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PHYSICAL ENVIRONMENT DESIGN CRITERIA FOR THE NEW CONTROL ROOM IN THE ENEA TRIGA-RC1 PLANT.

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Introduction.

The ENEA research reactor TRIGA-RC1 has been working for about twenty years and during this period of time the original system has often been modified (for example the yelded capacity was changed from 100 kW to 1 MW).

Parallelly to the plant modifications, many changes of the instrumentation in the Control Room (CR) were necessary in order to deal with the various aged components and the completion and integration needs turning out from the experience in reactor running.

In the room, besides the control activity of the RC1 plant, continuous training and updating activities are currently performed which are intended for the operators working in the control rooms of nuclear power plants.

With reference to these activities and owing to the

fact that the current technological development in the field of control systems is characterized by the design and use of informatic supports and VDTs, the necessity appear to test this advanced kind of system for the RC1 reactor, mainly in view of the generalized adoption of a similar system in power plants in the near future.

In particular the testing of the control system designed and brought about in the ENEA Laboratory for Applied Informatics was foreseen.

The existing CR is not provided with enough space for the necessary equipment both for the new advanced console and the traditional one, required for safety reasons, and also for the staying of trained operators. Therefore, the managing staff decided to build a new control room fit to meet the changed requirements.

Many experiments and tests carried out in the various industrialized country and widely reported in literature, showed how important are the problems linked with the human factor when generally considering the safety of plant operations.

Hence, the design of the physical environment of the new CR - carried out in a more general research project between ENEA and Politecnico di Milano - was based on the following fundamental criteria:

- to ensure conditions fit for the performance of the suspervision, diagnosis and control tasks the operators are entrusted with;

- to set up a model of control room for the more complex power plants.

First of all a detailed analysis of the environmental conditions relating to microclimate, lighting and noise was accomplished. Afterwards, the goals to be attained were defined as well as the technical means necessary for providing the operators with comfortable working conditions.

1. Analysis of the present situation.

1.1. Description of the existing control room.

The existing CR has a size of about 12 m x 8 m and a height of 3 m; the surfaces provided with windows, (totalling about 10 m^2) are equally subdivided on the northern and southern walls.

The door of the room is located on the eastern wall while on the western wall a window of about 4 m^2 allows the operators working at the console to visually control the operations carried out near to the reactor top.

Artificial lighting is ensured through ten ceiling diffusing luminaires provided with three fluorescent tubular 20 W lamps.

The air conditioning is ensured through the centralized conditioning system providing the whole building; because of the specific requirements of the CR, a further local air-conditioning unit was installed.

The acoustic treatment of the room was accomplished by means of a false ceiling having sound absorption properties.

Before starting the collection of physical environment experimental data, three questionnaires were submitted to the operators concerning the following factors:

- microclimate;
- noise;
- lighting.

Afterwards the following parameters were recorded in the various significant positions of the CR:

a) as to microclimate:

- PPD (Predicted Percentage of Dissatisfied) index;
- PMV (Predicted Mean Vote) index;
- relative humidity;
- air temperature;
- operative temperature;
- air velocity;

b) as to noise:

- overall value of the noise in dB(A);
- spectral composition in octave bands of central frequencies from 31.5 to 8000 Hz;
- overall noise value and spectral composition in third octave bands of all the sound signals and alarms of the console;

c) as to artificial lighting:

- illumination levels on the horizontal working plane and on the vertical console surfaces;

- luminance values in the field of view of the console operator due to the presence of various light sources and signals.

2. Evaluation of the reported situation.

The situation under study was evaluated on the basis of experimental data and of the informations from the questionnaires.

2.1.Microclimate.

With reference to the recommandation ISO 7730 (1984) "Moderate thermal environments - determination of the PMV and PPD indices and specification of the conditions for thermal comfort", the room microclimatic conditions turned out to be within the limits of the complete comfort area during the intermediate seasons of the year and non at all satisfying in summer and winter.

