PROCEEDINGS RELATIVE TO A QUICK DETERMINATION OF THERMAL PERFORMANCES OF PASSIV SOLAR SYSTEMS (*)-(* *).

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1. ABSTRACT.

In the following report it's reported on a research still going on, which aims at establishing easy to use computing methods to allow to quickly compute the thermal loads at first stage of approximation and the performances of the most significant solar systems, which can be applied to residence building, both public and private.

The research is developing through three steps.

In the first step the research team recognised the most frequently shapes of buildings and housings occurring in residence building.

In the second step, also with regard to the outcomes of the study on the building types, a theoretical reference model has been designed, which the thermal loads and the performances of the passive solar systems have been computed for, when varying a few parameters regarding building typology, alignment of the body of the building, flats layout, walls shape, and so on.

In the third step the interval range, where the model can fit into, and the correcting coefficients are set through theoretical and experimental tests.

The tool, the research team want eventually explain, shall consist of a set of tables easy to be read so that by entering them with the parameter values corresponding to a well definite real occurrence (of building alignment, flat layout, wall shape and climate) one will get the first approximation values of the thermal load and performances for the different kind of solar systems.

2. TYPICAL OCCURRENCES IN ITALIAN RESIDENCE BUILDING.

At the time the most frequently occurring and mapping typologies and housing types have been recognised; with regard to a typological and geometric point of view, 50 projects have been analysed of a repertoire of the Lombardia District [1], chosen from those, who took part to a contract competition issued in 1978.

Once the building types, the associating rules of the houses and the most common geometrical forms have been recognised, each type of house (distinguished by a geometrical shape and typological constraints) is analyzed in detail. The structure of the front wall is also studied, with the purpose of controlling its geometric compatibility with passive systems and corresponding energy consumptions.

For example, for 45/55 mq house Fig. 1 shows a paper which puts into correspondence the house geometry with that of the open front-wall.

Four possible structures of the open front-wall have been considered, namely: corner loggia, front-loggia, constant loggia, wall with no loggias. At all eventually. The functional placing of the inner spaces of the houses has been analyzed. As an example for 45/55 mq houses Fig. 2 shows a sheet putting in correspondence the house geometry and related typological constraints with their inner functional placing. Therefore we were able to calculate inner spaces, which can be directly suitable for solar heating. In our opinion this feature plays a rather important role, because passive solar systems taking up the whole of open front-wall facing South give a direct thermal contribution, to adjacent rooms; therefore it is important to know how they will be used and everything about their geometry, in order to avoid inadequacies and contradictions, for example: overheating, "useless" solarization of rooms such as bathrooms, stare-rooms, etc.

3. DEFINITION OF THE "THEORETICAL" REFERENCE MODEL AND EVALUATION OF ITS ENERGY PERFORMANCES WITH REGARD TO A FEW PASSIVE SOLAR SYSTEMS.

3.1. GENERAL ISSUES.

We have established a theoretical reference model made of a matrix, which in turn consists of 24 houses, by increasing 12 M (M= 10 cm) the two plan-sizes of a standard house (72M X 6OM).

The 24 housing, obtained insofar, with this method are subject the geometric constraint to have a surface smaller than 110 mq or, at the most, equal to this size.

In other words, they fall within the useful sizes allowed by economic and public building most common standards.

Up to now only 8 housings, among the 24 obtained, have been accounted, as Fig. 3 shows using the following short notations: Sl, S3, S5, Sll, S13, S15, S20, S22. The study has been carried out based on the assumption that stationary conditions occur for each separate house, for three building types (multistory buildings on line, terraces-buildings and isolated house, see Fig. 4), and for the nine "Type position" that can be taken on by the houses (see 1, 2, 3, 4, 5, 6, 7, 8 and 9 in Fig. 4).

It is assumed that at least one of the front-wall in any house is facing South.

Each standard house is thought of as a parallelepiped, which in planta maps to the others as shown in Fig.5.

For each house the windows are supposed to cover 10% of the vertical covering surface of the house [2] and they are equally distributed on the southern and northern walls.

The computing programs implemented for this very model have been written in Fortran and run computer center Faculty of Engineering University of ANCONA.

3.2. THERMAL LOAD DETERMINATION.

Up to now the thermal load of 8 standard houses could be determined, with regard to three cities: Ancona, Bolzano and Cagliari.

The variables accounted so far are: the structure of the southern wall of the housing (traditional, with endless thermal resistance and solarized passive systems); the heat-transmitting capacity of frames (KV=5.0, 3.0 W/mq°C) and opaque surfaces (KP=0.5, 0.75, 1.0, 1.25, 1.5 W/mq°C), thermal dispersions of thermal bridges produced by the edges of the parallelepiped, that is the shape of each housing (KS=5.8 W/mq1C for the "non-corrected" [3]). It is assumed that the houses in typical positions 3, 6, 7, 8 and 9 touch the ground-level. The energy wasted for changes of air is equal to 0.18 w/mq°C (see art. 21 D.P.R. n. 1052 28.06.1977).

Tables A, B, C, D, E, F and G show the flow-chart which point-out the approach used to compute thermal load, with respect to the southern wall kind.

3.3. DETERMINATION OF SOLAR SUPPLIES.

The passive solar systems considered are the following ones: Trombe wall, direct interception, separate-storey interceptor with floor thermal accumulator, blade interceptor and floor heat-accumulator, back to back hot house (outer screening = hot-house, inside screening placed close to the accumulator wall = cool-house), hot house acting wall.

The solar contributions of a standard house are only accounted when the southern wall is of traditional kind and has an endless thermal resistance (solar benefit only produced by the windows facing south).

