EUROPEAN COAL AND STEEL COMMUNITY

Community Ergonomic Research

DOC. N° 3277/72 e RCE

Original : Italian

Translations : French, German

Distribution : Enterprises

Technical Report n° 10

ERGONOMICS STUDY OF TRAVELLING CRANE DRIVERS IN HIGH-LEVEL CABINS

Source : Final report of research n° 6242/22/009

Author : Prof. C.P. ODESCALCHI

Reference period : 1.4.1966 - 31.12.1972

65.015

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Financial assistance was provided for this study by the European Coal and Steel Community

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OECH : 787

C O N T E N T S

- SCOPE OF THE RESEARCH . . . . . page 1
- PROCEDURE . . . . . page 2
- METHODS . . . . . page 4
- PREPARATORY ANALYSIS . . . . . page 6
    - Environmental analysis . . . . . page 14
    - Study of workplaces . . . . . page 19
    - Workload . . . . . page 20
- ANALYSIS OF RESULTS . . . . . page 22
- EXAMPLES OF ERGONOMICS DESIGN OF TRAVELLING CRANE CABINS . . . . . page 24
    - First example . . . . . page 25
    - Second example . . . . . page 68
- LITERATURE . . . . . page 75
- **A N N E X E S**

SCOPE OF THE RESEARCH

Brief interviews with crane drivers and our own knowledge of the workplaces concerned, pointed to the importance of careful design of travelling crane drivers' cabins in casting and ladling shops, in the wharf area and in scrap metal yards.

The ergonomics design of these workplaces with a view to ensuring and maintaining maximum comfort for the drivers in the performance of their activities, required, in the different procedural phases of the ergonomics research, a higher level study of the man-machine - environment system making reference - in the case of the latter factor - not only to the physical environment but also to the man-man system.

Obviously this approach needed to be supplemented by verifications at the individual cabins to determine the effectiveness of the design and evaluate possible corrections to it.

Our practical research involved a group of 170 workplaces in 13 metallurgical and metal-processing works and a further 50 concerns in the electrical engineering and construction sectors.

PROCEDURE

The problem
↓
formation of the study and working team

External group	+	Internal works group	+	Internal user group

↓

Input analysis — Practical study — Operational
Processing — General aspects of work ← experience
Output →
Feedback

↓ Priority choices ←

↓ Implementation with participation ←

Workload

↓ (Model if necessary) ←

Optimization →

↓ Verification ←

(Joint validation)

The working procedure adopted is indicated in the diagram which shows the relationship between the different points of intervention.

In view of its inter-disciplinary nature, formation of the working party required the participation of the company structures familiar with the ergonomics approach and willing first of all to bring to bear the attitudes necessary to achieve genuine inter-disciplinarity which may initially consist of an effort to adopt a language common to the technical and biological sciences, and secondly to continue to respect ergonomics criteria at later stages; it was also essential to obtain the participation of the direct users who not only gave the group the benefit of their own daily experience but also provided a continuing stimulus to its work.

The following enterprise sections were involved:

1) The design experts who must be present at all times and make themselves familiar with the group's work by observing operational conditions in each phase so that they can then design from the human angle and not merely in terms of technical efficiency.

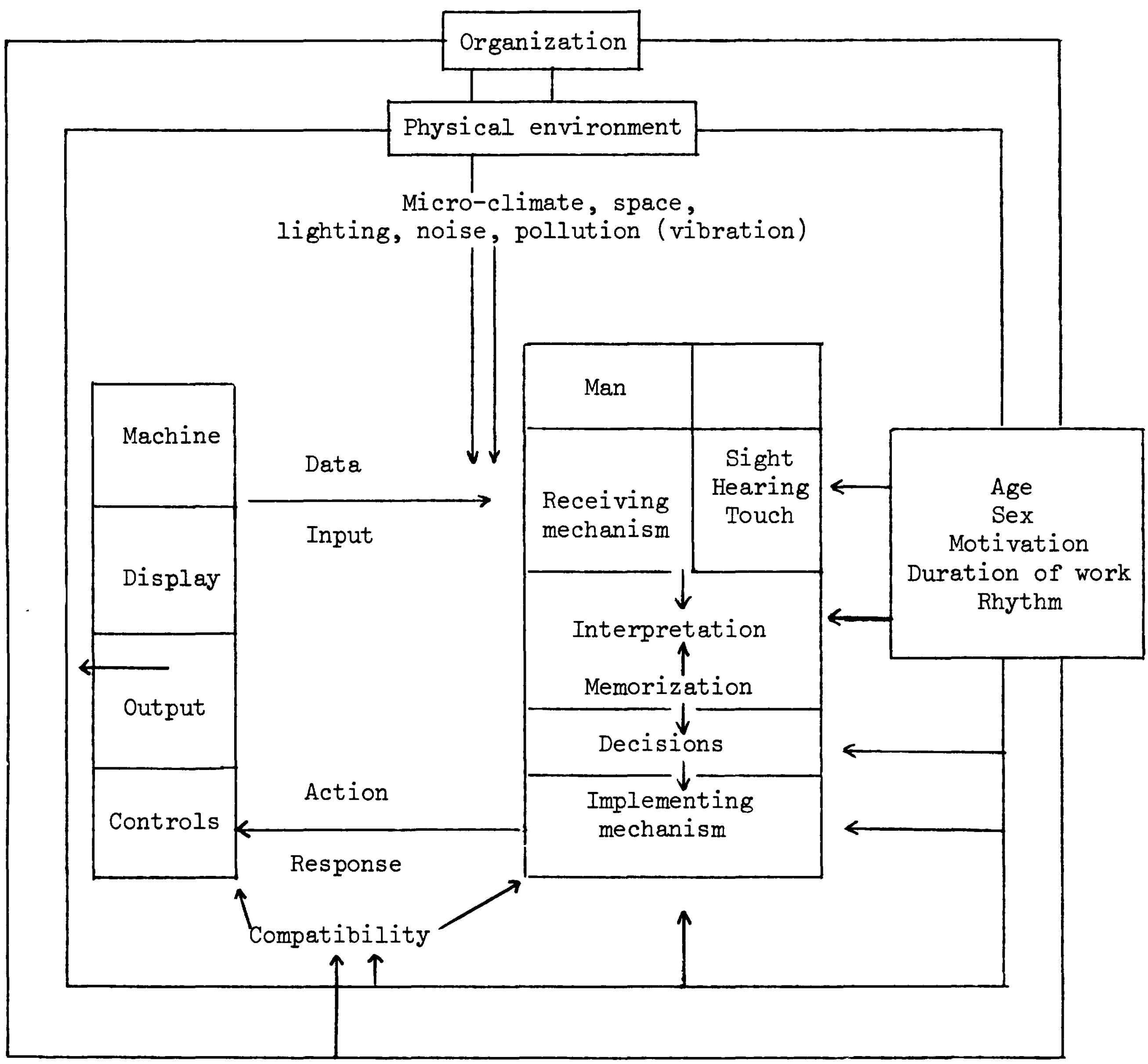
2) The training department which has a clearer grasp of the operational and human factors involved.

3) The safety department which participates in order to draw attention to technical shortcomings which are an obstacle to technical safety.

4) The handling specialists who have assumed considerable importance as a result of technical progress; to our way of thinking design has tended to subordinate human requirements to the desired efficiency of the system. For literature on this subject, we would refer readers to the impressive research by R.G. Sell and colleagues who were concerned primarily with the theoretical standardization of working positions; their conclusions apply to all travelling crane cabins and possibly also to the cabins of storage area cranes.

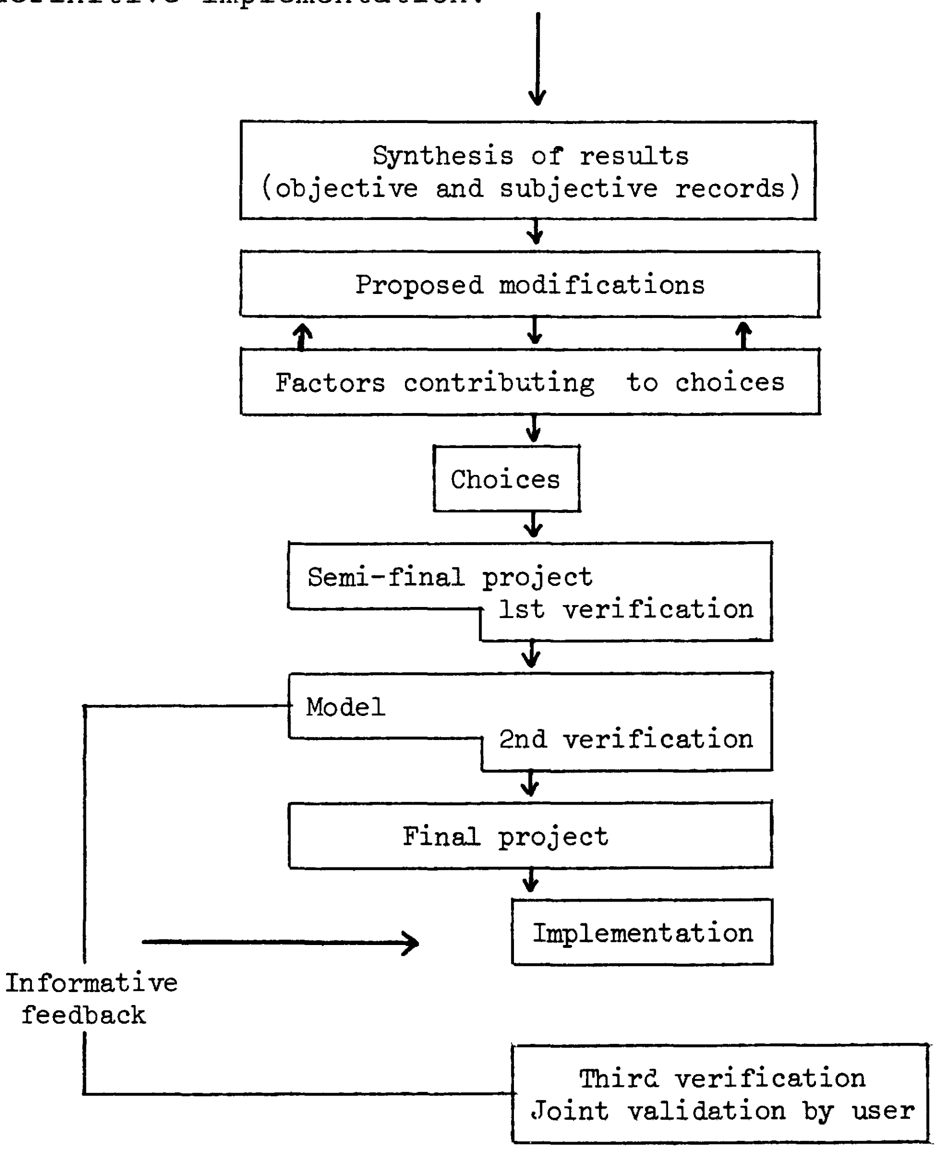
5) The workers whose presence may be considered the key to the whole operation.
Not only do they provide the benefit of their practical experience, they are also able to understand, through their participation, the development of the ergonomics study, recognize the technical and practical difficulties and verify the effectiveness of the results. In addition to the group of selected drivers, a number of chief crane drivers also participated in the study.

METHODS



The above diagram shows the working model used by us in our research. It should be noted that the man-machine system must be interpreted not only in relation to the wider physical environment but also to the man-man system which is equally important in the case of the workplaces studied by us because of the highly responsible nature of the drivers' duties and the complex organization involved.

To complete the investigation it would be desirable to introduce a special "model" to verify semi-final projects with a view to making such corrections as may be necessary before definitive implementation.



The research group consisted of a multi-disciplinary external group so that the various structures indicated in our introductory remarks were all involved in the study.

PREPARATORY ANALYSIS

Subjective factors, i.e. working experience, were taken into account by the inclusion in the research group of two crane drivers other than those directly consulted through questionnaires (a specimen of which is attached) or group meetings with content analysis. The drivers' role was to illustrate working methods, draw attention to difficulties, communicate the research results to their colleagues, express opinions on a personal basis or on behalf of all their colleagues in respect of certain design choices and acceptance decisions or at least in regard to various proposed solutions.

A trade union representative also attended meetings of the enlarged working party.

The research advanced with an alternation of interdisciplinary and area-specific phases; the area-specific phases included:

- meetings of the full working group (enlarged group) to take certain basic decisions, in particular:

  - definition of the study limits;
  - choice between alternative cabin locations and consequent structural modifications to the system;
  - technical solutions for cleaning the windows;
  - choice of types of controls to be adopted;

- meetings of the restricted working group to check special aspects:

  - work analysis;
  - verification of conformity of certain solutions with safety standards;

- evaluation of reasons for user resistance to certain solutions.

- The area-specific phases as such comprised:

  - determination of internal and external environmental conditions;
  - design of the cabin shape in the light of direct input data;
  - study of posture, signals and controls;
  - criteria for cabin air-conditioning.

Analysis of individual interviews yielded the following information:

1) In regard to the <u>cabin</u>, 64.7% of interviewees complained that it was not waterproof and over-exposed to vibrations. 26.4% stated that the heat insulation was inadequate. 23.5% complained of inadequate habitability and 5% of general discomfort (seats, controls etc) of the cabin; finally 2.9% complained of defective movement of the cabin on the bridge and insufficient maintenance.

2) In regard to the <u>working position</u>, 54.2% stated that they were obliged to work standing up because no seat was provided (8.5%) or because the seat was inadequate (17%); because visibility in the seated position was insufficient (37%); because of the position of the controls especially the brake (17%) and because of excessive vibrations in the seated position (2.8%).

3) 82.5% complained that visibility was insufficient; 17.1% felt that visibility was only inadequate in the lateral and downward directions.

The lack of visibility is due to poor maintenance, inadequate cleaning (57.5%) and badly designed window frames (51.5%), to dazzle (17%) and reflection from the glass (11.5%).

4) 82% stated that the lighting was inadequate; because of poor lighting of the working area (26.4%) or of the whole shed (41%) insufficient maintenance of the lighting equipment (5.8%) or poor arrangement of the light sources in relation to the cabin position and movements (2.9%).