Therefore, the performance of the centralized air-conditioning system does not meet the requirements of the room and makes the use of the local air-conditioning unit necessary, though this is not always a resolving practice.

2.2. Noise.

The noise measured in the CR is mainly due to the running:

- of the cooling ventilation of the electric and

electronic equipment,

- of the centralized and local air conditioning system.

At the various significant room positions, the background noise level ranges between 50 and 55 dB(A); when the local air-conditionning system is operating, this level increases of about 5 - 10 dB(A).

Near the console operator place, the sound signals and alarms produce an overall noise level ranging between 61 and 65 dB(A).

Thus, as to the background noise of the room even with reference to the possibility of perceiving acoustic signals, the situation tested does not turns out to be fit for the specific requirements.

2.3. Lighting.

The mean illumination level was about 300 lux at the working plane and about 100 - 150 lux at the console vertical surfaces.

The luminance values in the field of view of the operator were:

- about 300 - 400 cd/m^2 for the luminaires;
- about 50 - 80 cd/m^2 for the reflections of the luminaires on the screens of instruments;
- about 20 - 35 cd/m^2 on the console vertical surfaces.

The luminance ratios of the console optical signals in the on/off conditions was generally included within the range 1/10 - 1/20.

Finally, as to the natural lighting of the romm through

the windows turned south, the entering sunbeams give rise to glare and luminance unbalance problems.
The lighting conditions of the room appear not completely adequate.

3. The new control room: design criteria for the physical environment.
According to the space requirements previously highlighted and to the possible future needs, the new control room dimensions are about 12 m x 18 m ; the figure 1 shows the planimetry and the location of the room under investigation.
The height of the room was fixed in 4.75 m in order to realize a proper underfloor as well as a technical opening over the false ceiling for the passing of electric wires and air ducts.
It was decided to let the southern wall blind and to provide the northern wall with windows to both meet the requirements of the thermal load originating from the sun and avoid the direct shining of sunbeams.
Being the room at the top floor of the building, the natural lighting may be achieved through openings on the room covering.

3.1. General considerations.
On the basis of all the elements resulting from the previous phases, the following general requirements

were pointed out:

a) air-conditioning: the installation shall:

- ensure comfort conditions and promptly face the maximum seasonal and daily loads;
- carry out differentiated performances in the room areas which are subjected to different thermal loads;
- be regulated by the operators who may adjust it to their own needs.

b) Lighting:

b1) artificial lighting: the artificial lighting system shall be designed according to the specific visual requirements of the two zones the room may be subdivided into: the console and the complementary zone.

As to the console zone, in order to realize a proper lighting condition fit for the VDTs, shall be avoided:

- high luminance reflections on the surface of the screens;
- uncomfortable glaring for the console operators;
- luminance umbalances in the field of view of the console operators.

The lighting requirements of the complementary zone are in general less critical. However a proper visibility level as well as visual comfort conditions shall be ensured.

b2) Natural lighting: the request by the operators to have a visual contact with the external environment is quite justified.

Moreover, the natural lighting system shall comply with the same qualitative standards provided for the artificial lighting both as to possible reflections and glare.

c) Noise: the noise level shall be such to:

- ensure the operators a good concentration easiness as required by the mental effort related to the task they are entrusted with;
- ensure the good perception of the sound signals and verbal communications, if any.

3.2. Thermal environment.

With the aim to achieve the goals pointed out as to the air-conditioning system the following design choices were brought about:

1) utilisation of an all air-two ducts-air-conditioning system with mixing boxes and ceiling air diffusers in order to:

- carefully adjust the input air conditions;
- easily adjust the system performances to future changes of internal thermal load;

2) utilisation of a temperature control system fit to allow the operators to modify the ambient air temperature according to their needs within a limited range. Particularly the operators will be able to adjust the environment air temperature between 20 and 24 C;

3) removal of the endogenous component of the thermal load due to the electric wall boards by means of air input through the underfloor and removal from top in a separate duct to avoid that this thermal load may significantly affect the comfort of the operators;

4) removal of the residual thermal load (originating from sun, walls transmission, people, lighting system and the other electric or electronic equipment of the room) by means of air input from the ceiling diffusers and taking up from the side walls grilles provided in the lower part of the northern and southern walls.