The passive solar systems are considered with or without thermal screening placed either outside the interception surface (glassed surface) or the heat-accumulation; the thermal resistance relative for such screening is 1.58 mq°C/W, on the assumption that the insulating screening is installed during night-hours, that is from 5 p.m. to 8 a.m. [4].

The solar energy supplies are calculated by adopting the method of the vertical, transparent and equivalent surface facing south, (see C.S.T.B. cahier n.1757 avril 1982: Régles th-B82). The solar contribution has been determined in case of both "weak" and "strong" thermal inertia (see Régles th-82), relative to the cities of Ancona, Cagliari, and Bolzano.

Tables H, I, L, M, N, 0, and P show the flow-charts which display the approach for solar supplies contribution.

3.4. DETERMINATION OF AUXILIARY ENERGY.

Auxiliary energy is defined as the energy that either the heating plant or the air-conditioning unit really deliver during winter-time.

Such energy is the result obtained subtracting the wasted energy, corning from standard houses(thermal load), from the solar energy supplies. The flow-harts regarding the approach used to compute auxiliary energy are shown in tables Q and R.

3.5. DETERMINATION OF CORRECTING COEFFICIENTS.

The method followed in this research so far has allowed to estimate the correcting coefficients, applicable to thermal loads, solar contributions and auxiliary energy, which have been taken from the model created on purpose for Ancona, in order to calculate the equivalent values for Cagliari and Bolzano.

4. RESULTS OF THE STUDY ON THE MODEL.

4.1. GENERAL ISSUES.

As far as this model is concerned, the application of the suggested method has been carried out through the following steps:

a) listings processing (see Fig. 6)

b) graphs' processing (see Fig. 7, 8, 9)

c) comparison between the outcomes obtained for the city of Ancona and those regarding other towns, by computing the correcting coefficients.

4.2. LISTINGS.

Three kinds of listings have been implemented for each house and for each kind of solar plant. They show either thermal loads, solar supplies (solar covering ratio relative to thermal loads) or auxiliary energy. Each listing is structured in such a way that the numerical values determined by the crossing between lines and columns (see Fig. 6) shows the required value.

Nine columns have been particularly stressed corresponding to the positions which can occur on the basis of the three assumed building types (see Fig. 4). Each column is then divided into two others: one for solar equipments with night-thermal screening (S), the other one for non-screened solar equipments (NS).

Eventually the listing is finally divided into twenty lines corresponding to the other variables already accounted for namely: thermal transmitting capacity of the opaque shell (KP), window-surfaces (KV) and thermal bridges (KS).

On the whole each listing can be traced back to a prospect showing matrix of 20 lines and 18 columns.

4.3. GRAPHS.

4.3.1. GENERAL ISSUES.

The results obtained and systematically reported on listed matter can be discussed using graphs.

The most important geometrical parameters are: living volume/southern opaque surface ratio (VA/CS); ratio length/depth, that is the plan sizes of the living unit (L/P); wasting surface/living volume ratio (SD/VA).

The thermal insulation of the outside shell of houses is considered in terms of total volumetric coefficient relative to thermal dispersion CG (W/mq°C) to the value of the energy wasted in winter-time (CT, in Kwh or in wh).

Thermal performances of passive solar equipments are accounted on the double assumption of weak (FFD) and strong thermic inertia (FFI).

The first group of graphs shows the values FFD, FFI, CG and CT by using the geometrical parameters VA/CS, L/P and SD/VA (see Fig. 7 and 8).

The second group of graphs connects thermal insulation with solar contribution to heating (see Fig. g).

4.3.2. ANALYSIS OF GRAPHS.

Graphs C.T-L/P (see Fig. 7).

This graph shows 8 points, regarding the kind of houses which have been taken into account.

At the time, only these graphs have been elaborated and they refer to the type-positions 1 (shown in Fig. 4) and to the city of Ancona. The points relative to the houses with equal depth have been put together [5]; (the dotted lines indicate the values corresponding to the maximum C.T., that is the highest values assumed, namely KP, KV and KS; points and lines show values, relative to the minimum C.T., that is the lowest values assumed KP, KV and KS). Hence the following rule valid for houses with equal depth (P=Cost).

$$CT_{i+l} = CT_i + (20\text{-}26\%)\ CT_i \qquad (1)$$

Where CT_i represents the thermic load of the house (the energy wasted during winter-time), whose plan-size are LXP;
CT_{i+1} represent the thermal load of the house whose plan-sizes are (L+24M)XP.

Vice-versa, for houses with steady length (L=cost.) the expression is the following:

$$CT_{i+1} = CT_i + (18\text{-}25\%)CT_i \qquad (2)$$

where CT_i is the thermic load of the house, whose plan-sizes are LXP;

CT_{i+1} is the thermic load of the house whose plan-sizes are LXP (P+24m).

If one of the plan-sizes of the houses, building up the theoretical reference model, increases by 24 M, the result is an increase in the thermic load ranging between 18% and 25%.

Finally it is also important to see how the houses with steady depth (Ex.: S1 , S3, S5) show an almost steady value of the solar contribution fraction if the length has been increased (side facing south), although there is an increase in the thermal load, as indicated in 1.

Vice-versa, if we keep unchanged the sizes of the side facing south and gradually increase its depth (namely 24 M by 24 M), the value of the solar heating fraction undergoes an average decrease by 10%.

- GRAPHS VA/CS - VA (see Fig.8).

This graph shows 8 points corresponding to the houses considered for type-position 1.