5) 80% thought that the controls were not functional because they were too numerous (48.5%) or poorly placed (17%), because of the inadequacy of the safety devices (11%) or the slowness of response of the controls (generally due to the presence of safety devices) (28.5%).

31% answered the question "Are you in favour of combined controls ?" in the negative because of poor accuracy, slow response and inadequate safety.

6) 60% thought that signalling arrangements were necessary, 20% unnecessary and 20% gave no reply.

34.3% were in favour of a telephone and 11.4% against. 31.4% considered visual signals sufficient provided that there were expert personnel on the ground.

8% felt that signals were primarily necessary during handling operations.

8% suggested that workers on the ground should be given clothing (gloves, jackets, helmets) of a clearly visible colour.

7) On the subject of safety, all the interviewees complained of shortcomings in particular sectors, i.e. inadequate maintenance (26%) or controls (21%), poor visibility (21%), poor general organization (4.3%), insufficient training on

the ground (4.3%), lack or inefficiency of fire extinguishers (8.6%), fatigue (4.3%) and tension associated with responsibility to others (4.3%).

8) In regard to comfort, all the interviewees complained of stress during their work due to physical disturbances (68.5%) and psychological factors (22.8%). 22.8% complained of a lack of comfort due to the length of the shifts and 8.5% referred to their excessive isolation.

9) Air-conditioning was lacking in 14.2% of all cases. Drivers working in air-conditioned cabins complained of the invariable direction of the air jet (60%) while 17% referred to the lack of a filter, 62.8% to excessive noise and 45.7% to the lack of a thermostat.

The graphs based on analysis of individual interviews show in outline form the relative importance (in percentage terms) of the different problems as it emerges from the replies to each individual question. They clearly show the functional and organizational shortcoming of the crane driver's work and also indicate which deficiencies seem most important to the driver because of the physical discomfort and mental insecurity or fatigue caused by them.

It is significant that almost all the opinions stated in reply to the individual questions overlapped; for example the problem of handling is connected with the structure of the cabin, lighting, safety, air-conditioning and visibility; visibility is linked in turn with the structure of the cabin, the lighting (dazzle from furnaces, reflections in the windows) and ventilation of the working environment.

The results of the practical survey must therefore all be taken into consideration for the purposes of redesign, without priority choices, because of the clear intercorrelation between environmental factors, man-machine and man-machine-environment criteria.

Analysis of the group interviews with crane drivers fully confirms the results of the individual interviews since the same deficiencies are noted and the same problems highlighted.

The subject-areas considered were subdivided as follows:

Ergonomics problems including:

- environmental comfort in the cabin;
- comfort of the external environment;
- convenience of instrumentation;
- convenience of positions;
- convenience in regard to visibility and noise;
- convenience in regard to communications from and for the crane.

Problems concerning working safety:

- safety of handling operations;
- safety of access to and from the crane;
- safety of operation (brakes, limit stops);
- safety of manoeuvre (space).

Human problems:

- insufficient scope for relations with other workers;
- shifts, replacements and working breaks;
- relations with colleagues and management.

Ergonomics problems

Environmental comfort: the problem of the cabin is immediately apparent. The cabin provides no insulation from heat, noise and dust; on the contrary it makes these factors intolerable because of its confined space, the impossibility of movement and the discomfort resulting from the air-conditioning, noise, presence and dimensions of the instruments.

Above all the confined space and difficulty of communicating with the outside and with other workers make the environmental strains even more intolerable to the crane driver.

External environment: space, light, dazzle, dust and position of the cabin are the most evident factors. The equipment and installation of the crane must be designed in such a way that they are not impaired or damaged by the external environment.

Instrumentation: considered inadequate for the reasons which emerged from individual interviews; in addition, differences between instruments fitted on various cranes create difficulties for the drivers; this makes training even more difficult and the work of replacement drivers more dangerous.

Position: the structure of the cabin and the nature and layout of the controls force the oeprator to adopt artificial postures to see the external environment for handling work and to operate the controls (the brake is the biggest obstacle to a seated position).

Visibility: this is a key problem. The poor visibility is due, as individual interviews showed, to the structure of the cabin, maintenance difficulties and the external environment.

Psychologically, poor visibility increases the crane driver's sense of isolation, insecurity and tension in the performance of his work.

Noise and communication: communication is a basic requirement because it makes for greater safety, less isolation and better contacts with others.

Safety

during handling operations and access to and from the crane: this is a purely organizational problem which makes the crane driver further aware of his isolation and lack of contact with the enterprise. The crane driver is liable to feel neglected (the importance of cabin maintenance must be borne in mind at the design stage as well as the need for proper repairs and replacements so that the handling operation can be made as safe as possible in structural terms); during operation and manoeuvres: the crane driver's task which involves an evident responsibility to the machine and other workers is made even more difficult by the lack of proper maintenance and the type of instrumentation (over-complicated, slow to respond and differing from one crane to another).

Human problems

Lack of human relations: this is a major and complex psychological problem which can to some extent be remedied above all, but not exclusively, by a reorganization of breaks, rest periods and replacement rosters.

Shifts and replacement rosters: the replies revealed the lack of an organic method of ortanization of the work, viewed as a man-machine system. Ergonomics and operational improvements cannot be envisaged without taking into account the psychological reality of the crane driver's work with his "alienation", isolation, tension and anxieties.

In view of the interrelationship between the various problems which arise, it is impossible to place in a strict order of importance the difficulties facing crane drivers, as they are perceived by the drivers themselves.

The psychological situation of the crane driver who feels himself fundamentally excluded and isolated from the rest of the group aggravates his concern over the factors of discomfort to which he is exposed (structure of the cabin, external environment).

These discomforts at the ergonomics and environmental level do indeed exist; but they are heightened and worsened by the driver's psychological situation. Improvements in the crane driver's conditions of work must therefore be examined not only from the ergonomics and environmental point of view but also in psychological and organizational terms (man-machine-environment).

Analysis of the interviews with senior operators confirms the existence of most of the problems and shortcomings of which crane drivers complain (poor visibility, inadequate air-conditioning, poor cabin insulation, defective or incorrect lighting, vibrations, defective cabin movement, inadequate seats, space and signals, excessive noise, poor maintenance etc.).

Other problems connected with work organization also arise: the need to standardize the controls of different cranes in order to facilitate the replacement and rotation of crane drivers and therefore enable more breaks to be taken with a view to relieving tension and isolation, thus increasing safety.

For the same reasons there is a need for better training and an increase in the number of drivers on the payroll.

A further factor emerged, namely that some managers have no direct knowledge of the problems (which they discuss only at second-hand), since on their own admission they are not acquainted with the crane driver's workplace and have never set foot in his cabin.

ENVIRONMENTAL ANALYSIS

48 measurements were taken of the micro-climate (temperature, relative humidity, air speed), atmospheric pollutants in dust or other form, lighting and noise at the travelling crane drivers' workplaces in areas ZC, SL, PR and PB.

Micro-climate

This is the basic parameter determining the driver's comfort either outside or inside the shed.

Our measurements showed in almost all cases a clear correspondence between the external temperature (either in the open air or in the shed) and the temperature inside the cabin.

Moreover measurements taken in the cabin but in different shed zones (from SC to ZF, SL and ZS) showed slight temperature variations (4 to 5°). It should be noted that cabin movements take place fairly rapidly so that the operator is exposed to these variations in a very short space of time.

The highest temperatures were recorded in summer with the cabin in the open air where the lowest temperatures were also observed in winter, varying only marginally from the macro-climatic values, and in areas ZF, ZC and SL.

In regard to relative humidity, psychrometric recordings showed values which were generally higher than in the open air and even exceeded 70 to 80% in the annealing furnaces and ZC.

The air speed was always less than one metre per second in the cabin when the ventilators were switched off.

Recorded measurement data will be found in annex 3.

The following instruments were used for recording purposes:

- thermistor-type thermopsychrometer to measure air temperature (ta) and relative humidity (ur), bulb-thermometer;
- Lambrecht anemometer to measure air speed in m/sec (va).

Pollutants

Dust - The following instruments were used to measure dust levels:

- MSA electrostatic precipitator;
- "Fixt Flo" with cellulose filters;

- Dräger pump with "millipore" filters.

In the case of dust samples, the measurements made with the electrostatic precipitator were preceded by analytic weighings with a Galileo Sertorius precision balance. The millipore filters were examined, after diaphanization with methyl-cellosolve, in an optical microscope giving an enlargement of 200 X. Grain size measurements were made with an enlargement of 2000 X.

The examination for free SiO_2 in the deposited dust samples was carried out by the chemical method using hydrofluoric-phosphoric acid, together with X-ray diffractometric analysis.

The numerous samples taken showed a high dust content in the confined atmosphere of the crane cabin at PR, ZF and ZS.

In 60% of all cases, the granulometry of the dust was fine (80 to 90% of the particles had a diameter of less than 5 n).

In the ZC cabins dust contents were weighed with the windows open (for better visibility) and closed; there was of course a clear increase in the gravimetry (by 40% in almost all the cases examined).

In some areas with a particularly high quartz dust content (SL, ZS) the presence of SiO_2 was detected in deposited powder together with fine particles of SiO_2 in the dust in suspension in the cabin.

Annex 3 contains the most significant data relating to the qualitative and quantitative measurements of dust contents.

Smoke and gas

A number of CO, CO_2 and SO_2 measurements were taken in the cabins primarily in areas ZF and ZC.

CO and SO_2 were detected in quantities such as to certainly bring about, in the medium-term, pathological changes in the respiratory tract of crane drivers, under the given microclimatic conditions.

The concentration of CO_2 in % by volume was of course lower than that observed in operators at floor level.

An analysis was made to detect all the oxides of the metals present as impurities in steel, i.e. Cr, Sn, Zn, Cu and Al in the smoke generated by the melting process.

These substances were present in discrete quantities within limits tolerable to the human organism in the confined air of the travelling crane cabin at ZC.

All the measurements were taken with the cabin open as is normally the case during working operations. In 15% of all cases samples were taken in what may be described as abnormal conditions, i.e. with the cabin completely isolated from the remaining working environment. While a discrete quantity of pollutants was still present in these cases, there was clearly a considerable reduction.

Annex 3 lists data for the samples taken.

Noise

A Bruel and Kiaer type 2204 phonometer with a band-pass filter was used to record noise.

The sound pressure levels were determined in three weighted circuits dB(A), dB(B) and dB(C).

A slow recording was taken and in each case a spectral analysis was made of the sound.

In some cabins equipped with ventilation, double measurements were taken with and without the fan operating.

The data (the most significant items of which will be found in annex 3) shows a fairly low noise level corresponding in the various frequencies to the type of noise in the remaining working environment (prevalence of low frequencies in area ZF).

In cabins in which double measurements were taken (with and without the ventilation equipment operating), the increase in noise confirms the subjective impressions of the operator as revealed in the survey referred to above, concerning the noise level and air-conditioning of the cabin.

Lighting

Measurements expressed in lux were made of the lighting at the place of work; they gave results which in our opinion are relevant to the work done directly in the cabin (controls, movements etc) but do not reflect the problem of lighting in the working area as a whole which, for the crane driver, is external.

We therefore considered lighting factors in the working area and the discrepancies between the latter and the remaining environment, either indoors or outdoors, involving in the latter case a further factor dependent on variations in the position of the natural light source during the day.

The study of visibility carried out on 15 cabins is more revealing. The relationship between the human angle of vision and that allowed by the cabin structure was considered; the shortcomings of the existing structures are highlighted by the graphs (annex 4).

STUDY OF WORKPLACES

Analysis of the cabin structure shows that the three essential factors in making the driver's work comfortable and relaxed, i.e.

1) visibility ensured by the arrangement of the windows;
2) layout of the controls;
3) seat position;

which must be integrated with the driver to form a man-machine system are completely uncoordinated to the extent that there is no relationship between them; and this lack of coordination forces the driver to assume strained working positions which are clearly shown on the attached photographs (annex 4).

In our opinion the problem is therefore to ensure convenient movement patterns for the driver in relation to his controls and seat, by first adapting and designing suitable structures away from the cabin as a function of the various types of work to be performed.

This procedure should lead to an optimum window layout in relation to the movement structures, the arrangement of the controls, the seat and optimum visibility in the area of work.

WORKLOAD

The cardiac frequency (cf) of travelling crane drivers was measured during various phases of their work. At the same time measurements were taken of micro-climatic parameters (t_a, RH, t_g) and sound pressure levels inside the cabins; in conjunction with the sensation of discomfort for the human organism and other strictly psychological factors (maximum concentration, responsibility to others etc), these factors may create an excessive workload for drivers.

The graphs in annex 3 reproduce the recordings of cardiac frequencies in the various phases of work.

They show an increase in the cardiac frequency of approximately 30 beats per minute in the active phases by comparison with the state of rest.

Close examination of the graphs shows a higher increase in cardiac frequency during the ladle filling phase than in other operations. Measurements taken with the bulb thermometer during casting revealed a heat situation in the cabin which differed from the micro-climate during the other work phases.

The radiant heat is very intensive during casting operations. The sensation of discomfort resulting from radiant heat depends on the wave-length of the radiation which ranges from 1.5 to 2 n in the situation under examination and is all absorbed by the outer layers of the skin, thus giving rise to an extremely disagreeable sensation.

The radiant heat of the casting operations not only influences the overall heat balance with a corresponding rise in ambient temperature, but also causes specific discomfort by direct action on the human organism with an increase in the workload which is reflected in a further rise in cardiac frequency.

ANALYSIS OF RESULTS

The validity of the information obtained by putting questions to individuals and groups is confirmed by the results of our survey of the working environment for which we considered the most significant parameters.

Similarly the objective examination is substantially confirmed by the subjective experience of drivers.

All the objectifiable factors of discomfort reported by drivers (caused by the micro-climate, pollution and lighting) were checked; the results confirmed the subjective impression of discomfort.

It may readily be concluded that these disadvantages could be avoided by designing a working environment, in our case the cabin, on the basis of subjective and objective data including criteria which cannot be evaluated technically (isolation, responsibility etc.) but are statistically valid; pathological (bronchitis) and psychosomatic (ulcers, colitis, high blood pressure) factors must also be considered.