3.3 Lighting.

In order to meet the visual requirements of the console and complementary zone the following design choices were made.

1) Console zone.

a) Artificial lighting.

A lighting system was foreseen with indirect light in order to avoid reflections and uncomfortable glaring conditions. The light system will ensure an illumination level of about 350 lux on the working plane.

The utilisation of luminaires equipped with halogen lamps was foreseen owing to the excellent properties of the light emitted and to the easy dimming of the light flux too.

The figure 2 shows the general scheme of the light

installation.

The detailed performances and quality indices of the lighting installation has been verified by a computerized point by point method, operating on the basis of the calculation of the primary component relating to the ceiling luminaires and of the secondary component due to the multiple reflections on the walls.

b) Natural lighting.

Owing to the particular visual requirements of the zone, no natural light source was foreseen.

2) Complementary zone.

a) Artificial light.

For this zone a direct lighting system was foreseen with dimming of the light flux, in order to create less uniform lighting conditions than those of the console zone. The system was calculated on the basis of an illumination level of about 600 lux provided by means of "dark light" luminaires in order to minimize glare and to reach a Contrast Rendering Factor of about 1. The calculations were performed by means of a computer program which also allowed the evaluation of the main lighting quality indices; fig. 2 illustrates the arrangement of the luminaires.

b) Natural lighting.

The natural lighting system was set out in order to reach a mean daylight factor value of about 5. To this aim, windows totalling about 15 m^2 were arranged on the

northern vertical wall; eight openings of about 1 m^2 were planned on the room covering, with height of about 0.8 m in order to avoid any glare effect. The design was carried out by means of a computer program for the calculation of the sky component, the external reflected component and the internal reflected component; fig. 3 schematically shows the proposed arrangement of the openings.

3.4. Noise.

In order to reach the abovementioned goals, the background noise level was thought to be not higher than 45 dB(A). This level may be attained by both reducing the noise power emitted by the various noise sources in the CR and giving the room proper sound absorption characteristics.

In particular, on the basis of the geometric shape of the CR and of the characteristics of the noise emitted from the different sound sources and of the sound properties of the ceiling, the required performances were verified by means of a computer programme based on the image source method.

4. Conclusions.

The design criteria adopted led to the outline of a working environment characterized by microclimatic, lighting and acoustic parameters fit to ensure general comfort conditions for the operators.

Moreover, the chance has been given to the operators to adjust the environmental parameters, if possible, according to their individual requests.

The designed environmental conditions, the ergonomic study of the working site as well as the careful examination of the operators tasks, may lead to minimize plant running mistakes with consequent increased reliability of the whole system.