Those points relative to houses with almost equal values FFI and FFD have been connected through dotted lines. The above-mentioned values are also indicated on a particular print-out, which refers to the southern wall assumed.

This listing is divided into two columns corresponding to the double assumption of weak and strong thermal inertia and each column is then divided into two others, which show the lowest and upper values of solar contribution.

This graphic, together with the above-mentioned list is very important, because it allows to compute energy supplies of solar plants if the geometrical values of the house are already known: living volume (VA) and southern opaque surface (CS).

- GRAPHS FFI, FFD - CG (see Fig. 9).

Up to now those graphs regarding type-position 1 and to solar equipment Trombe wall have been implemented; the graphs also indicate the values corresponding to the eight houses, which are being studied.

The graphic (FFI-CG) shows the solar contribution for houses with strong thermic inertia, the other one (FFD-CG) refers to solar contribution for houses with weak thermal inertia.

The solar heating fraction and the CG are linked by a hyperbolic curve, which is structured in such a way that given a house, an increase in CG causes a decrease in FFI and FFD. Three groups of curves can be recognised on the graphs and they refer to the three depths of the houses considered.

We can see that on the same CG, with steady length and gradual increase, in depth from 24 M to 24M, there is a percent-decrease of the solar heating fraction ranging between 10% and 16%.

If we compare the graphs FFI-CG and FFD-CG, we observe that with given a house and a fixed CG, the solar contribution for houses with weak thermic inertia is about 25% - 33% smaller than that for houses with strong thermic inertia.

4.4. COMPARISON BETWEEN THE RESULTS OBTAINED FROM THE MODEL BASED ON THE CITY OF ANCONA AND THOSE COMING FROM OTHER ITALIAN TOWNS.

The research has allowed so far to compute the correcting coefficients to be applied to thermal load values (C.T.) and to the solar contribution fraction. They have been computed by means of the modelset up for the city of Ancona (AN), in order to calculate the corresponding values for Bolzano (BZ) and Cagliari (CA) with regard to solar equipments - Trombe wall and direct interception.

- THERMIC LOAD

The following expressions have been obtained:

CT (BZ)= 1.57 - 1.68 CT (AN) (3)

CT (AN)= 0.57 - 0.59 CT (AN) (4)

the numerical values, which link the thermic load value of Ancona with those of Bolzano and Cagliari, are not in connection with the size of the house.

The correcting coefficients reported in (3) and (4) can be quite approximately considered independent by the type-position, which can be adopted by houses in mild climatic environments (Ex. Cagliari). Vice-versa as far as rigorous climatic conditions are concerned (Ex. Bolzano) type-positions can be divided into two groups: the first one gathers type position 1, 2, 4 and 5; the second one lists type positions 3,6, 7, 8 and 9.

The following expressions are valid for both of them:

Ist group

CT (BZ)= 1.62 - 1.68 CT (AN) (3')

IInd group

CT (BZ)= 1.57 - 1.62 CT (AN) (3")

- SOLAR HEATING FRACTION

We have elaborated the following expressions, referring to solar equipment with direct and Trombe wall interception, with or without night thermal screening.

- DIRECT INTERCEPTION

FFI (BZ)= 0.86 - 0.92 FFI (AN) (5-I)

FFI (CA)= 1.12 - 1.53 FFI (AN) (5-II)

FFD (BZ)= 0.89 - 0.91 FFD (AN) (5-III)

FFD (CA)= 1.30 - 1.35 FFD (AN)

- TROMBE WALL

FFI (BZ)= 0.85 ~ 0.94 FFI (AN) (6-I)

FFI (CA)= 1.16 - 1.58 FFI (AN) (6-II)

FFD (BZ)= 0.88 - 0.91 FFD (AN) (6-III)

FFD (CA)= 1.26 - 1.42 FFD (AN) (6-IV)

bO. SUMMARY

Following the first tests it has been seen that the theoretical model fits enough to real environments to insure a good approximation: nevertheless it is thought that it is necessary to carry on further studies and enhancements to better test and compute the corretting coefficients, which in particular occurrences must be used to account for the geometry and building typology.

With respect to this, a few sample buildings have been recognised, whose real performances are computed, monitored and compared with those expected by using the model.

It's foreseen that for the coming year also this further step of the research shall be accomplished.

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2) A. STAZI, P.MUNAFOI , "Prototipo solare ad Ancona", in Atti del I Congresso Nazionale dell'Area della Produzione Edilizia, Roma maggio 1984, Ed. E.S.A., Roma 1984, Vol. IV, pp.79, 93.
3) G.TARDELLA, A.STAZI, P.MUNAFO-, E.PETTINARI, "La tipologia edilizia in rapporto ai problemi del risparmio energetico", Istituto di Edilizia, Facoltà di Ingegneria di Ancona - Rapporto Informativo sullo stato della ricerca al 20.05.1984.
4) A.STAZI, P.MUNAFO', "La costruzione facilitata dei sistemi solari passivi", in Atti del Convegno Nazionale "Innovazione Tecnologica e Costruzione Facilitata", Genova giugno 1985.
5) P.MUNAFO', O.GIAMPIERI, "Procedura per la determinazione rapida delle prestazioni termiche dei sistemi solari passivi", in corso di stampa.

NOTES

[*] This article summarizes subjects and outcome of one research MPI 60% of title: "Risparmio energetico e recupero edilizio", by: A.STAZI (coordinator), P.MUNAFO', O.GIAMPIERI.

[* *] Translation by **ROSANNA MICATI.**

[1] See: Repertorio dei progetti tipo Regione Lombardia", Ed. BE-MA, Milano, 1978.