The above observations have shown that travelling crane drivers are exposed to the following stress factors: micro-climate, pollution, noise, poor visibility and a workload creating further significant stress due to psychological reasons of responsibility especially in the central bay and in key job positions. To this must be added the frustration which we always recorded, due to a lack of recognition of the driver's special responsibilities.

In addition a number of subjective criticisms were made by drivers which the drivers themselves considered of secondary interest because they were connected with situations which are not central to the job, i.e. safety of access, automatic stop devices and maintenance of the cabin which our observations showed, however, to be extremely important.

We observed completely irrational working postures in the cabins; drivers were provided with whatever seats happened to be available.

EXAMPLES OF ERGONOMICS DESIGN OF TRAVELLING CRANE CABINS

FIRST EXAMPLE OF ERGONOMICS DESIGN OF TRAVELLING CRANE CABINS

ANALYSIS

Compilation of basic data

Compilation and examination of background documents

- Survey of crane drivers' working conditions (annex 2).
- Plan of ingot mould preparation bay and drawings of existing cabins and travelling cranes.
- Study of air-conditioning of crane and control station cabins for hot-working.

Investigation of existing installations and of the working process (annexes 5 and 6)

- Study of the existing cabin (observation and interviews).
- Job description (observation and interviews).

Study of subjective data (driver's experience) (annex 2)

- Problems described by drivers.

Visibility of working areas from existing cabins

Direct visual input and working sectors

We analyzed the "direct visual input" to define the individual "working areas" (drawing No. 1):

- area A - actuation and release of lifting magnet.
- area B - internal cleaning of ingot moulds with a brush;
  - cleaning ingot mould trolleys and plates with magnet;
  - positioning plates away from working area with magnet;
  - shifting trolleys;
  - assistance in cleaning plates.
- area C - storage of plates, ingot moulds, magnets, brushes, beams, pistons, scrap iron trucks etc.
- area D - supply of aluminium to hopper.

Area C was sub-divided into main storage areas for the following items:

1 - brushes;
2 - ingot moulds;
3 - scrap iron trucks;
4 - magnets, beams and pistons.

Examination of present visibility of direct visual inputs

Drawing 1 shows in outline form the visibility of direct visual inputs for an operator in the normal working posture (i.e. normal by ergonomics standards). In view of the

- structural configuration of the cabin,
- its orientation and
- position on the travelling crane,

the operator has a frontal visibility of 69° and a lateral visibility of 40°.

The following conclusions may be drawn in regard to the visibility of the direct visual inputs in the present situation:

- there is a distinct need for better lateral vision;
- visibility, in a normal posture, of the ingot mould opening (point K) requires an angle of vision of 68°;
- visibility, in a normal posture, of the bay level overlooking travel of the block (point P) requires an angle of vision of 75°;
- the optimal view (P.V.) of point K, from a seated posture, is obtained at a distance of about 2.5 m;
- the optimal view (P.V.) of point P, from a seated posture, is obtained at a distance of about 4.8 m;
- the central axis of the cabin is not in the line of travel of the block but perpendicular to the travelling crane track.

It follows that if he is to observe handling operations directly, the driver must turn his head to one side while standing up, thus maintaining a tiring posture because of the curvature and twisting of the trunk and joints.

Saturation of tasks in the different sectors

The table shows the duration and frequency of the various tasks in relation to the four individual sectors. The data was obtained by observations in three shifts on LG1, LG2 and LG3.

		Time recorded	Frequency x 23	Frequency x 604	Total time
			Ingot mould trains		
Area A	Actuation and release of lift magnet	1.90	20		38.00
Area B (x)	- Cleaning inside of ingot mould with brush	0.62		604	372.48
	- Cleaning trolleys and ingot mould plates with magnet	5.30	43		227.90
	- Positioning plates away from work area	1.37	27		36.99
	- Shifting trolleys	2.36	61		143.96
	- Assistance in cleaning plates	2.84	26		73.84
					855.17
Area C (xx)	- Loading new plates on trolley	2.24		22	49.28
	- Loading ingot moulds on trolley	1.47		604	880.88
	- Unloading ingot moulds and stacking	1.43		314	449.02
	- Loading plates, billets	2.25		54	121.50
	- Transporting new hot ingot moulds	1.32		31	40.92
	- Removing or stacking brushes, magnets	1.10	115		126.50
					1668.10
Area D	- Supply of aluminium to hoppers	4.53	2		9.06
Mis-cella-neous	- Cleaning bay with magnet	5.33	10		53.30
	- Miscellaneous operations	2.95	24		70.80
					124.10

(x) These times may be considered effective since operations are fixed, primarily at points around the centre of the ingot mould.

(xx) The times must be considered through travel from B to C and vice versa.

The table shows that:

- work is performed for 63% of the total working time in area C and consists in operations of loading and transporting ingot moulds and plates; this may be considered "precision" work;
- for 32% of the total time, work is performed in area B and consists in operations which are not as precise as those in area B (with one or two exceptions);
- in areas A and D work is infrequent; adding the time required for these activities to that spent on other irregular work of various kinds we arrive at 5% of the total working time.

Analysis of the influence of external environmental conditions on the visibility of direct visual inputs

This analysis was effected during interviews with drivers. It was found that dust was deposited on the cabin windows and reduced visibility. Everyone agreed on the need to clean the windows systematically but opinions differed as to who should be responsible for this work. A relationship was noted between the depositing of dust on the cabin windows and the presence of hot ingot moulds while meteorological conditions (wind) also play a part.

Environmental conditions

The analysis served to evaluate the parameters which to varying degrees determine environmental conditions in the cabin.

External cabin temperature

Relevant data is shown in the table. The measurements were taken:

- in the presence of the hot ingot mould train;
- in the presence of the cold ingot mould train;
- in four cabin positions, two forward and two on the left-hand side (viewing the cabin from in front);
- by applying a thermometer to the metallic structure of the cabin for ten minutes;
- on cabins LG1 and LG2.

EXTERNAL TEMPERATURE	HOT TRAIN		COLD TRAIN	
	LG1	LG2	LG1	LG2
- high forward position	44	46	31	32
- low forward position	46	47	30	30
- high lateral position	41	41	29	30
- low lateral position	40	42	29	31

It was noted that:

- the temperature of the structure varied, as a function of the train temperature, by 13 - 17° in the high positions and 11 - 12° in the lateral positions;
- the temperature is higher in the forward than in the lateral positions;
- the temperature at LG2 is slightly higher than at LG1 (approx. 1°C).

Temperature and atmospheric humidity in the bays

Measurements were taken on a number of days in December in different bays. Each measurement lasted 24 hours. The measurements were effected with recording instruments. The table shows the maximum daily values observed.

DATE OF OBSERVATION	BAY	TEMPERATURE		HUMIDITY	
		MAX.	MIN.	MAX.	MIN.
21.12.1971	2	23	13	65	35
22.12.1971	4	23	13	60	35
24.12.1971	6	36	15	65	25
27.12.1971	8	20	12	60	30
28.12.1971	10	18	12	65	30
29.12.1971	12	17	8	50	30
30.12.1971	14	17	10	45	35

As a function of the orientation of the bays, it was observed that when the wind blew from the North-East, the natural replacement of air in the bays was reduced and an increase in the air temperature noted because of the presence of hot ingot moulds; conversely when the wind blows "from the sea" air currents are generated in the bays and the air remains cooler.

Temperature of ingot moulds

The maximum temperatures observed in the upper section vary around 200°C; in the lateral section they are around 350°C.

The radiant system consists, in the extreme condition, of trolleys with a length of 5 m transporting the largest ingot moulds at a temperature of 350°C in the lateral section with four moulds to each trolley.

<u>Utilization of temperature, humidity and ventilation data</u>

This data is used to evaluate the most severe temperature increase conditions in the cabin, if necessary considering the air temperature difference between the interior and exterior of the bays. Since this difference, assuming identical ventilation, depends on the heat emitted by the ingot moulds, it appears possible to extrapolate from the recorded winter data the summer temperature values in the bay simply by using maximum summer temperatures. This method is considered acceptable even though the data obtained may not be altogether accurate.

Further details on this aspect will be found in the separate study on the design of the cabin air-conditioning system.

<u>Instrumentation, controls and verbal communication in existing cabins</u>

Relatively simple equipment is used and a detailed analysis was not thought necessary of all the instruments and controls or of the verbal communication systems used in existing cabins. Only two factors worthy of special note emerged.

The first concerns the reliability of the separate controls which practically all the crane drivers confirmed, even though combined operations appear objectively difficult to perform.

The second relates to the opinion of users on communication by intercom with other areas: drivers disliked the idea of duplex communication with the foreman; this hostile attitude seemed to be linked with the problem of supervision to which the trade unions attach great importance.

These observations demonstrate that a purely functional approach is not sufficient and must be integrated with a study of interpersonal relations and union problems.

These aspects will be considered in more detail later on.

DESIGN CRITERIA

Criteria for optimization of visibility in the work zones

- consider areas C and B, in that order, as the most important for orientation and positioning of the cabin in the light of the
  - frequency of operations performed;
  - complexity of the work (need for precision);
  - importance of the work content;
- orientate the cabin axis in such a way that the operator faces areas C and B, without having to turn his head;
- situate the operator's point of vision in such a way that in both the seated and standing positions, there is a sufficient angle for good visibility of the work zones;
- develop a system to clean the windows which can be operated directly by the driver or other persons, while respecting safety standards and remaining easily accessible;
- determine the inclination of the windows with the fullest possible allowance for the operator's cone of vision (optimum 90°), particularly for full visibility of areas C and B with the driver in an optimal posture;
- examine the driver's posture with reference to mean characteristics, the hierarchy of sectors (direct visual inputs), the freedom to choose working positions (seat design) and simulated adjustment of dimensions;
- allow the possibility of lateral and rearward view of the travelling crane (or cranes) situated on the same line.

Design criteria for internal environment

(micro-climate, lighting, noise, vibrations, space, comfort floor covering).

- ensure that the internal climatic conditions are independent of external conditions by:
  - installing an automatic air-conditioning system which can be adjusted by the driver (temperature, humidity, ventilation, air purity);
  - insulating all non-transparent sections;
  - providing glazing designed to absorb and reflect radiant heat;
  - ensuring diffused low-speed air distribution in order to avoid ventilation currents with a local cooling action on the driver's body;
- diffused lighting, controllable by the driver, with the following characteristics:
  - sufficient luminous intensity for actions and movements in the cabin equivalent to or preferably less intense than the lighting in the work area;
  - light sources arranged to avoid reflections on the glazed walls and on other internal cabin surfaces (no highly reflective surfaces);
  - chromatic range of light chosen to improve perception of the external environment with a psychological effect of greater relaxation (the internal cabin colours must also be taken into account);
  - appropriate lighting for access ways and movement areas, without disturbing (by direct dazzle or reflections) the operator in the cabin and perhaps with a facility to

switch on when required (the possibility of enabling the operator to control the work area lighting was also discussed, allowance being made for the incidence of dazzle of the operator of the adjacent travelling crane);

- limitation of internal noise by:
    - acoustic insulation of walls (double glazing);
    - ad hoc arrangement of air conditioning system;
- reduction of vibration by appropriate mechanical or oleo-pneumatic absorption systems;
- design of the internal cabin layout with provision for a single operator, taking into account:
    - the ease of access to and from the working position (seated);
    - the possibility of movement inside the cabin with a minimum risk of contacting controls, fixed structures etc.;
    - the possibility of installing in the cabin a number of mobile structures to facilitate work and increase comfort;
- comfort elements to be included in the cabin:
    - a small cupboard with a clothes hanger and shelf for drinks, food etc.;
    - ashtray (preferably fixed with manual emptying arrangement);
    - additional seat;
    - broom and refuse container (placed outside the cabin);
- easy washable floor-covering, non-slip, vibration-resistant.

Design criteria for instrumentation, controls and verbal communication within the cabins

- Avoid instrumental signals which are unnecessary for conduct and control of the working process.

- Wherever possible use signals which can be interpreted rapidly (pilot light on/off or red/green to indicate the on/off function).

- Use wherever possible of tactile channels in controls to facilitate immediate recognition of the control by manual/ finger contact, the effect of the control being associated with the position of the joints; use of tactile channels reduces saturation of the visual channels and facilitates control movements.

- Use the commoner movement stereotypes for controls activated by the lower and upper joints, avoiding contrasts between the direction of the induced movements and the direction of the joint movement.

- Avoid simultaneous operation of several controls with the same joint by adopting combined controls.

- Avoid interlocked controls which tire the user and complicate actuation, partly because of the diseducative effect of their voluntary exclusion.

- Arrange the instruments for improved perception as a function of the frequency of operation and importance of the control.

- Arrange controls in the light of ergonomics criteria of accessibility in a normal posture.

- Provide the possibility of verbal communication with workplaces with which the operator is functionally linked, allowing for:
  - the possibility of exchanging verbal information with one or more positions selected by the driver;
  - the particular stress situation created by verbal communication when it is used to supervise the driver's actions and give unnecessary instructions which restrict his independence.

Safety criteria

Safety criteria are implicitly contained in all the other criteria described. Without going into safety standards for the design of specific equipment, it is worth stressing a number of special criteria which emerged from the overall design:

- possible extension of the buffers if the cabin is moved from its present position;
- ample space on the landings below the access ladders with adequate parapets;
- locks for movement controls in the off position;
- rapid stop systems (if necessary).

DESIGN MODEL

Once the analysis had been completed, documentation compiled and design criteria defined it was necessary, before moving on to optimized design as such, to check the existing interrelations between the criteria specifically adopted for the various factors considered. This approach is advisable because it:

- enables the logical sequence of action to be determined;
- enables the links between the various factors under consideration and the system components (man, man-machine-cabin-system) to be highlighted;
- demonstrates the interrelation between different factors in the light of the criteria chosen;
- shows possible conflicting effects of different criteria on a given factor or of a single criterion on different factors.

The methodological approach is shown in annex 7 (DESIGN MODEL FOR CABINS LG1, LG2). The links between the different components of the model are summarized below.