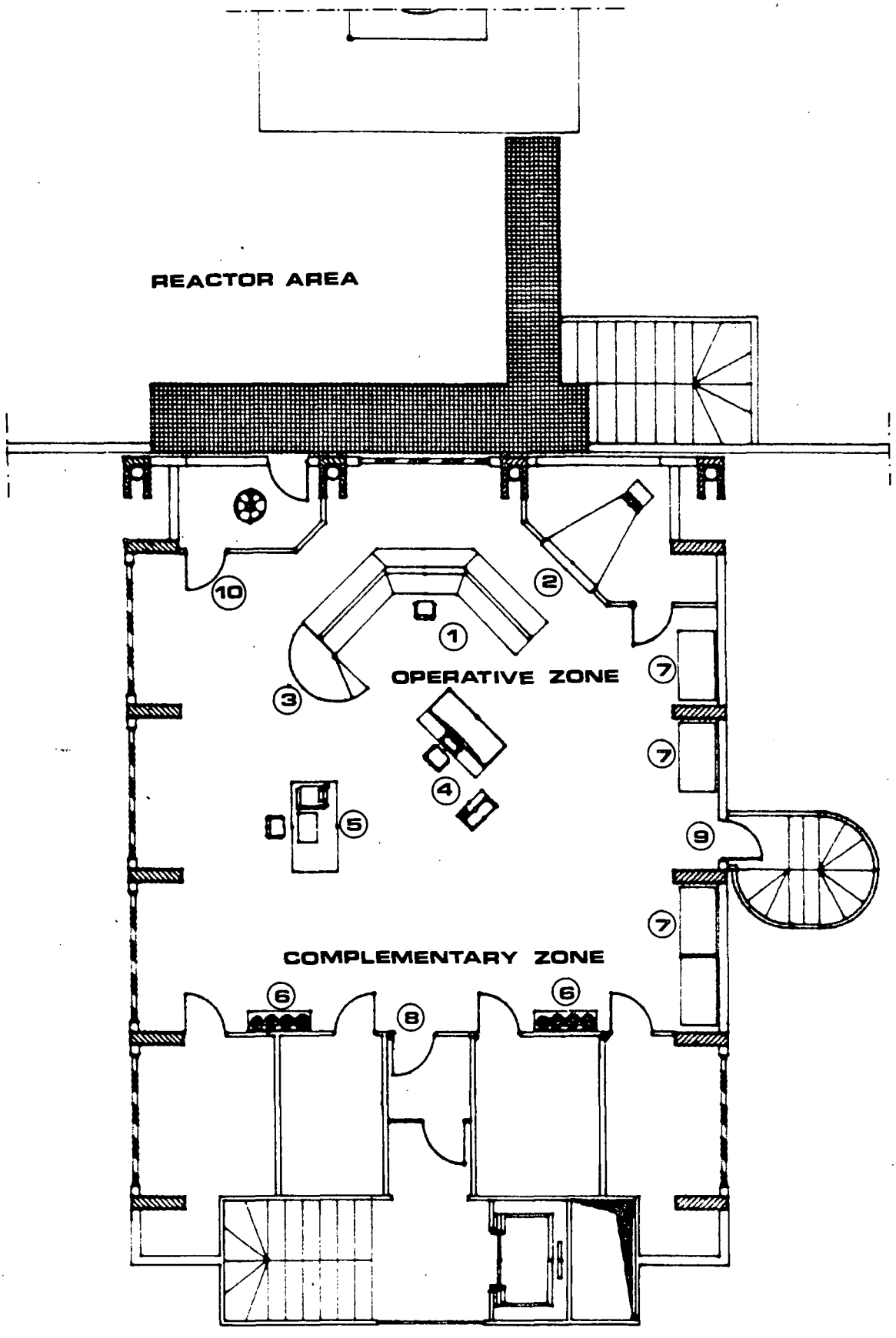

FIGURE 1 : GENERAL LAY-OUT OF THE NEW CONTROL ROOM

FIGURE 1

LEGEND

1 CONSOLE (advanced + traditional)

2 LARGE SCREEN

3 DRAWINGS HOLDER

4 SUPERVISORY CONSOLE

5 TABLE