[2] This hypothesis is supported by an analysis carried out on a sample of about 250 living-cells. Hence the possibility of assuming a total window-surface equal to 10% of the wrapping vertical surface of the cell (See Ref. 3).

[3] See: "Isolamento termico-guida pratica per la legge 373", by ANCE.

[4] See for example: J.Balcomb, R.Mc. Farland, "A Simple empirical method for estimating the performance of a passive solar heated building of the termal starage wall type", in 2end National Passive Conference, Philadelphia 16-18 march 1978.

[5] Depth is defined as the leugth of the paln-wall of the house orthogonal to that wich presumably faces South (See Fig. 1).

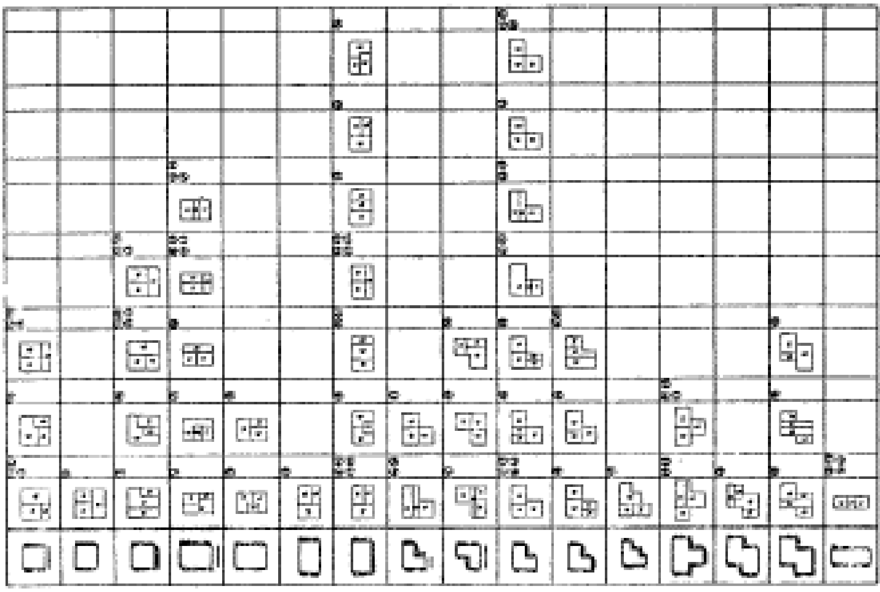


FIG.2. Geometry and type limitations of the houses relative to the functional distribution of inner. G=day-area; N=night-area; S=bathrooms. Type index-card relative to 45/55 mq housing.

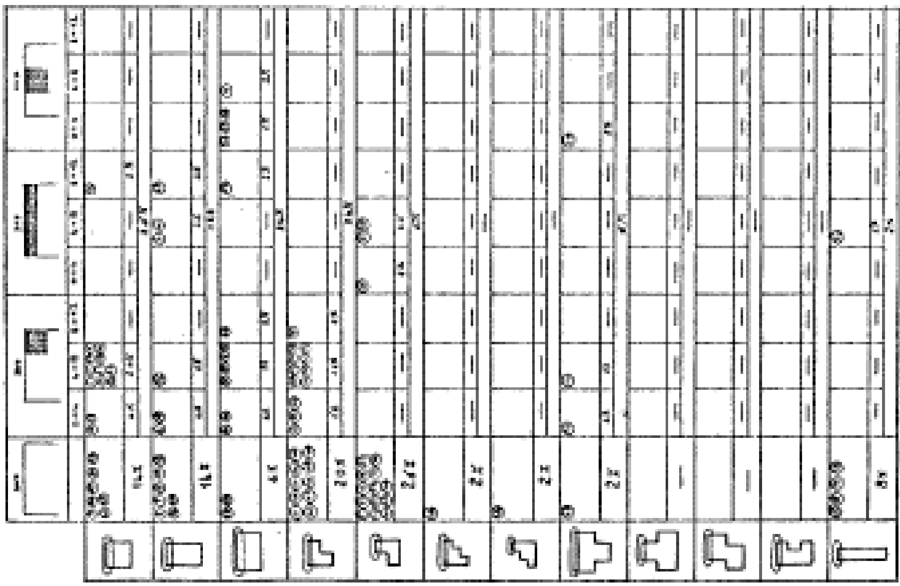


FIG.1. Percentage incidence of the different geometries relative to open front-wall as function of house front.

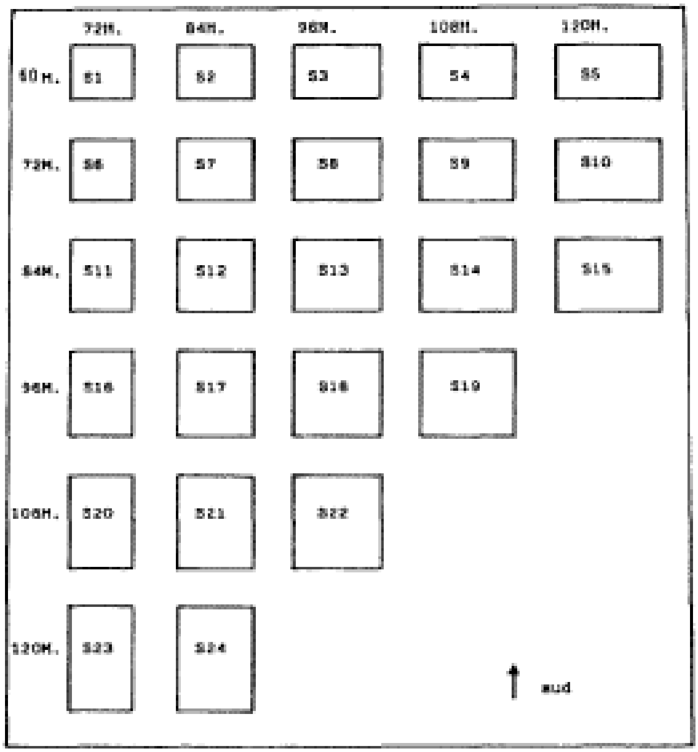


FIG. 3. Standardhouses.