1.	OPERATOR ⟵ external environment:		- radiant heat of ingot moulds
2.	External environment ⟶	visual: inputs	- lighting, favourable or unfavourable meteorological conditions
3.	External environment ⟶	internal: climate	- influence of external environment on internal environment (temperature, humidity, ventilation, radiation, pollution, noise, lighting)

4. OPERATOR ⟷ internal climate:	- heat, humidity, CO_2 emitted by operator - facility for operator to regulate internal climate - effect of internal climate on operator as a psycho-physiological entity
5. OPERATOR ⟷ visual inputs:	- direct visual inputs necessary for work - possibility for operator to modify visual inputs
6. OPERATOR ⟶ cabin position:	- perceptive and safety requirements of operator as criteria for cabin positioning
7. Visual inputs ⟶ positioning:	- importance of visual input criteria for positioning the cabin
8. OPERATOR ⟶ cleaning windows:	- need for window-cleaning system
9. Positioning ⟶ cleaning cabin windows (input):	- window-cleaning system suitable for cabin position, without disturbing inputs or endangering safety

10. Cabin arrangement ⟶ posture: - the position of the cabin influences the choice of posture optimization criteria

11. OPERATOR ⟷ posture:
   - anthropometric variables are criteria for posture choice
   - posture has a psycho-physiological influence on the operator

12. Visual inputs ⟷ posture:
   - inputs condition the choice of posture
   - the posture determines good or poor reception of inputs

13. Posture ⟶ angles of vision: - posture criteria determine the visual angles of incidence

14. Visual inputs ⟷ angles of vision:- input requirements determine choice of the angles of vision and therefore the extent of the range of vision

15. Visual inputs ⟷ instruments and controls: - design criteria for instruments and controls as a function of visually controllable working requirements

16.	OPERATOR $\longrightarrow$ comfort:	- the operator uses comfort factors and derives benefit from them
17.	OPERATOR $\longrightarrow$ instruments and controls:	- psycho-physiological design criteria for instruments and controls
18.	Controls $\longleftrightarrow$ posture:	- posture determines the control layout - actuation of controls may be a criterion for posture choice
19.	M/MS $\longleftarrow$ angles of vision:	- the angles of vision are a factor in the design of an efficient M/MS
20.	M/MS $\longleftarrow$ posture:	" "
21.	M/MS $\longleftarrow$ inputs:	" "
22.	M/MS $\longleftarrow$ internal climate:	" "
23.	M/MS $\longleftarrow$ controls:	" "
24.	M/MS $\longleftarrow$ comfort:	" "
25.	Angles of vision $\longrightarrow$ organization of visual range:	- the visual range (windows, glazing etc.) is designed with reference to angles of vision

26.	Comfort ⟶ organization of cabin space:	- the comfort elements to be adopted are a criterion in the choice of space - beyond certain limits, space restricts the comfort elements
27.	Space organization ⟷ visual M/MS:	- criteria for efficiency of the system (and verification)
28.	Space organization ⟷ cabin M/MS:	- criteria for efficiency of the system (and verification)
29.	Organization of visual space ⟷ organization of cabin space:	- possibility of reciprocal links
30.	M/MS ⟶ cabin:	- verification of functions and efficiency of M/MS in the context of the cabin
31.	Organization of visual space ⟶ cabin:	- visual space as a determining factor for the cabin structure
32.	Organization of cabin space ⟶ cabin:	- cabin dimensions and shape.

DESIGN

Position of cabin on the travelling crane

Detailed analysis and the criteria for determination of the direct visual inputs were the decisive factors in choosing the arrangement of the cabin on the travelling crane. Five solutions were worked out and one finally selected.

First solution

- Arrangement almost identical to that of the existing cabin with improved visibility by a more rational organization of the dimensions and inclination of the glazed surfaces. This solution has the disadvantage that satisfactory access is practically impossible (see drawing 2).

Second and third solutions

- The need to set the point of vision at a distance of 2.5 m for point K and 4.8 m for point P to ensure full visibility from a seated position entails displacement of the cabin away from the main travelling crane structure (see drawing 1).

This situation determines the orthogonal adjustment of these distances on the main travelling crane structure or towards the central bay axis.

The two solutions are illustrated in drawings 2 and 3.

The disadvantages of solution 2 are as follows:

- reduced visibility of the ingot mould orifice;
- considerable exposure to heat due to positioning above the ingot mould store;
- difficulty of cleaning windows;
- safety problems.

The disadvantages of solution 3 are:

- considerable exposure to heat;
- practical impossibility of installation on the travelling crane, to the extent that the cabin would be situated below the traversing reducer;
- clear space between cabin and ingot mould store too limited;
- difficulty of cleaning windows.

Fourth solution

In this solution, the possibility of providing a series of fixed cabins with radio-control was examined. It would take too long to examine how this solution would eliminate a number of anomalies in the crane driver's activities and affect the present organization of work as well as the arrangement of equipment and corresponding design criteria (see drawing 3).

By a unanimous decision of the group this solution was not studied in depth.

Fifth solution

which was eventually chosen (drawing 4).

The first solution was reviewed with the following modifications:

- Point of vision (P.V.) at height of 775 mm above bay level in seated position.
- Point of vision (P.V.) displaced laterally (with reference to beginning of the travelling crane structure) by 900 mm.
- Point of vision (P.V.) 3100 mm forward of travel track axis (as in the first solution).

In this solution the driver is able to see one side of the plate and can therefore position the ingot moulds from a seated posture; but the lugs must be eliminated from the plates.

Drawing 4 shows the level curves (parallel sections) representing:

- firstly (crown shaped semi-circle), the commencement of visibility at bay level (outside the crown) from a standing position;
- secondly (intermediate semi-circle), the commencement of visibility at the level of point K, from a seated posture;
- thirdly (large semi-circle), the commencement of visibility at bay level.

To give even better visibility, the possibility and desirability of moving the ingot mould preparation track northwards during major works at a future date will be considered.

The cabin base is approximately 3050 mm above the walkway used by ingot mould preparation staff.

Accessibility

After eliminating the trap-door at the present position for obvious reasons of safety and space, access to the cabin is ensured by a normal ladder on the outside of the main travelling crane structure.

Two solutions were examined:

- the first (see drawing 4) does not allow much use to be made of the cabin roof surface since the rear section of the ladder takes up half the available space;
- the second (see drawing 5) allows complete use to be made of the cabin roof because the ladder is continued up to the main beam.

The choice of one of these solutions depends on their technical feasibility and on the need to use the cabin roof (e.g. for instrument boxes).

For the reasons explained earlier, the buffers of the travelling crane on the Sestri side must be extended by about 1500 mm.

Window-cleaning

Because of the environmental characteristics of the bay (dust, heat etc.), the cabin will be built to a leakproof design with the windows hermetically sealed.

The windows can only be cleaned from the outside.

It was decided to provide a parking zone at the far end of the bay, consisting of two fixed landings - one for each cabin - from which the windows can be cleaned.

The landings are positioned in such a way that the hand-rails are 100 mm from the base of the cabin. They must be accessible from the ingot mould preparation walkway and from the cabins.

Fixed ladders are arranged on the landings (see drawing 6) for access to the cabins; fixed handrails are provided on the cabins towards these ladders.

A suitable system to isolate the power supply to the rails will prevent the travelling crane from moving while the windows are being cleaned. This isolating system must be actuated by the operator immediately after positioning the cabin on the appropriate platform or before he or the cleaner has stepped onto the window-cleaning platform.

The safest solution is an interlock preventing the gates from being opened unless the isolating switch has been actuated.

Posture

The operator's posture (position at the workplace) must be determined in the light of the following factors:

- visibility of all the direct visual inputs;
- frequency of use of the different visual inputs;
- work saturation.

The seated/standing position was chosen to enable the driver himself to choose his posture during certain operations and because for some direct visual inputs the driver must be upright for reasons connected with the cabin position. The work zones - from which visual inputs originate - which are not visible from a seated position are the train and the bay surface at block travel points close to the cabin.

In addition to the need to observe some operations from a standing position, the driver has the advantage of being able to choose the working posture which suits him (change of position, relaxation, stretching his muscles etc.).

He can also assume a particularly relaxed posture at moments of rest.

In fixing the posture the following factors were maintained constant:

a) optimal perception of the visual inputs;
b) optimal perception of the control and indicating instrumentation;
c) control positions.

To ensure that these three factors remain constant, the driver's line of sight (eye level) had to be at the same height in the seated or standing position; consequently the position of the elbow and shoulder joints must remain constant.

The driver's height was taken as 1700 mm, an arbitrary measurement based solely on published data and not derived from a statistical study of the local population.

To determine the measurements of the various body segments (from joint to joint), data for the Dutch and American population (PHILIPS and DREYFUS) was consulted.

Based on this anthropometric data, the diagram of joint positions in the seated posture was prepared (see drawing 6).

The study of posture not only gave indications of the height and characteristics of the seat but also determined the following relationship:

posture ⟶ seat ⟶ footrest ⟶ control layout.

Seat

The eye level of a 1700 mm tall man is 1580 mm.

To obtain the same height in the two working positions, i.e. seated and standing, a seat with a height of 860 mm would be needed. This measurement was considered too high for comfort and was reduced to 760 mm with a consequent drop in the eye level to 1480 mm. During work in the standing position, the point of vision is also shifted forwards by 500 mm, corresponding more or less to the distance between the hip and knee joints.

These factors determine the characteristics of the seat which may be summarized as follows (see drawing 7):

- rotation of 135° to extend the field of vision to 180°;
- height adjustment ± 100 mm;
- forward and backward adjustment of ± 100 mm in relation to the normal point;
- possibility of adjusting the height and inclination of the back rest (10° backwards in relation to the vertical axis);
- inclination of the seat level by 6°;
- discontinuous contact surface with the body to allow for perspiration.

Organization of the field of vision in the cabin in relation to the posture and to DIRECT VISUAL INPUTS

After defining the posture and direct visual inputs, it was possible to determine the field of vision which must be 180°, subdivided into four sectors. Three of these are for working inputs and one for movement in the "Sestri" direction. A window with a width of 300 mm and the same height as the cabin was added to provide further visibility during traversing movements (see drawing 6).

The three sectors required for the working inputs were situated to give visibility of sectors A, B and C respectively.

The two vertical structures for these three sectors were arranged facing the intermediate areas of block travel between working sectors A and B and B and C. In this way there was no interference with visibility of the working sectors.

As far as the horizontal structures are concerned the lower sector of the glazed surface is the resultant of the point of intersection of the angle of vision of 53° and the angle of vision of 75° (+)

The intermediate sector of the horizontal structure is situated above the two points of vision to maintain the driver's normal visual cone of 30°.

The upper sector of the horizontal structure extends as far as the upper limit of the cabin.

To maintain a constant external visibility ratio in the four sectors, the distance between the axis of rotation of the seat (coinciding with the projection of the P.V.) and all points in the same horizontal section of the glazed surfaces must be constant.

This naturally involves a circular arrangement of the glazed surfaces.

To eliminate the possibility of optical separation and reflection, the vertical arrangement of the glazed surfaces should be perpendicular to the P.V. In our specific instance this is impossible because of the difference between the two P.V.s in the seated or standing positions.

As the centre of curvature of the axis of the cone of vision we therefore took an intermediate point between the seated P.V. and standing P.V. (see drawing 6).

(+) The angle of vision of 53° is the resultant of the angle from eye level to the tip of the feet in the seated position.

The sectors of the glazed surfaces are circumscribed by two circles on the drawing, i.e.

- the lower base circumscribed by a circle with a radius of 730 mm;
- the upper base circumscribed by a circle with a radius of 1400 mm (see drawing 6).

Choice and position of instruments

Position of instruments and controls

The control panels are situated on either side of the seat (see drawing 7):

on the driver's left:

- emergency control;
- magnet selector;
- siren actuator;
- oil pump control;
- ashtray;
- combined travelling crane/trolley manipulator;

on the driver's right:

- transmitter/receiver for verbal communications;
- manipulator for raising and lowering the block.

- The main switch has been fitted overhead on the cabin ceiling to allow rapid actuation when necessary (in an emergency); the switch lever must not be less than 1900/1950 mm above the cabin floor.

- There are two brakes:

  one for operation in the seated posture situated below the entire length of the foot rest and designed for use in all the driver's working positions in the three working sectors;

the other for operation in the upright posture is located 100 mm above the floor surface and can be used in all three working sectors.

A braking adjustment mechanism must be fitted.

- The two control panels can be shifted back and forward by 350 mm with reference to the seat so as to avoid the need to work with the arms behind the trunk in the standing posture.

Manipulators

The position of the manipulators has been designed to place less strain on the arm and forearm muscles (bicipital and palmar).

The manipulator is located:

- at a height of 1010 mm above the cabin floor corresponding to the level of the elbow joint with the driver in the seated posture;
- at an angle of 35° for the forearm perpendicular to the arm held vertical;
- at a distance of 300 mm, corresponding to the distance between the palm of the hand and elbow.

The electrical safety contact of the manipulator must be actuated by the simple weight of the forearm when the control is gripped.

The dimensions are shown in drawing 7.

Drivers had expressed some reservations about the use of combined manipulators; in the end, however, this solution was accepted.

Almost all the crane drivers had initially refused the installation of combined manipulators. Interviews on this subject had revealed a fear of incorrect actuation as well as a dislike of the necessary retraining.

It was therefore decided to collate information on combined manipulators, and present this information to the drivers concerned; the adoption of controls of this kind was decided after questioning crane drivers in the scrap metal yard who had already used them for some time.

At a number of meetings the introduction of combined manipulators was agreed to, provided that adequate training could be given in the scrap metal yard (one to two weeks) and possibly also with a simulator.

Verbal communication

The system consists of an intercom unit flexibly mounted on a support cylinder. Communication is possible in both directions with the following points:

- other LG cabins;
- two points on the ground with the operator responsible for ingot mould preparation;
- GT cabins;
- first aid post.

A switch with three different positions is provided for each station:

- off (transmission and receipt of messages impossible)(+);

(+) A switch-off facility was requested by the users who stressed the need to be able to decide with whom they communicated; their request was accepted after discussion. This was a typical instance in which decisions cannot be based merely on the functional criterion. The need to respect users' wishes was evident.

- standby (messages can be received);
- on (messages can be transmitted and received).

One or more stations can be connected simultaneously.

In the standby position, calls are notified to the operator by a light signal indicating the calling station and accompanied by a brief acoustic signal (buzz).