6 HALON BOTTLE

7 ELECTRICAL BOARDS

8 CONTROLLED ACCESS

9 EMERGENCY EXIT

10 ACCESS TO/FROM THE REACTOR AREA

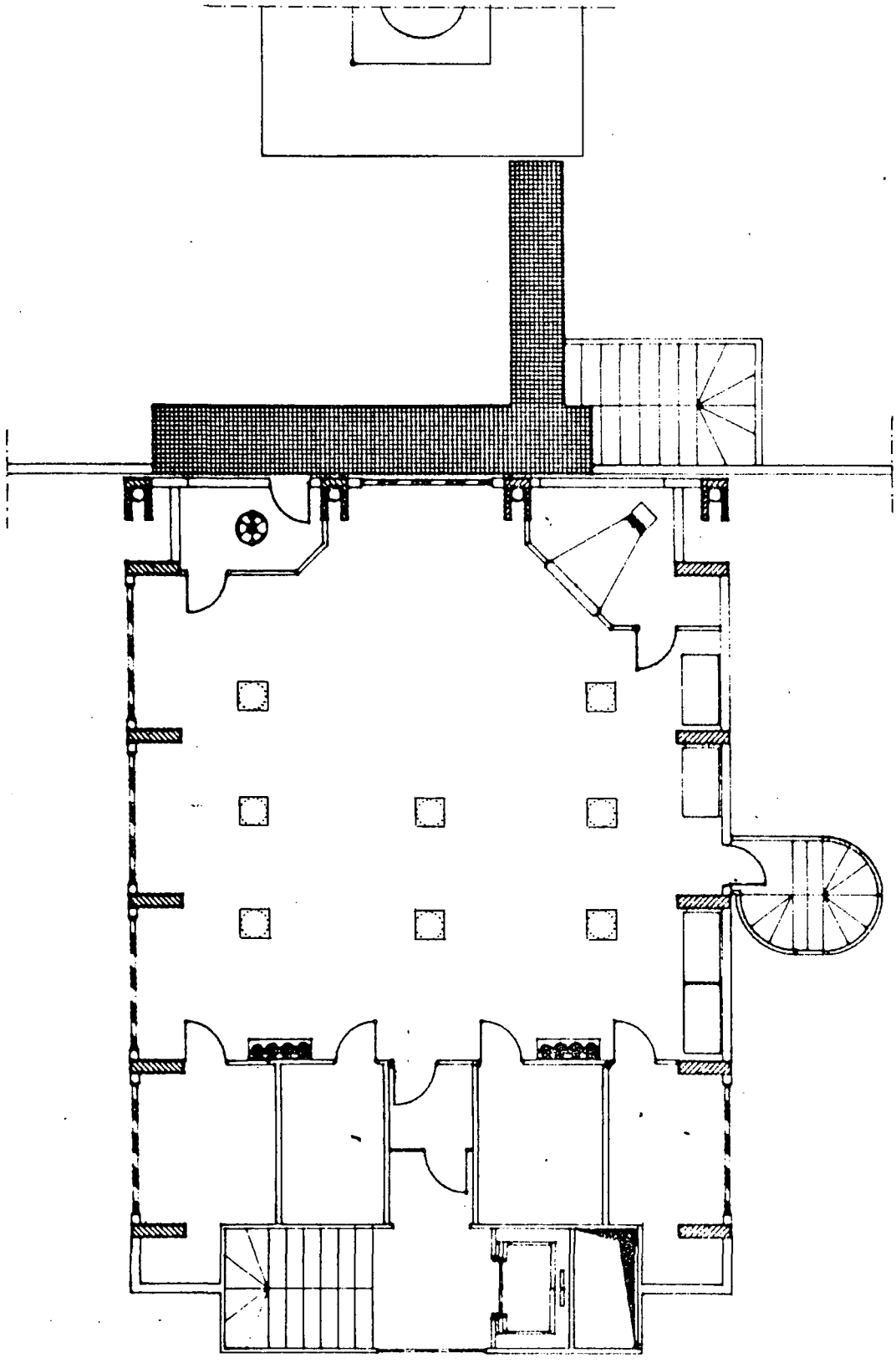

FIGURE 3

ceiling openings

0 100 200 300 400 500 cm.