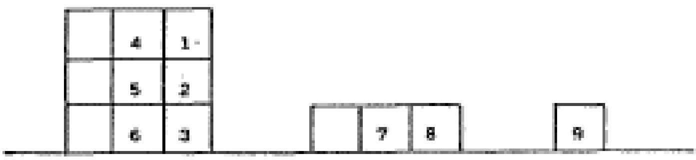


FIG. 4.

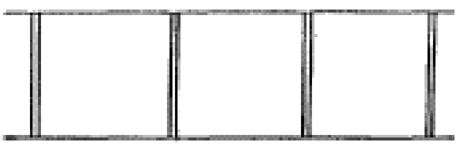
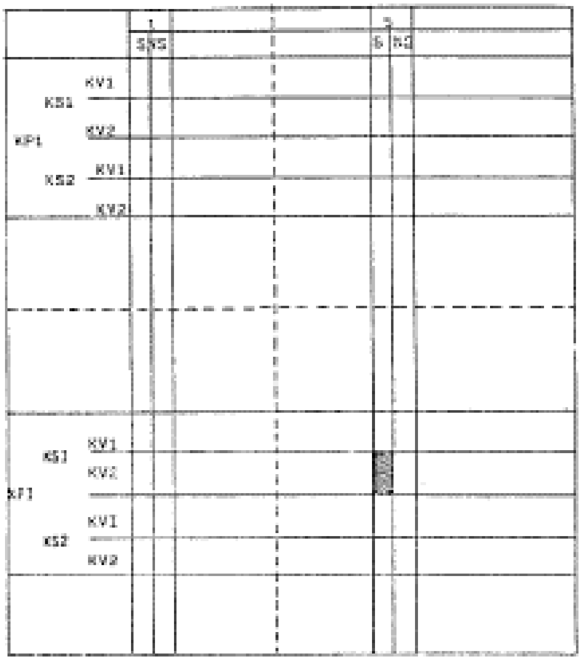


FIG. 5.



KP = K opaque walls; KS= K thermal brides; KV - K frames;
S =screening either on the interception system or the beat accumulator;
NS = no screening.

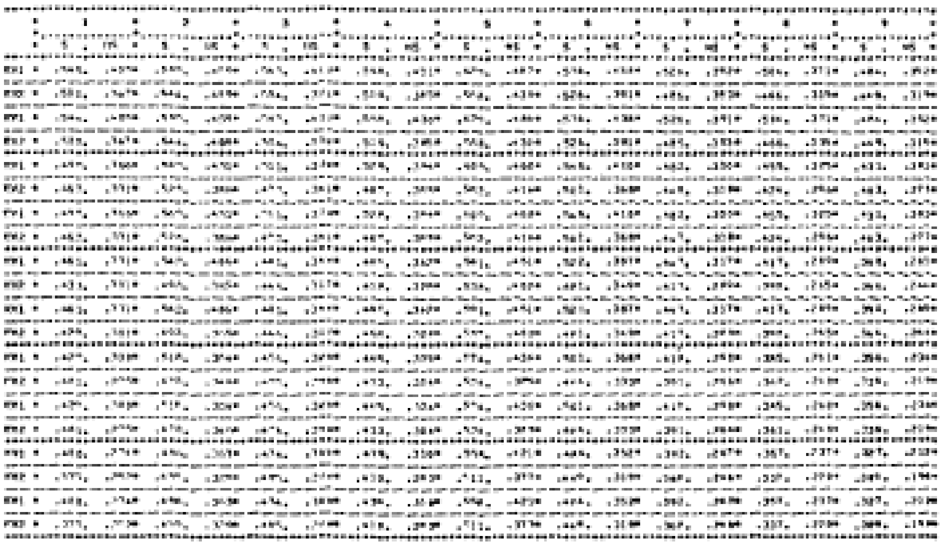


FIG. 6. listing scheme on which the values are reported CT, FFI or FFD. AUX; example of a listing produced by the computer.