MICRO-CLIMATE

External climatic conditions

Temperature and humidity of air outside the cabin

Without going into details of our recordings, the maximum summer temperature may be assumed to be 40°C taking into account the fact that wind measurements showed the north-east wind to be very rare in summer; this wind reduces the natural exchange of air in the factory bays. On the other hand "sea winds" which favour the exchange of air are very common.

A maximum humidity value of 65% and a minimum of 25% may be assumed.

Radiant energy from ingot moulds

The maximum temperature of hot ingot moulds varies around 200°C at the top and 350°C at the sides.

Integral radiation $\gtrsim$ for hot ingot moulds was calculated for the assumption of a grey body on the basis of Kirdroff's principle for which the formula is as follows:

$$J = \int_0^{\infty} \varepsilon \, d\lambda = \int_0^{\infty} a \, \varepsilon_0 \, d\lambda = a \, J_0$$

where ε is emission by the ingot moulds and ε_0 emission by a black body at the same temperature; a is the absorption by ingot moulds which remains constant on variation of λ in the hypothesis of a grey body. Stephen's law for a black body gives:

$$J_0 = \sigma T^4$$

from which:

$$J = a \sigma T^4$$

therefore, assuming T = 600°K, we obtain:

$$I = a\ 2 \cdot 10^{-4}\ KC/s\ cm^2$$

The maximum radiation in the above hypothesis is obtained with $\ell_m \simeq 5\,\mu$.

To calculate radiation from the ingot moulds on the cabin walls we adopted a simplified diagram enabling graphs already available to be used.

The radiant surface is assumed to be a rectangle of infinite length with a height of 3.00 m at a distance of 6.00 m from a point in the cabin from which incident radiation is calculated. On the basis of the previous calculations we obtain:

$$I = a \sum o\ .\ 0.26 = a\ .\ 0.26\ .\ 2 \simeq 1800\ .\ a\ KC/hm^2$$

The coefficient of absorption a may be taken as 0.6 giving:

$$I \simeq 1{,}100\ KC/hm^2$$

<u>Sources of heat and water vapour in the cabin</u>

Of the various sources of heat and water vapour present in the cabin, we shall only consider the operator himself for whom it may be assumed that under the internal climatic conditions of the cabin and for the work involved in this particular instance, the following data will apply:

$$Q_i \simeq 200\ KC/h$$

$$v.a. \simeq 200\ g/h$$

Thermal insulation of the cabin

Glazed surfaces

We have seen that maximum radiation is obtained with $l \simeq 5\,\mu$. The transparency of ordinary glass is normally very high for radiant energy with a short wavelength ($l < 2\,\mu$) but falls rapidly as l increases and practically ceases with $l > 5\,\mu$.

This fact eliminates the need to use special glass and enables the glazed surfaces to be considered, for all practical purposes, perfectly opaque to radiation from the ingot moulds. Ordinary double-glazed glass is therefore used with an air gap of at least 10 mm.

Metal surfaces

It was decided to use stainless steel sheets for the external surfaces; although the coefficient of reflection of steel is lower than that of bright aluminium, it is nevertheless higher than that of aluminium after oxidation.

For the internal surfaces, an insulating material is used consisting of mineral wool with a thickness of 40 mm for the vertical walls and 100 mm for the floor.

Optimum micro-climatic conditions

Air temperature in winter $\simeq$ 18°C and in summer $\simeq$ 23°C.

Relative humidity $\simeq$ 50 - 65%.

One to two complete changes of air each hour.

Temperature of cooled air preferably $\simeq$ 5°C below the ambient temperature.

Maximum speed of incoming air 0.3 - 0.5 m/s.

Maximum speed of air extracted through apertures at base of wall $\simeq$ 0.5 m/s.

<u>Heat input</u>

The calculation was made for the most stringent working conditions in summer with a hot ingot mould train. Assuming the glass to be perfectly opaque, the calculation will not differ substantially for glazed surfaces or metal walls. The calculation procedure is as follows:

T_1 (external temperature in bay) is assumed to be 40°C. T' (external temperature of cabin surfaces) is taken as 50°C and T_2 (internal cabin temperature) as 23°C.

For the quantity of heat transmitted into the cabin in a unit of time, we therefore obtain in the case of glazed walls assumed to be perfectly opaque to radiation(total area 6.00 m2, coefficient of internal thermal conductivity at the given temperatures C = 2.60 KC/hm^2°C):

$$q_v = 2.60 \;.\; 6.00 \;.\; 27° = 420 \text{ KC/h}$$

For the metal walls with a glass wool layer of 40 mm (total area $\simeq$ 8.00 m2, coefficient of internal thermal conductivity C = 0.80 KC/hm^2°C):

$$q_m = 0.80 \;.\; 8.00 \;.\; 27 = 170 \text{ KC/h}$$

Finally for the metal floor surface with a glass wool layer of 100 mm (total area 4.00 m2, C = 0.55):

$$q_{m''} = 0.55 \ . \ 4.00 \ . \ 27° = 60 \text{ KC/h}$$

Hence the total quantity of heat transmitted inside the cabin is:

$$Q_{est} = 650 \text{ KC/h (1) (2)}$$

Comparing the values obtained with the quantity of incident radiation I, the reduction in the case of glazed walls is found to be:

$$r = \frac{420}{1100} = 38\%.$$

<u>Cabin air-conditioning</u>

<u>Determination of air capacity</u>

The heat balance inside the cabin is as follows:

$$Q_{est} + Q_{int} = 650 + 200 = 850 \text{ KC/h}$$

The humidity is 200 g/h (water vapour emitted by the operator.

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(1) The supply of heat from the ceiling may be disregarded because it is effectively screened against radiation and has a substantial thickness.

(2) The value given by this calculation is on the high side but a number of other heat admission factors which are not always negligible have been disregarded (e.g. cabin access door).

Referring to the psychrometric graph, let A be the point representing environmental conditions (T = 23°, u = 50%).

To determine the conditions under which air must be introduced into the environment (point I), it will be sufficient to calculate the variations in enthalpy and specific humidity of the air inside the cabin during the transition from the conditions of introduction to the ambient conditions.

Ja = 850 Kcal/k

Xa = 0.200 kg/h

$$\frac{> Ja}{> Xa} = 4250$$

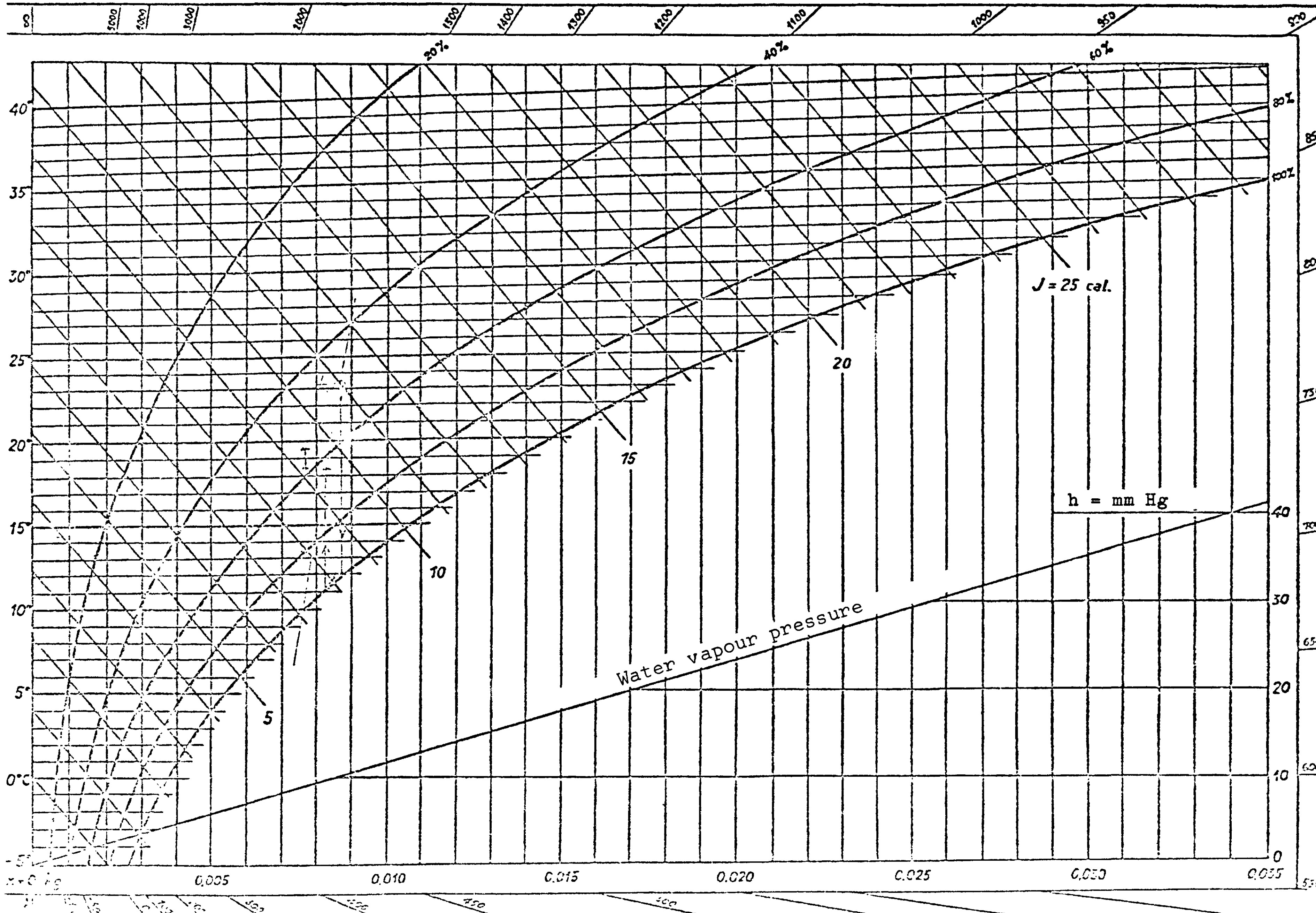
The point I is situated on the line from A to the value corresponding to 4250. Positioning I at different points on this line implies a variation in the quantity of air to be introduced; in fact when the thermohygrometric characteristics of the incoming air approach those of the ambient air, greater quantities must be introduced and vice versa.

The limits are imposed by Δ T which must not exceed certain values if driver fatigue is to be avoided. We have already assumed Δ T $\leqslant$ 5°C.

It follows that the quantity of air G_m to be admitted is:

$$G_m = \frac{Je}{J_A - J_I} = \frac{850}{11-3.4} = 530 \text{ Kg/h (Kg air to be admitted).}$$

GRAPH (J.x) FOR HUMID AIR BETWEEN TEMPERATURES OF - 5° AND + 40°C AT A TOTAL PRESSURE OF 760 mm Hg.



(It will be recalled that the enthalpy values shown on the graph related to kg air), or indicating the corresponding quantity in terms of volume:

$$V_m = \frac{G_m}{1.2} = 440 \ m^3/h$$

The air undergoes the following processing in the conditioning unit: cooling without conduction, cooling along the saturation line to obtain the desired specific humidity value and subsequent heating (with constant specific humidity) to the selected point I (1).

Disregarding the exchanged air which is negligible in relation to the total recirculating air ($\simeq$ 20 m^3/h), a conditioning system capable of cooling an air flow of $\simeq$ 440 m^3/h by $\simeq$ 11°C must be designed.

The dimensions of the air extraction orifices assume a maximum velocity of 0.5 m/s.

$$S = \frac{440}{0.5 \ . \ 3600} = 0.25 \ m^2$$

The admission of air (with a ceiling height of 2.30 m) is ensured through a perforated metal false ceiling with 3 to 8 mm holes and a drilling coefficient (ratio of perforated to solid surface area) of 10 to 15%.

---

(1) This system is more onerous than others from the point of view of maximum or normal cooling capacity but has the advantage of allowing simple and effective regulation regardless of the ambient temperatures and relative humidity.

Air purity

The external air and recirculated internal air contain high quantities of dust and smoke which should be eliminated.

The separation of solid particles is rendered difficult by the broad range of sizes which they may assume: in fact the particles which it is desirable to separate vary in size between 0.1 and 50 microns and it is not generally possible to build filters to eliminate all of them. Standard economical filters of good quality usually enable particles up to 1 micron to be separated (i.e. not most smoke particles, which range from 0.1 to 0.3 microns in size, but a great deal of those which are liable to damage the respiratory tracts and vary between 0.5 and 10 microns in size).

Filters may be classified as follows as a function of their method of operation:

a) dry filters in which separation is effected by passing the particles through porous layers whose apertures are of the same size as the particles to be separated;

b) wet filters in which separation occurs by bringing the particles into contact with walls covered with a film of adhesive substance;

c) electrostatic filters.

There are various types of dry filters which differ primarily by the nature of the material used.

Wet oil filters consist of thin metal strips held in frames supporting the inflow and outflow grids.

On passing through these filters, the air is broken up into an extremely large number of small currents which follow a winding path while the particles which strike the walls of the metal strips are held back by the layer of viscous substance.

In the case of recently developed electrostatic filters, the air first passes through an intense electrostatic field in which the particles are charged negatively and then through a second field in which the negatively charged particles are precipitated onto plates situated at the base and covered by a thin layer of adhesive oil. Electrostatic filters are particularly effective even for extremely small particles and are therefore also suitable for separating smoke.

In regard to gas absorption good results are obtained with activated carbon, but at temperatures above 45°C its absorption capacity declines.

Drawing 6 shows the system of air distribution inside the cabin. The criterion is not to create a single point of exit for the air but to distribute flow over the entire cabin area except for the space occupied by the operator himself.

Air enters the cabin through a "filter" in the ceiling with orifices oriented towards the walls and a low-level intake to prevent dust rising.

It is advisable to use double glazed windows with a dehydrated air gap to prevent vapour condensation.

For fuller details of the design of the air-conditioning system, reference should be made to the special note in the annexes.

Other environmental factors

Lighting

To provide internal lighting, a green light source of adjustable intensity should be provided at the level of the operator's shoulders.

The external light sources must be directed towards working sectors A, B, C and D and the operator should be able to adjust their intensity.

The necessary controls should be situated on the left-hand panel.

Noise and vibration

The design of the air-conditioning system necessarily implies criteria to reduce internal noise.

The problem of vibration is solved in this specific design by suitable means of fixing the cabin on the travelling crane.

