
Phenomena	
Contaminant transport	A one way model exists; a two way model could be developed.
Humidity source and sink	P. Dalicieux develops a model which computes the exchange of water vapor between air and various materials; the validation of this model is in progress; the task consists of incorporating this model into COMVEN (H. Phaff).
Pollutant absorption/desorption	Partially done (Hans Phaff);
Pulsation of the flow	To couple COMVEN with a dynamic ventilation model; the outputs of COMVEN will be used as inputs to the dynamic model.
Single sided ventilation	To incorporate in COMIS the model developed within Annex 20.
Data and parameters	
Component leakage data	Some data are available (Dan Colliver, AIVC).
Pressure coefficients	To provide Cp data base for infiltration simulation.
Kitchen hood efficiencies	Data are available; it is also intended to provide a model of hood.
Utilities	
Exposure model for occupants	A routine already exists (Hans Phaff).
Ventilation effectiveness	To incorporate an existing model as a COMVEN routine.
Comparison with standards	This is a routine to be added to COMVEN.
Blower test module	To renormalize the leakage parameters as a function of the comparison "computed air flows / measured air flows";
Automatic sizing of duct systems	Iterative process to size the ducts in order to reach face values for the air flows;

1.04 ISE design

The goal of this task is to define the specifications of the ISE from the user's point of view. The result of this task is an internal report.

1.05 Development of On-Line Helps (OLH)

The ISE must be as easy to use as possible for any kind of users ; that's why it should involve OLH programmes; the development of the OLH programmes will be divided into two phases. The first phase aims to design the OLH (i.e. to define what the OLH must explain and how this will be displayed). The second phase will be an implementation phase (the OLH will be implemented).

1.06 Specification of checking functions

In order to develop the checking functions, we must specify the purpose and the scope of the work ; experts rules will have to be written for the checking functions which are as follows :

- parameters checking function (the goal is to verify if the values of the parameters are within the validity ranges -specified in the PROFORMA files-),
- liaisons rules (the goal is to help in choosing what are the models which can be linked together, this function will use the information contained in the PROFORMA files and concerning the possible upstream models),
- consistency by virtue of the simulation goal (i.e.: assessment of the ventilation efficiency, air change rates, etc); the goal of this function is to help the user in choosing modules adapted to his simulation goal (this function could use the results of the task 3.12 "Report on application limits"),
- consistency of the set of numerical parameters needed in relation to the simulation goal and the assembly of COMIS components (this function could be developed only if valuable information concerning this topic is provided by tasks 3.04 and 3.10 "User's tests 1 and 2"),

In addition, the following problems will be considered:

- expert systems to help in analyzing the outputs (use of utilities subroutines),
- coupling with AIVC data base
- integrated data model (the goal of such a model is to make easier the sharing of the data between various computation codes as, for instance, COMVEN and TRNSYS).

1.07 Use of COMIS for Building Energy Performance computations

In order to assess the advantages of COMIS to compute Building Energy performances, COMIS will be both coupled with thermal computation codes and/or compared with existing airflow models already used in tandem with BEP computation codes. Tests will be made in order to check the performance of the coupled programmes (running times, results accuracy, etc). This task will be performed with the following BEP codes (the result of this task will be an internal report.):

Codes	
BLAST	Sequential coupling: COMIS is used to built a matrix of the airflows entering each zone as a function of time; this matrix is used by the BEP computation codes to assess the thermal conductances due to air exchanges.
DOE-2	
TARP	
ESP	Comparison between ESP and COMIS.
TRNSYS	Viktor Dorer will look at the possibility to incorporate COMVEN as a TRNSYS subroutine. Roger Pelletret will look at the possibility of coupling COMVEN and TRNSYS in the frame of IISIBât which will act as a general supervisor, invoking at each time step COMVEN and then TRNSYS and taking care of the convergence.
VA114	This BEP computation code is limited to three zones. COMIS will be used to provide VA114 with a matrix of air flows.

1.08 Development of Graphical Front-Ends

Two graphical front-ends will be developed, one for the PC/DOS machines (COMELS), the other for UNIX machines (IISIBât/COMIS).

To develop IISIBât/COMIS, most of the graphical ISE functionalities, described in the design report (result of the task 1.04), will be implemented. This involves the implementation of the data model of COMIS and to structure the standard library of components and utilities.

The product of this task will be software prototypes.

1.09 Development of checking functions

The goal is to develop the checking functions in a formalism adapted to the ISE.

1.10 Integration of new components in IISIBât/COMIS

When a new model of a component has been developed and documented, it will be implemented in the ISE. This implies to implement PROFORMA files, to draw icons, to store the components in a library, etc. Note that for existing models, PROFORMA files will have to filled and implemented.

1.11 COMIS 2.0

If there are differences between the measured and computed air flows and if it is possible to explain where these differences come from, then, it will be possible to improve COMIS 1.0; moreover, the improvements of existing models will implemented in COMIS; new models will be added (to help in incorporating new models in COMVEN, an engineering guide will be distributed to the participants). This will lead to a new version of COMIS numbered 2.0 (note that the modifications on COMVEN imply that COMIN is maintained; LBL is in charge of maintaining COMIN). On the other hand, the improved version of COMVEN will be integrated in the Graphical Front-Ends.

1.12 Draft User Guide

The COMIS User Guide will be updated as draft during the whole Annex. Versions of the User Guide will be published together with COMIS 2.0 and 3.0.

1.14 Final adjustment of COMIS 2.0

After the second set of experimental comparisons (cf. task 3.10), final adjustments will be made.