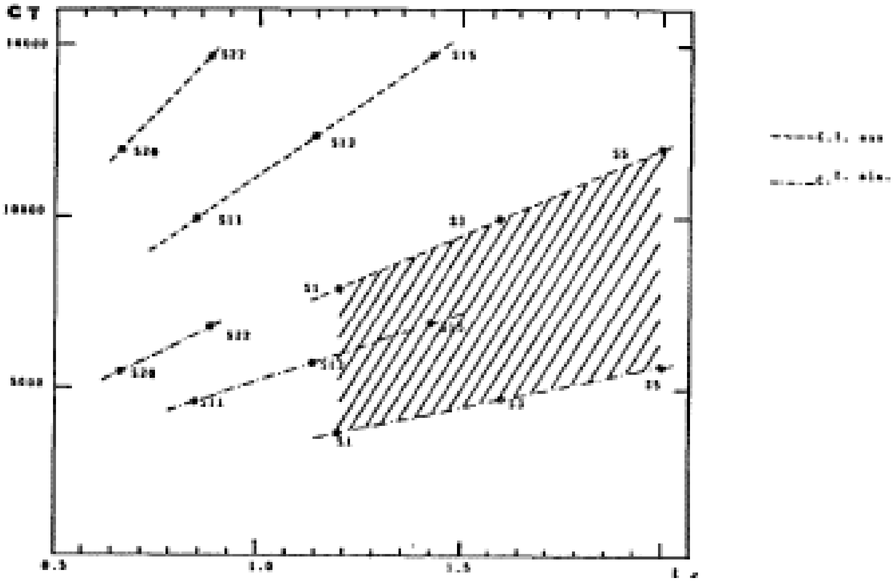
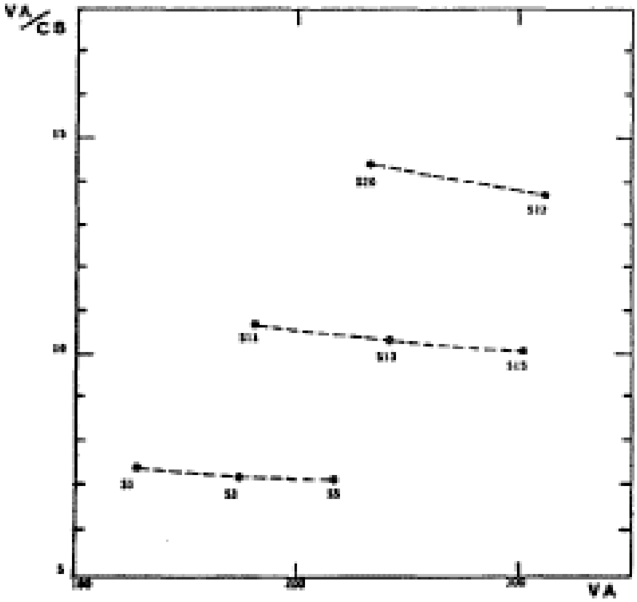


FIG.7. Graphic CT-L/P.Type position 1. The dotted lines shows the variation area of thermal load among houses with steady depth. CTthermal load; L,P= leught and dept.

FIG.8.Graphic VA/CS-VA Type position 1. The extreme points of the dotted lines indicate houses, which approximately have the some solar roof heating VA=living volume; CS= southern opaque surface; FFI, FFO=solar with strong dead weak thermic inertia.



AS	C	FFI MAX	FFI MIN	FFD MAX	FFD MIN
TB	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CPS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SSL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SSD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

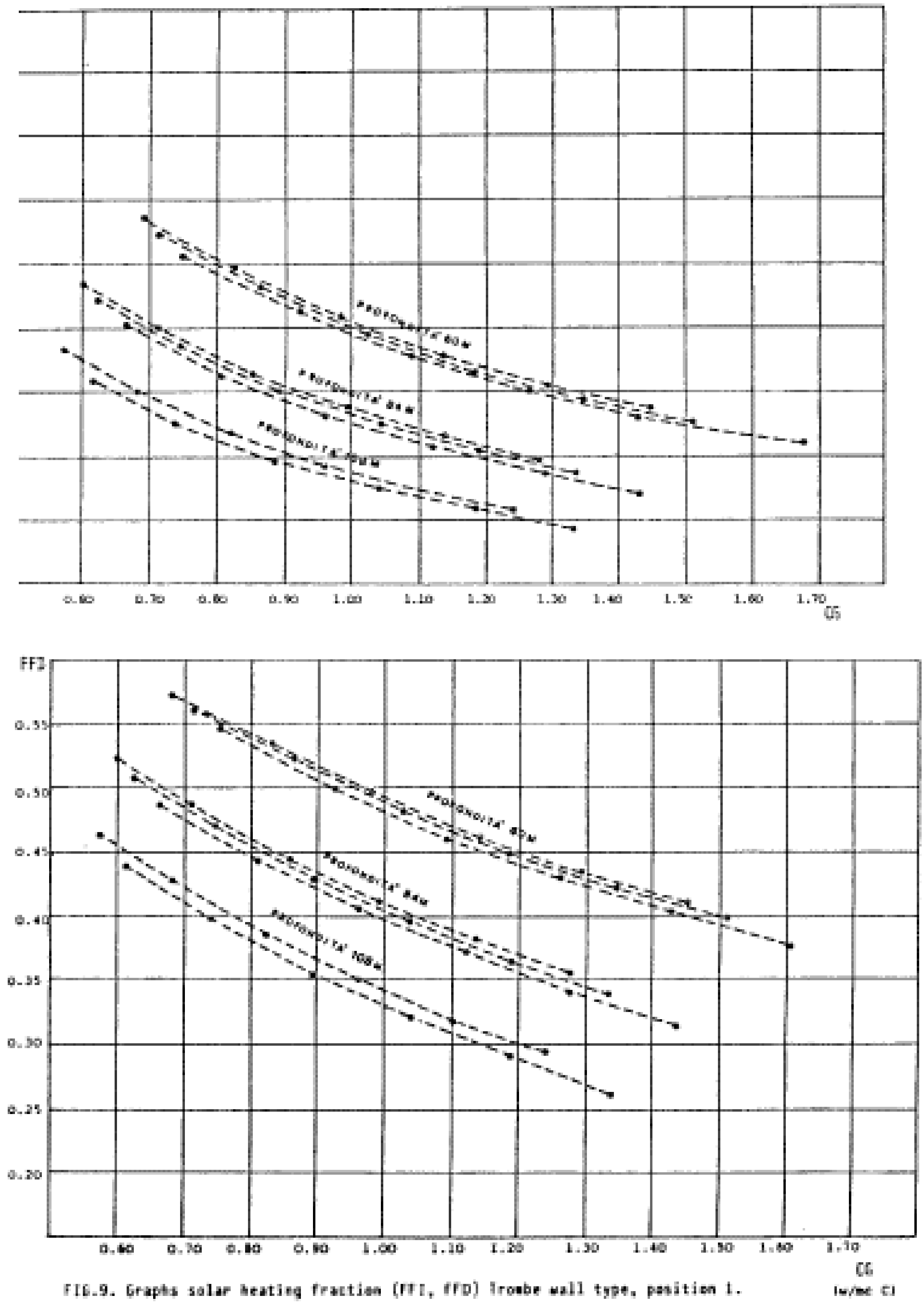
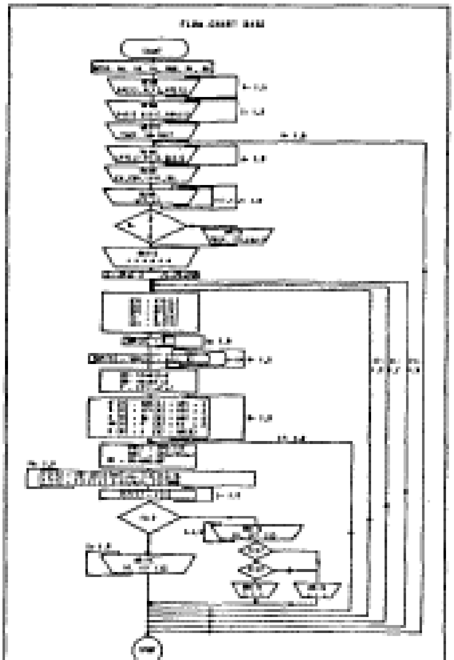