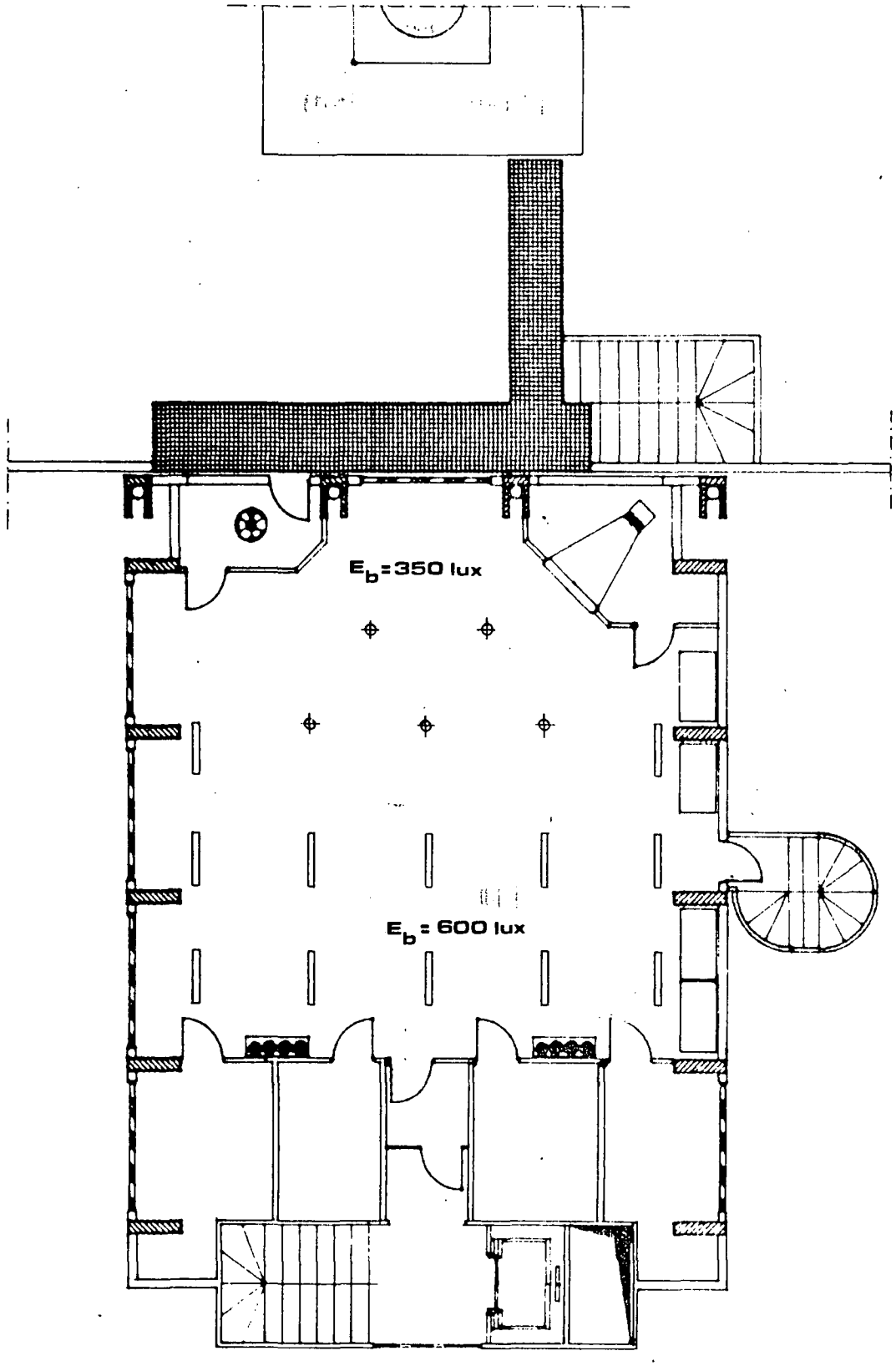
E_b=350 lux
E_b = 600 lux
direct lighting luminaires
indirect lighting luminaires
0 100 200 300 400 500 cm.

FIGURE 2