Space

The seat, panels and other accessories have been designed to allow free movement inside the cabin.

There is sufficient space for the various accessories (cabinet, additional seat).

Floor covering

The use of a neoprene-type material is advisable to give easy washability, a non-slip surface and ensure the absorption of vibrations.

SECOND EXAMPLE

Cooperative project for a travelling crane in a warehouse for cold-worked tubes

Working party:
- technical plant management;
- workers' representatives;
- Applied Ergonomics Society.

Design work began by a critical analysis of the type of travelling crane installed in the plant concerned.

At the same time a questionnaire was submitted to the drivers and brief informal interviews conducted with them.

The results of this analysis were discussed at a working meeting attended by representatives of the workers, the technical plant management and experts from the Applied Ergonomics Society.

Analysis of the type of travelling crane proposed

1° In the proposed solution, the travelling crane has a mobile block and cabin arranged on an axis passing through the centre of gravity of a single support beam; the distance between the axis of the block and cabin is 160 cm (see drawing 01). The storage units are given the references A, B and C at their respective centres of gravity (position of the block during loading and unloading operations). A and A' represent the two positions assumed by the mobile storage unit.

It is evident that a movement range of 490 cm must be considered a minimum which is undesirable since the travelling cranes in the warehouse and cold worked tube bay would then always be working in their limit positions.

2° Having regard to the extreme working positions (at A and C), the minimum and maximum distances between the axis of the block and cabin were determined (see drawing 02). The position at C indicates that the maximum measurement of 355 cm cannot be reached, since it would entail working at the limit of crane travel. The position at A indicates that the minimum distance may be equal to 0 cm. In this case the cabin and block would be operating on different support beams, i.e. on two different vertical planes.

3° Drawing 03 analyses the areas which are not visible during operations at A, B and C if the driver is seated (P.V.S) or standing (P.V.P) and leaning forwards without strain towards the working area. The area which cannot be seen on the block side is clearly much greater than on the other. It may be concluded that coincidence of the block and cabin would give identical conditions of visibility.

An increase in the cabin height would however improve conditions of visibility in both zones.

4° Drawing 04 analyses the angles of vision for tube nests in two typical conditions (tubes on the ground and at minimum movement height allowed by the fixed dimensions), with the driver seated or standing.

Bearing in mind that the axes of the cabin, block and tube nest may reasonably be considered to lie on a single level, the observations and values which follow are realistic inasmuch as they are linked to two dimensions only.

In this hypothesis, the limits of visibility due to the cabin structures which must be considered at the design stage are disregarded.

Point G (mean point of lower limit of tube nest) is always viewed in the "forward" direction (conventional) at an angle of between 78° and 55° from the horizontal.

Point C (forward limit of tube nest) is always viewed in the forward direction at an angle of 54° to 26° from the horizontal.

Point C_2 (rear limit of the tube nest) is always viewed from the "back" at an angle of 80° to 59° from the horizontal.

A summary of the angles of vision is given in drawing 05.

This shows that, to obtain a full view of the tube nest, the operator requires:

- a "forward" angle of vision (for view of C1);
- a "forward" angle of vision (for view of G);
- a "rearward" angle of vision (for view of C2).

Considering that the minimum optimal angle of visibility in relation to the horizontal axis (taken on the vertical plane) is 53°, it is evident that this minimum is not reached and that if he is to see the ends of the load the operator must constantly look in the forward and backward directions, making a theoretical rotation of 180°.

This is incompatible with the need to watch points C1 and C2 constantly and almost simultaneously to avoid damage to men, tubes and structures.

DESIGN CONSIDERATIONS

5° Examination of the proposed model shows that an intervention at the design stage is only possible if the design of the cabin is preceded by an analysis of the whole travelling crane layout.

We have already pointed out that the driver's work involves a continuous rotation of 180° to check the ends of the tube nest (see drawing 05). To obviate this fundamental drawback, two solutions are possible:

A - Axes of the tube nest, block and cabin situated in the same plane (see drawing 06).

Since the minimum optimal angle of vertical visibility is 53°, the distance between the axis of the block and that of the cabin is 398 cm. This solution contrasts with that shown in drawing 02 which gives the maximum distance between the block axis and cabin axis as 355 cm in the proposed layout. It is therefore apparent that adoption of this proposed solution involves a review of the layout. The following advantages are also achieved:

- the driver does not have to turn round since the load is all on one side;
- the cabin will not constitute an obstacle to raising of the tubes; this will rule out collisions with the cabin and it will be possible to use the full range of lift travel thus making better use of the factory height.

B - Cabin axis situated in a different plane from axes of block and tube nest (see drawing 07).

Since the optimal angle of horizontal visibility is 90° and the vertical angle 53°, the distance of the plane of the cabin and supporting beam axis from the plane of the block and tube nest is 398 cm. At this distance the angle of horizontal visibility is less than 90°, i.e. within the optimal value. This solution involves the adoption of a travelling crane structure which will enable the distance of 398 cm between the cabin axis and the block axis to be respected.

The advantages given by this solution are as follows:

- the cabin block system will always function with a broad margin of safety in relation to the travel limits;
- visibility of the areas not previously visible (see drawing 03) will be equally good;
- the layout will not have to be modified as a function of the travelling cranes;
- the driver will not need to turn his head since the load will all be on one side;
- the cabin will not be an obstacke to raising of the tube nest: in this way collisions with the cabin will be avoided and the full lift travel and height of the factory can be used.

GENERAL CONDITIONS

6° In all cases the travelling crane/cabin system must meet the following requirements:

- Seats and controls allowing the driver to work under optimal conditions either seated or standing.

- Seats adaptable to the individual driver through special allowance for the position of the legs.
- The cabin climate must be suitably controlled, if necessary by providing an appropriate air-conditioning system which must not hamper the driver.
- Safety standards must be carefully respected.
- Communication between drivers in the cabin and operators at ground level must be satisfactorily ensured, allowance being made where necessary for the presence of the air-conditioning system. An alarm signal must also be provided.
- The driver must have free and independent access to and from the crane.
- Points of reference facilitating all the operations must be readily accessible for maintenance.
- The height of the travelling crane/cabin system must be sufficient to avoid work close to the travel limits.
- The top of the storage unit frames must be clearly marked. The stowed load must never exceed this level.
- The crane trolley must have a double block giving the following advantages:
  a) elimination of vertical oscillation of the tube nest;
  b) reduction of oscillation and rotation in the horizontal plane;
  c) considerable simplification of the hook-up and release operations.

  These criteria mean that tube transport and stowage operations must always be effected on parallel planes.

The relevant proposals made by the AES at a series of working meetings with representatives of the workers and technical plant management were the subject of wide-ranging discussions highlighting the various aspects which the participating groups had analyzed from their own human, technical or ergonomics standpoints.

Particular attention was given to problems connected with the safety of the hook operators on the storage units when the cabin movement presents an obstacle and also to visibility difficulties resulting from the size of the shed and the presence of full storage units which hide operators working on empty ones.

After successive syntheses, the working party drew up a final proposal which is now undergoing further development and verification.

It provides for (see drawing 8):

- two distinct operations to be performed at fixed and separate times: stowage of tubes from the production lines and loading of the means of transport for distribution;
- variation of the warehouse layout and study of methods of storage as a function of the criteria laid down above;
- wider corridors around the cabin travel track to avoid interference with and possible accidents to hook operators working on the storage units;
- cabin transferrable from point 1 (storage of tubes from production lines) to point 2 (loading vehicles) in which the two operations would be carried out;
- mobile block with equalizer;
- system of interlocks:
  - to prevent block movement if the cabin is not at either of the predetermined points 1 or 2;
  - to limit movement of the block on storage units A and B when the cabin is at point 1 and on storage units B and C when the cabin is at point 2.

L I T E R A T U R E

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A N N E X E S

N. 1 - QUESTIONNAIRE

N. 2 - RESULTS OF SURVEY OF CRANE DRIVERS' WORKING CONDITIONS

N. 3 - TABLE OF MEASUREMENTS OF MICRO-CLIMATE, POLLUTION, NOISE AND CARDIAC FREQUENCY

N. 4 - STUDY OF VISIBILITY AND WORKPLACES

N. 5 - LAYOUT OF EXISTING CAB

N. 6 - JOB DESCRIPTION

N. 7 - DESIGN MODEL

N. 8 - TRAVELLING CRANE DESIGN PROJECT

D R A W I N G S

N. 1 - ANALYSIS OF PRESENT SITUATION

N. 2 - STUDY OF LAYOUT - SOLUTIONS 1 AND 2

N. 3 - STUDY OF LAYOUT - SOLUTIONS 3 AND 4

N. 4 - STUDY OF LAYOUT - SOLUTION 5

N. 5 - ACCESSIBILITY - ALTERNATIVE TO DRAWING 4

N. 6 - DIMENSIONED DRAWING OF CABIN

N. 7 - CRITERIA FOR SEAT DESIGN

ANNEX N. 1

Q U E S T I O N N A I R E

RECORD OF OBSERVATIONS AND INTERVIEW AT WORKPLACE

Operator's initials ....

Company ....

Department ....

Type of cabin
(year of manufacture)

		open	☐
		closed	☐
	position	standing	☐
		seated	☐
		air-conditioned	☐
		not air-conditioned	☐

Functions (working activity of machine) ....

....

....

....

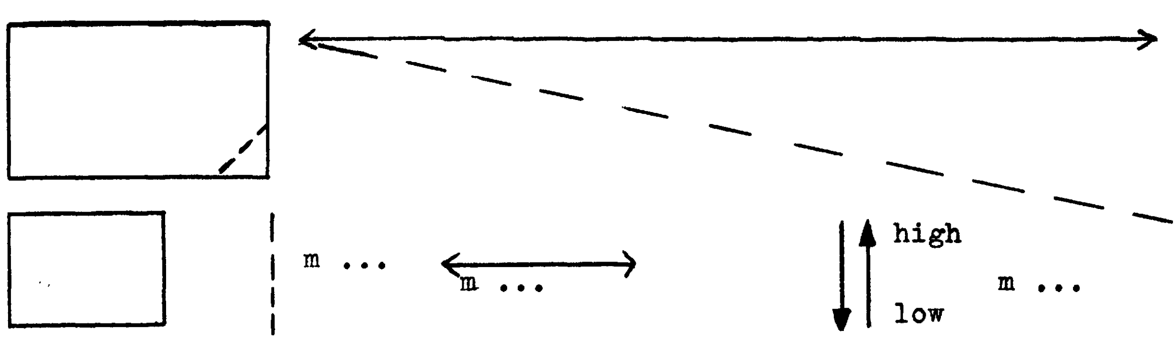
....

....

....

....

Working hours: ....



CONTROLS Yes ☐ No ☐
Combined
Dimensions
Input (convenience)

Data to be inserted

Height above ground in m.

Movements (range of action) in m

Visibility - working distance - indicate max/min high / lateral / low

Communication from ground
- Visual
- Coded
- Uncoded
- Telephone
- Radio

Questions put to operator - brief interviews:

	YES	NO	UNDECIDED

Comfort - Is comfort unchanged throughout shift?

- If not, when does the discomfort begin? ....
  ....
- Where does physical discomfort begin?

  Difficulty in coordinating movements

  Muscular pain, sense of numbness in the:

  - Arms
  - Head/neck
  - Back
  - Lumbar region
  - Feet
  - In other areas or parts of the body
  - Which parts? ....
  - When? ....

- Do you find your workplace comfortable?
- Do you think it could be improved for greater efficiency?

YES NO UNDECIDED

- In which specific areas?

  Seat?

  Back-rest?

  Height?

  Width?

  Position of hand controls?

  Which? ....

  ....

  How? ....

  ....

  Position of foot controls?

  Which? ....

  ....

  How? ....

  ....

- Do you have difficulty in understanding indications transmitted from the ground?

  If so, at what stage of your activity?

  ....

  ....

- How could this disadvantage be remedied?

  Radio transmission?

  Better coding of signs?

  Other: ....

  ....

- Do the environmental characteristics (of the working area) have a negative influence on your performance?

YES NO UNDECIDED

If so, which factors?

smoke .... when ....
vapour .... when ....
lighting .... general ....
lighting .... of working areas
....
noise ....

- Do you always feel "safe" in your actions?
- Do you always feel "safe" during the various movements?
- Do you always feel "safe" during handling operations?

- If "no", when do you feel unsafe?
  At the centre of the movement?
  At the extreme positions?
  During a movement?
  Under other conditions, such as ....
  ....
  ....

- Why did you choose this particular job?
  Economic reasons?
  Satisfaction?
  Independence?
  Other ....
  ....

- Up to what age do you think you can do this job perfectly?
  45 ....
  50 ....
  55 ....
  60 ....

YES NO UNDECIDE

For air-conditioned cabins

Do you find air-conditioning desirable?

Is the air-conditioning good?

Does it provide a degree of comfort which facilitates your work?

Throughout the shift?

If not when does discomfort due to the micro-climate begin?

after 2 hours ....

after 4 hours ....