FIG.9. Graphs solar beating fraction (FFI, FFD) Trombe mall type, position 1.



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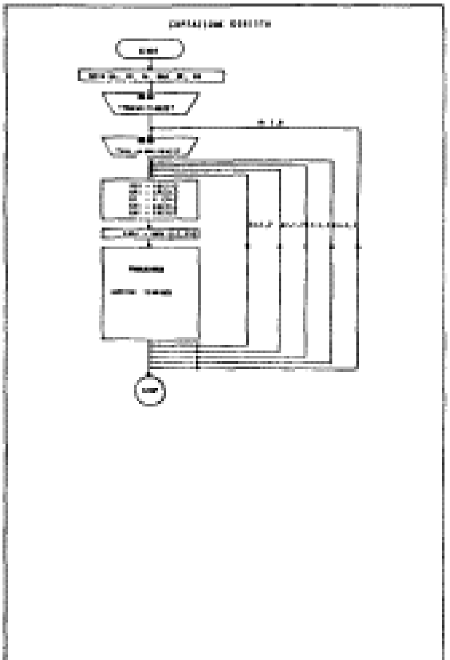

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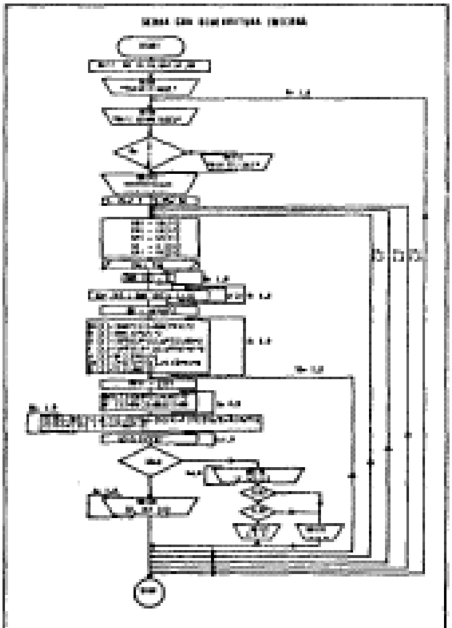

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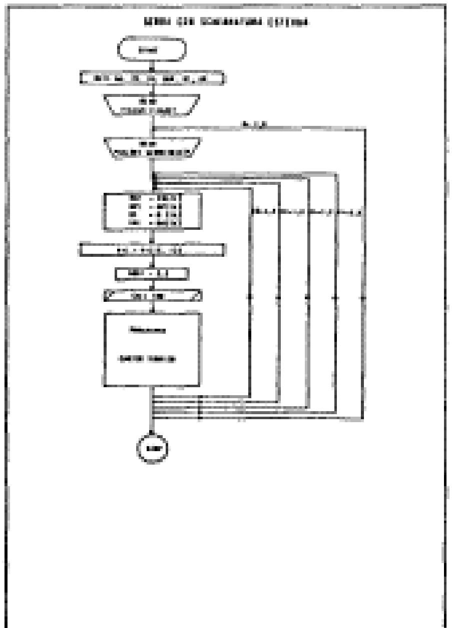

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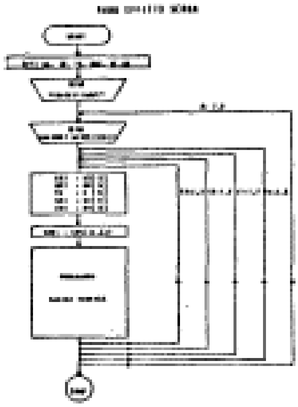

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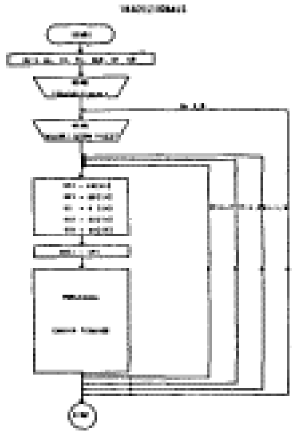