1.15 Improvement of the GFE

The comments of Annex 23 participants are taken into account to impr
new version of the GFE together with a contribution to the User Guid

1.16 Development of COMIS 3.0 and user guide

After having improved COMIS 2.0 and the GFE prototype, the new version of COMIS will be incorporated in the new version of the GFE; the checking functions and the on-lines helps will be added in order to create the first version (a prototype) of the Intelligent Simulation Environment: IISIBât-COMIS. A user guide will be produced, it will explain what can COMIS be used for and how to use the ISE. The result of this task will be:

- a new version of COMIS (3.0) running on PC/DOS, including a textual front-end (COMIN);
- a prototype of IISIBât/COMIS running on Unix machines.

2. Subtask 2 - Data

2.01 List available data

The goal is to identify the existing data sets which are available for COMIS evaluation.Result is a report with a list of data sets, including a short description, their type, availability and address.

2.02 Procurement of validation data

The validation data from each country will be converted to a common base for use in the COMIS model. A close contact with AIVC is essential for coordinating data obtained from different sources. For each evaluation test, the person who will be in charge of the evaluation, will have to get the set of validation data ready before the start of the evaluation phase.

2.03 Procurement of input data *(AIVC)*

The available data is to be divided into three groups:
- full scale measured data,
- model scale data obtained from measurements laboratories,
- computer simulated data.

These data will be made available for COMIS as input files usable by modules created in task 2.04.

2.04 Improving input

Modules allowing the use of data coming either from AIVC data base or from the DOE-2 computation code will be implemented into COMIS.

3. Subtask 3 - Evaluation

3.01 Specifications of validation data

The scope of this task is to answer the question: what are the interesting data for COMIS evaluation ? The result is a short report, completing the AIVC technical note 32.

3.02 Planning of user's test

First, people (volunteers) who will performed the tests have to be found; then, the user's tests have to be defined and planned. In this phase, the users will be mainly participants of Annex 23. A close contact between the users who will performed the tests is important for efficient performance of COMIS system.

3.03 Sensitivity analysis

The goal of the sensitivity analysis is to determine how the variability of input will influence the outputs of the system and then to select the main input data on which the error propagation study will be performed. MISA (Multi-run Interface for Sensitivity Analysis) allows one to perform automatically the sensitivity analysis and possibly the error analysis. At the end of this task a report will be produced.

3.04 User test 1

COMIS V1.0 and a benchmark will be distributed to the users who will perform the tests (in order to check this version of COMIS); the scope of the tests is to get feedback from users (could you use the program ? how did you find COMIN ? what are the results of the benchmark ? etc).

3.05 Error propagation study

After the sensitivity analysis a set of relevant input data will have been selected. The error propagation study will be performed only for this set of input data. The goal is to assess the confidence intervals of the outputs if the confidence intervals of the inputs are known. From the new knowledge produced by the error propagation study, the goal is to develop checking functions which can automatically answer to the following question : if a certain accuracy is required for a certain output, can this accuracy be reached knowing the confidence intervals of the inputs ?

3.06 Reliability study

The goal of this task is to develop a routine which will allow to assess the risk of insufficient ventilation or, to the contrary, too important ventilation rates.

3.07 Analytical evaluation

With simplified boundary conditions and simple configurations, COMIS is compared to analytical solutions.

3.08 Plan experimental comparison

The goal of this task is to prepare the comparisons between COMIS and the selected measured data sets.

3.09 Experimental comparison 1

The goal is to compare the experimental results versus the computed air flows in order to evaluate the relevance of COMIS (the experimental results will be mainly existing data sets), taking account of confidence intervals of both measured and calculated data. The product of this task will be an internal report.

3.10 User test 2

COMIS 2.0 will be distributed to the participants in order to make a new evaluation of COMIS it-self and of the Graphical Front-End (participants who want to test the GFE will have to deal with hardware and software problems -UNIX environment, required runtimes, etc). The product of this task will be an internal report.

3.11 Experimental comparison 2

After having improved COMIS, new tests will be performed in order to check the effectiveness of the improvements.

3.12 Report on application limits

The comments of Annex 23 participants about application limits will be compiled in a report in order to precise the main application fields of COMIS, the problems which can appear, etc. The results of this task could be used to develop a checking function of the ISE.

Appendix 2

List of Annex 23 documents

The following documents are provisional documents; some of them will be continuously updated. Each document is related to specific tasks (reference numbers between brackets).

- Fundamentals of the Multizone Air Flow Model - COMIS. (tasks 0.04 and 0.05)
  Technical Note AIVC 29, May 1990

- COMIS User Guide. (tasks 0.04 and 0.06)
  Version of February 1991 and additions of August 1991

- Evaluation Procedure Using Sensitivity Analysis of Model and Measurements. (task 3.03)
  Jean-Marie Fürbringer, September 1991

- COMIS Expert System (proposal TG #8) (task 1.01)
  Yashuo Utsumi

- Applications of Multizone Air Flow Simulation Models. (tasks 1.06 and 3.12)
  Claude-Alain Roulet, November 1991

- Modelling of the COMIS Data Structure. (task 1.02)
  Werner Keilholz, December 1991

- Selected data from LESO data set. (task 3.01)
  Jean-Marie Fürbringer, January 1992

- Specification of data. (task 3.01)
  Claude-Alain Roulet, Jean-Marie Fürbringer, February 1992

- Model Documentation. The Annex 23 PROFORMA. (task 1.03)
  Roger Pelletret, April 1992

- From Simulation Environment to Intelligent Simulation Environment (tasks 1.01 and 1.04)
  Werner Keilholz, April 1992