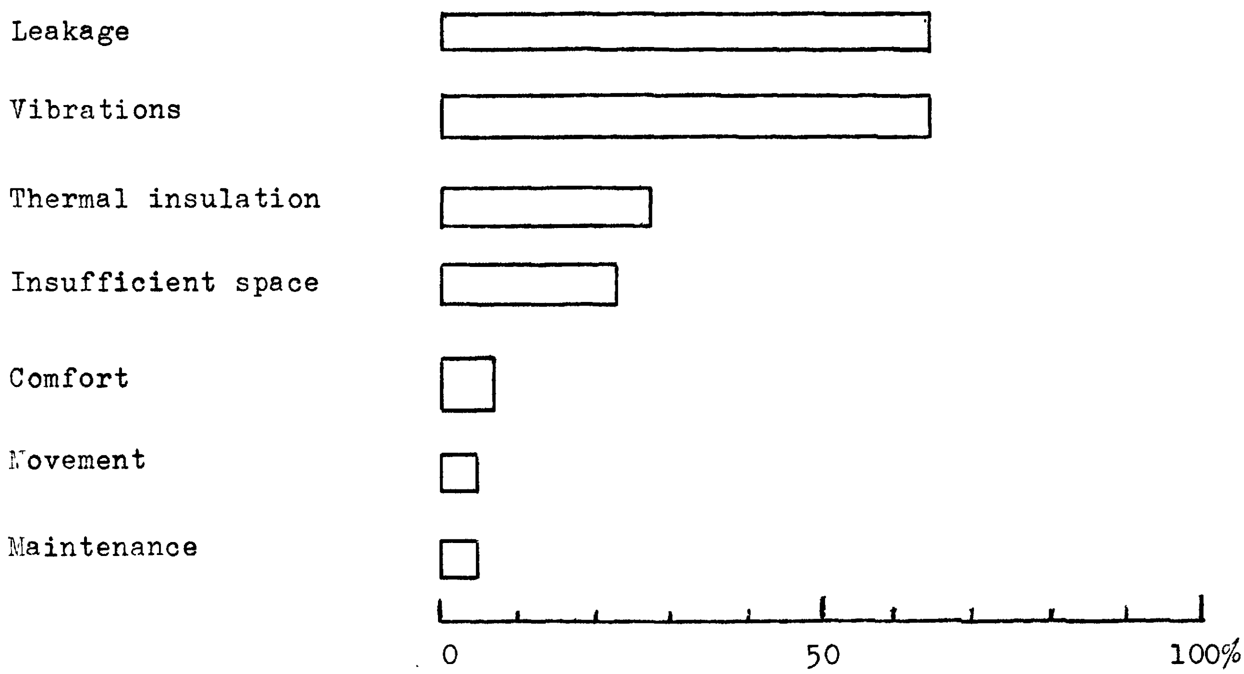
after 6 hours ....

after 8 hours ....

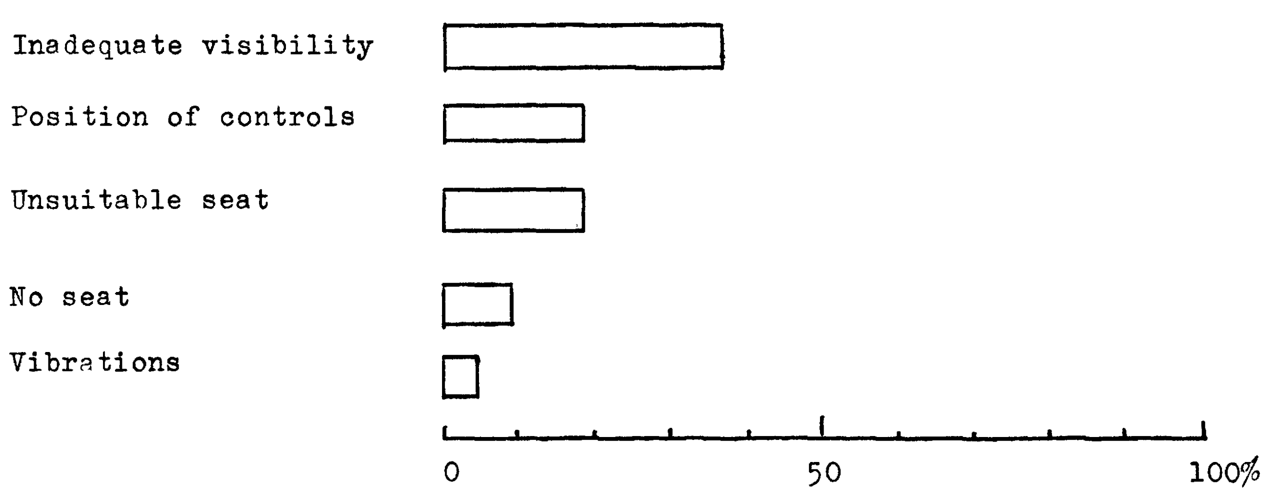
Is the noise of the air-conditioning system disagreeable?

Is the speed of the air current disagreeable?