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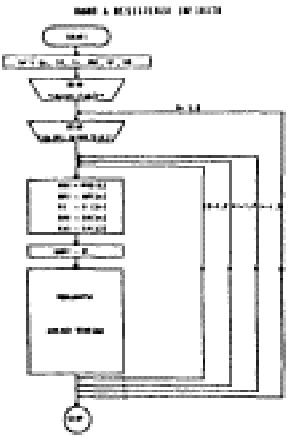

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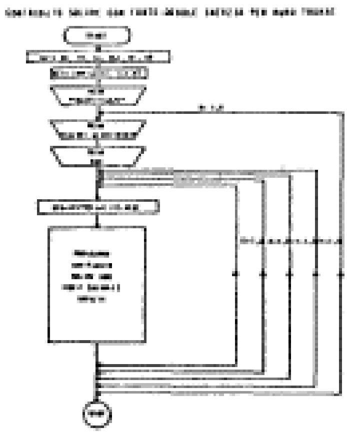

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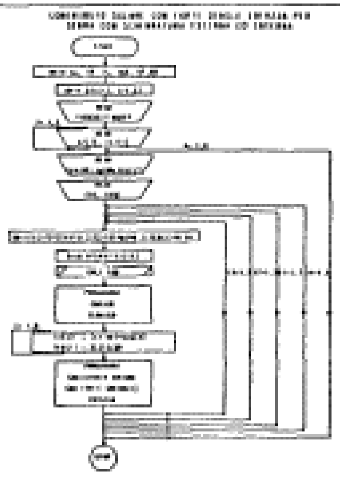

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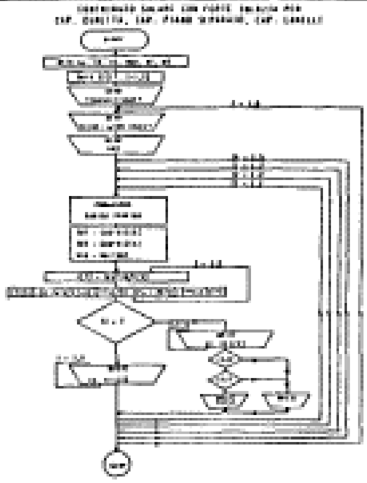

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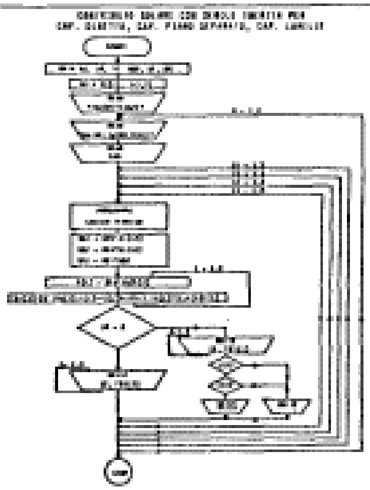

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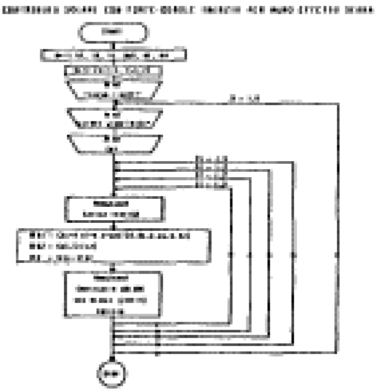

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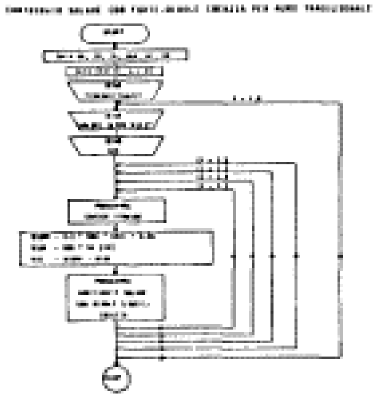

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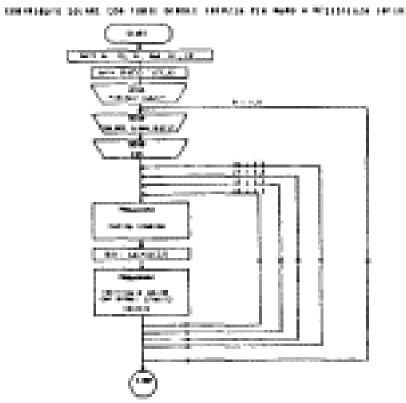
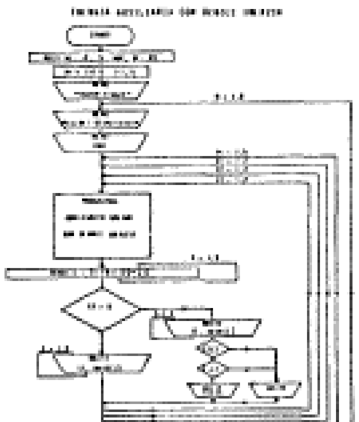
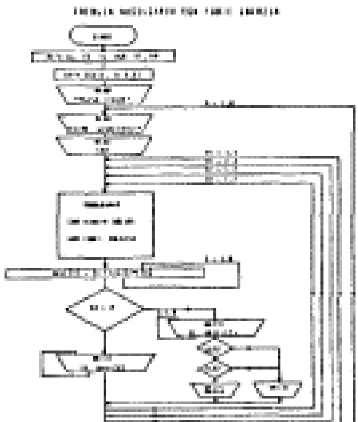


TAV.P



TAV.Q



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