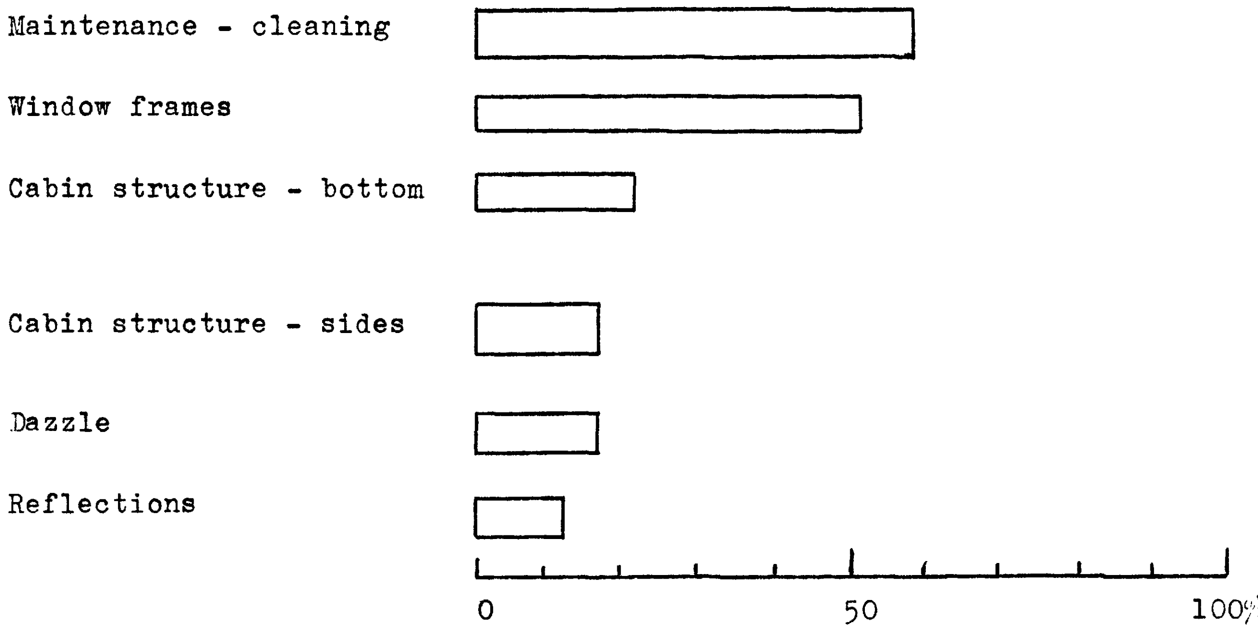
RESULTS OF SURVEY OF CRANE DRIVERS' WORKING CONDITIONS



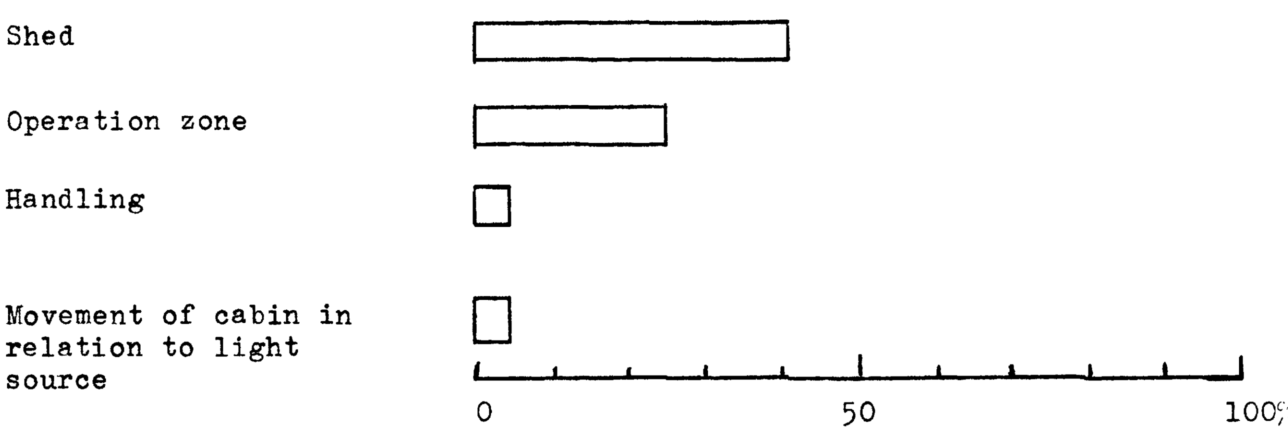
1) FUNCTIONAL DEFICIENCIES OF CABIN



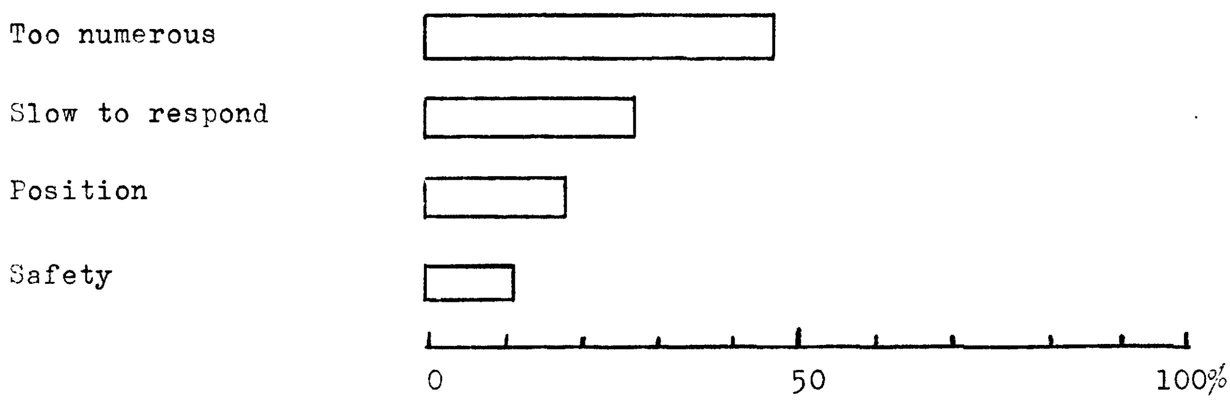
2) REASONS FOR INADEQUATE POSTURE



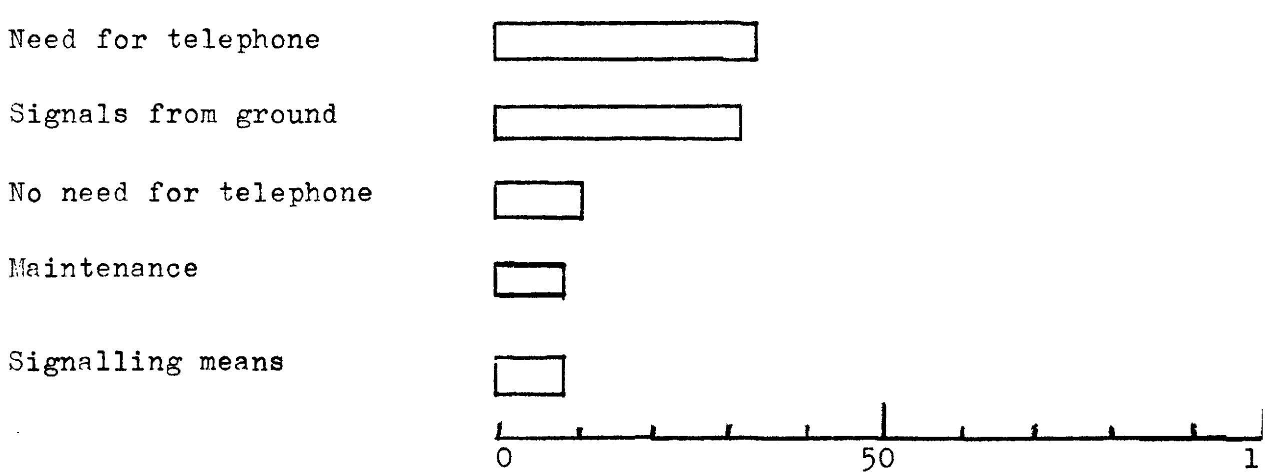
3) REASONS FOR INSUFFICIENT VISIBILITY



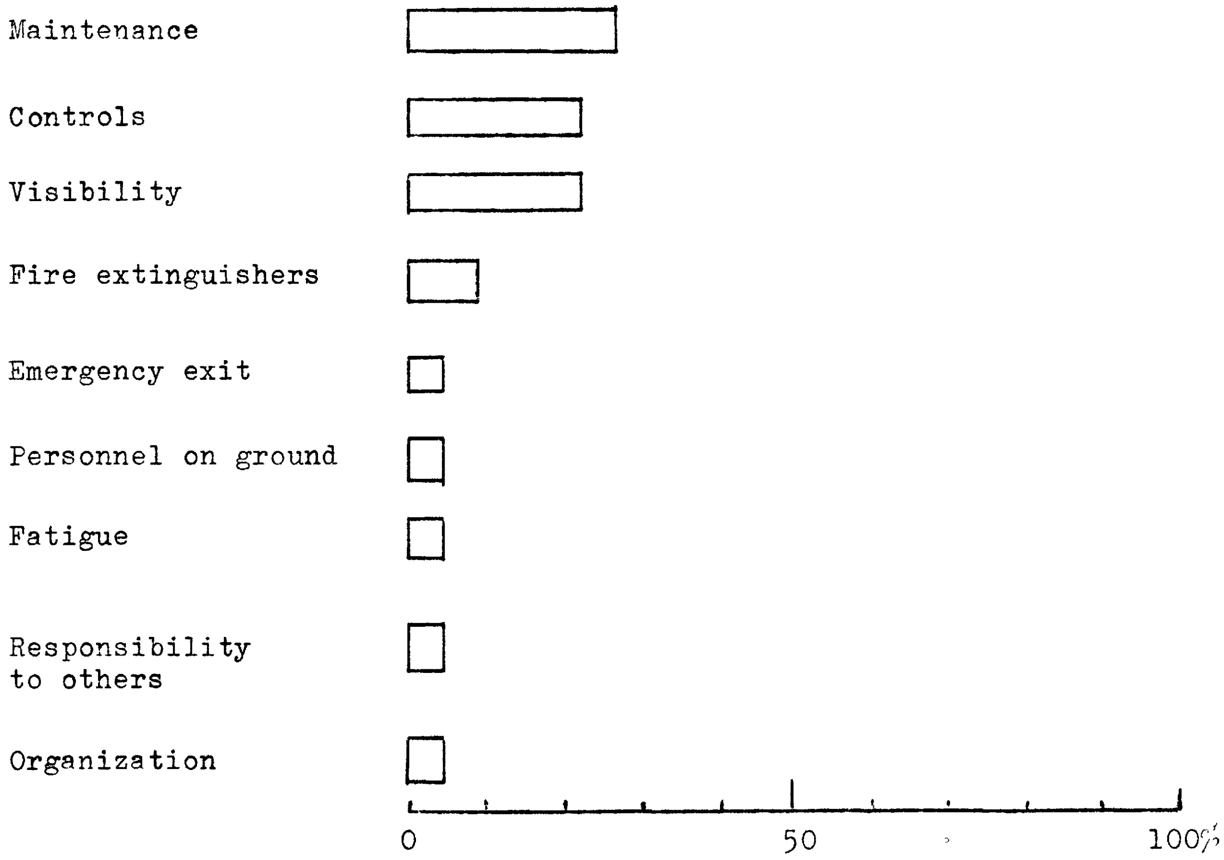
4) LIGHTING DEFECTS



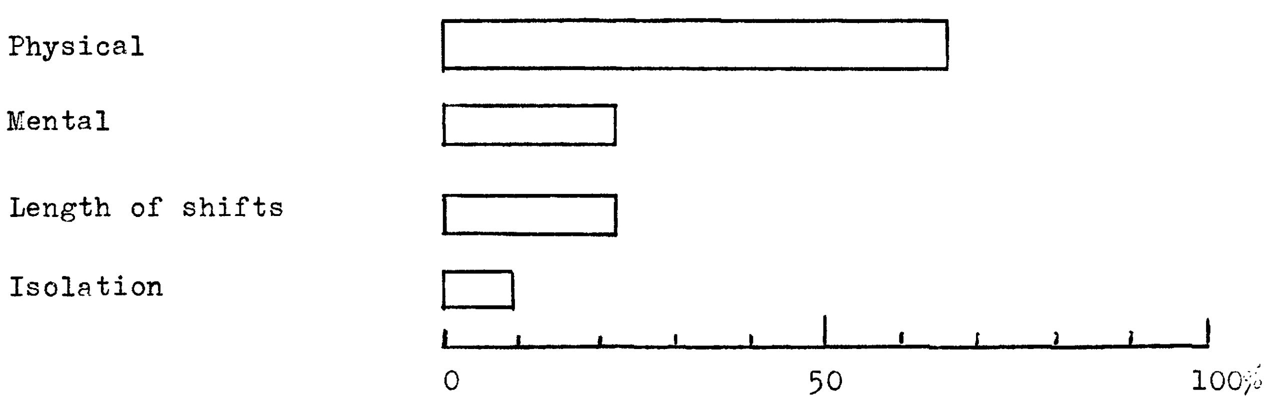
5) REASONS FOR POOR FUNCTIONAL QUALITY OF CONTROLS



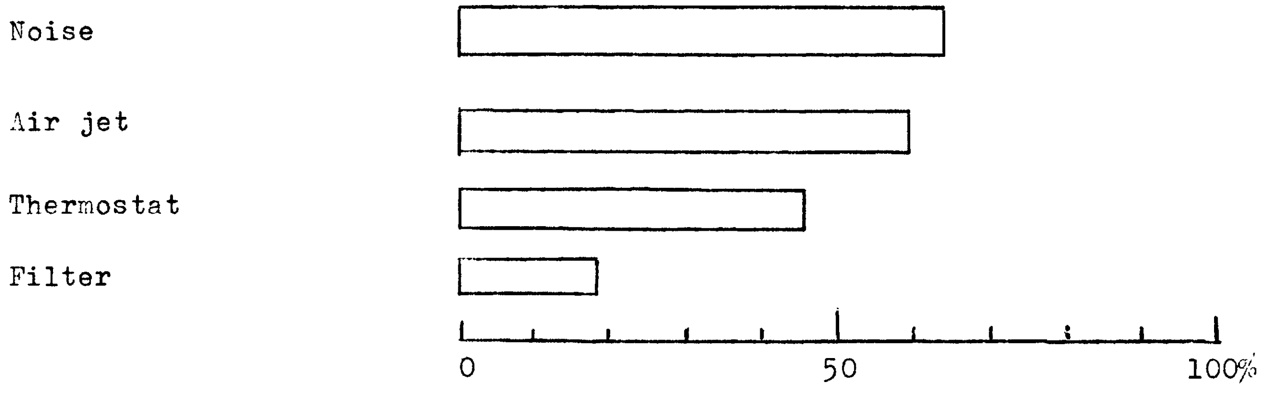
6) REPLIES TO QUESTIONS ON SIGNALLING



7) REASONS FOR LACK OF SAFETY



8) INCONVENIENCE AND DISTURBANCE DUE TO LACK OF COMFORT



9) REASONS FOR DEFECTIVE OPERATION OF AIR-CONDITIONER

TABLE OF MEASUREMENTS OF MICRO-CLIMATE, POLLUTION, NOISE AND CARDIAC FREQUENCY

MICRO-CLIMATE

Area	External		Internal	
	T°	RH%	T°	RH%
COK	18.7	53	22	47
	18.7	58.9	24.5	60
	21	65.3	22.7	66.4
PB	22	66.4	18.5	71.3
MR	28	50.9	25	61
CC	29	51.8	23.5	52
FP	50	11.5	24	27
SL	31	22.6	25	74.8
ZR	22	11.4	26.5	21.2
MM	19.5	17.3	20.5	19.7
CC	20	19.7	20	33.1
PR	15	23.1	19	39
ZG	40	1.7	21	28
ZS	28	13	20.5	33
ZC	26	14.4	21.5	21.6
ZG	15.5	23.1	16	25.6
ZF	38	14.5	26	37.2
	27.5	30	24.5	44
LC	29.5	38.4	25	68.7
CB	16.5	68.5	18	59.2
ZM	18	57.6	25.5	86
	31	82.5	36	89

DUST CONTENT OF AIR

Area	Dust in suspension		Deposited dust
	mg/m^3	ppcc% < 5 μ	free SiO2 %
ZC Windows closed	11.8	60	traces
ZC Windows open	15.2	62	traces
PR	27.5	84	1.2
ZF	37.4	82	traces
ZS	32.8	80	3.74
SL	25.7	92	3.60
PB	9.5	64	----
CB	24.5	95	traces
LC	4.5	95	2.4
FP	8.4	66	----
CC	12	80	----
ZG	15.6	85	1.9
ZR	30.8	90	----

GASEOUS AIR POLLUTION

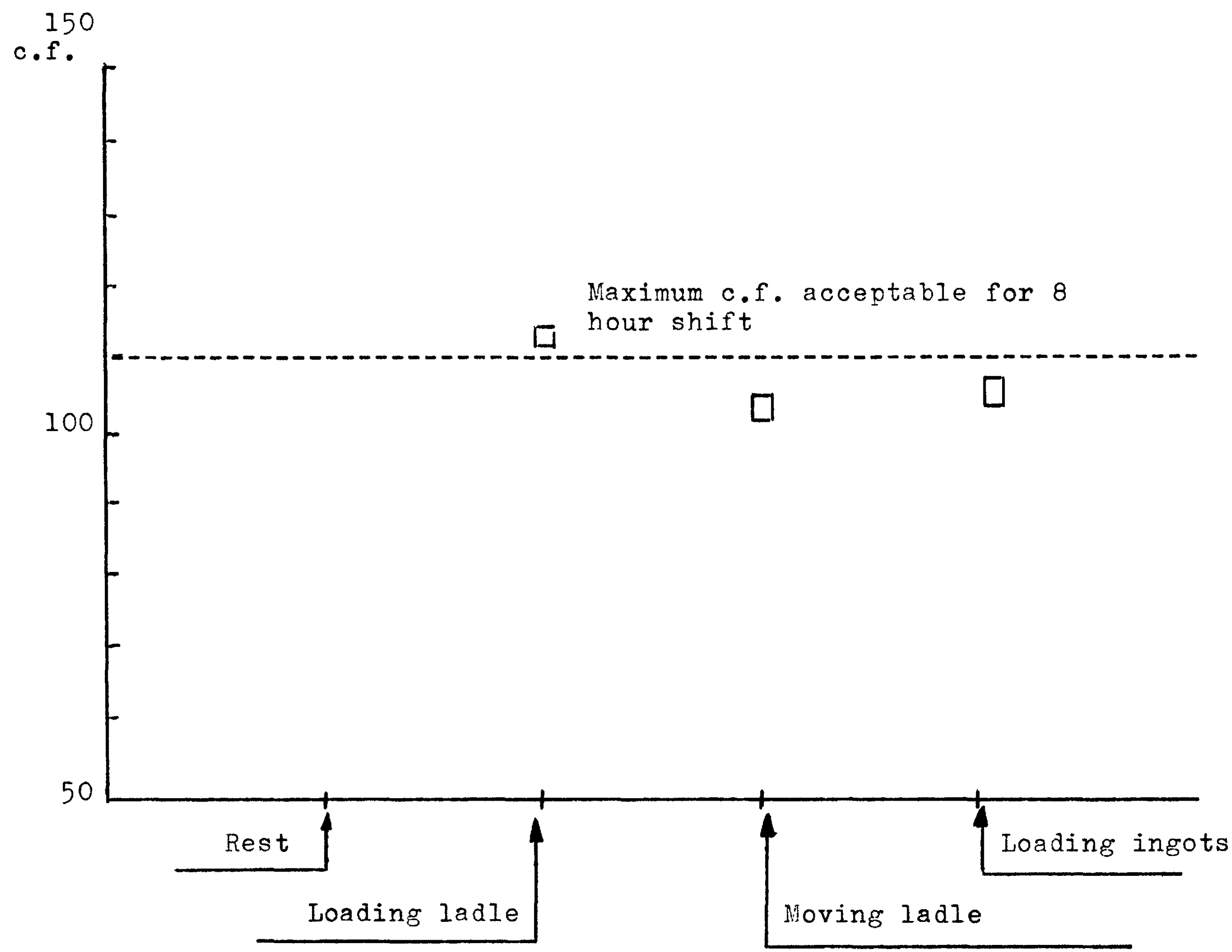
Area	CO ppm	CO_2 vol. %	SO_2 ppm
ZF	10	0.06	6
	14	0.02	4
loading	25	0.06	6
ZC	25	0.12	5
	15	0.08	4
	7	0.02	2
SL	5	0.02	----
	11	0.04	2
LC	traces	0.06	6
FP	8	0.02	----
ZG	12	0.04	2
	5	0.02	4
ZR	9	0.04	1
	5	0.02	----

AIR POLLUTION - SMOKE

Area	Pb mg/m^3	MgO mg/m^3	CrO mg/m^3	Cu mg/m^3	Mn mg/m^3	Fe_2O_3 mg/m^3
ZC	0.078	0.049	0.002	0.010	0.003	0.316
ZC Closed cabin	0.036	0.018	0.002	0.007	0.001	0.112
ZF	0.054	0.022	0.008	0.002	0.001	0.238
ZF Loading	0.066	0.051	0.008	0.014	0.003	0.452
SL	0.041	0.055	0.010	0.007	0.001	0.243
FP	0.124	0.034	0.002	0.010	0.002	0.267
ZG	0.092	0.054	0.001	0.024	0.007	0.472
LC	0.008	0.032	0.001	0.007	0.001	0.136
CB	0.012	0.012	0.002	0.010	0.001	0.249

SOUND PRESSURE LEVEL

Area	dB(A)	dB(C)	31,5	63	125	1250	500	1000	2000	4000	8000	16000	32000
ZC	83	92	90	82	87	88	85	82	77	70	62	49	35
ZF	81	90	80	84	89	81	83	77	72	68	66	58	35
ZF Loading	95	100	86	88	96	94	92	89	84	82	80	72	50
PR	84	88	76	83	81	81	84	81	78	75	64	50	35
ZS	73	78	70	71	70	69	74	73	71	64	60	40	30
PB	76	83	70	69	81	77	76	75	71	62	50	31	--
FP	86	89	70	75	85	82	84	83	79	74	66	56	43
LC	83	87	68	76	79	83	82	79	76	71	70	63	52
CB	86	89	76	87	80	80	88	86	82	79	75	65	58
ZG	76	83	69	75	75	80	81	78	79	75	73	60	45
ZG with fan operating	88	95	73	82	83	86	92	90	84	88	83	78	60
ZR	77	86	83	80	84	80	79	77	77	73	65	50	35
CC	83	86	82	80	81	83	83	81	77	72	60	48	30
SL	82	83	74	75	74	77	80	80	80	73	68	60	52



RECORD OF CARDIAC FREQUENCY IN DIFFERENT WORK PHASES

KEY TO ABBREVIATIONS

COK	Coke loading
ZF	Furnace area
ZC	Casting area
ZS	Ladle cleaning area
SL	Removel of ingots
PR	Scrap metal yard
PB	Slab storage area
CB	Billet processing
LC	Hot rolling
FP	Pit charging zone
CC	Cylinder changing zone
ZG	Liquid cast iron zone
ZR	Annealing zone
MR	Roll movement
MM	Material movement
ZM	Quay zone

ANNEX N. 4

STUDY OF VISIBILITY AND WORKPLACES

SECTION	CRANE TYPE	LOCATION
ACC	FC3	Casting zone

A - vertical travel hook and strap (distance between upper and lower travel limits) = 16.00 m

B - hook traversing = 21.5 m

C - longitudinal travel: grab = 340.00 mm

H cabin level above ground m 5.90

☒ operator seated

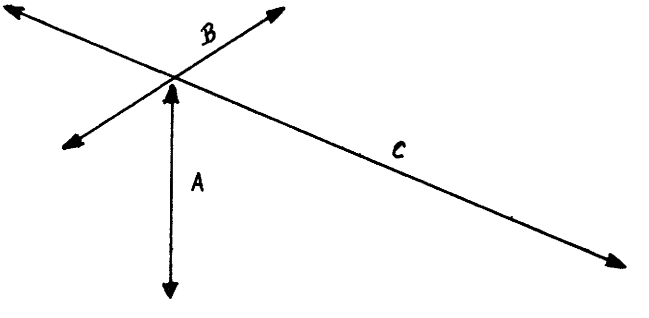
☐ operator standing

Distance between controls and operator's axis when seated cm

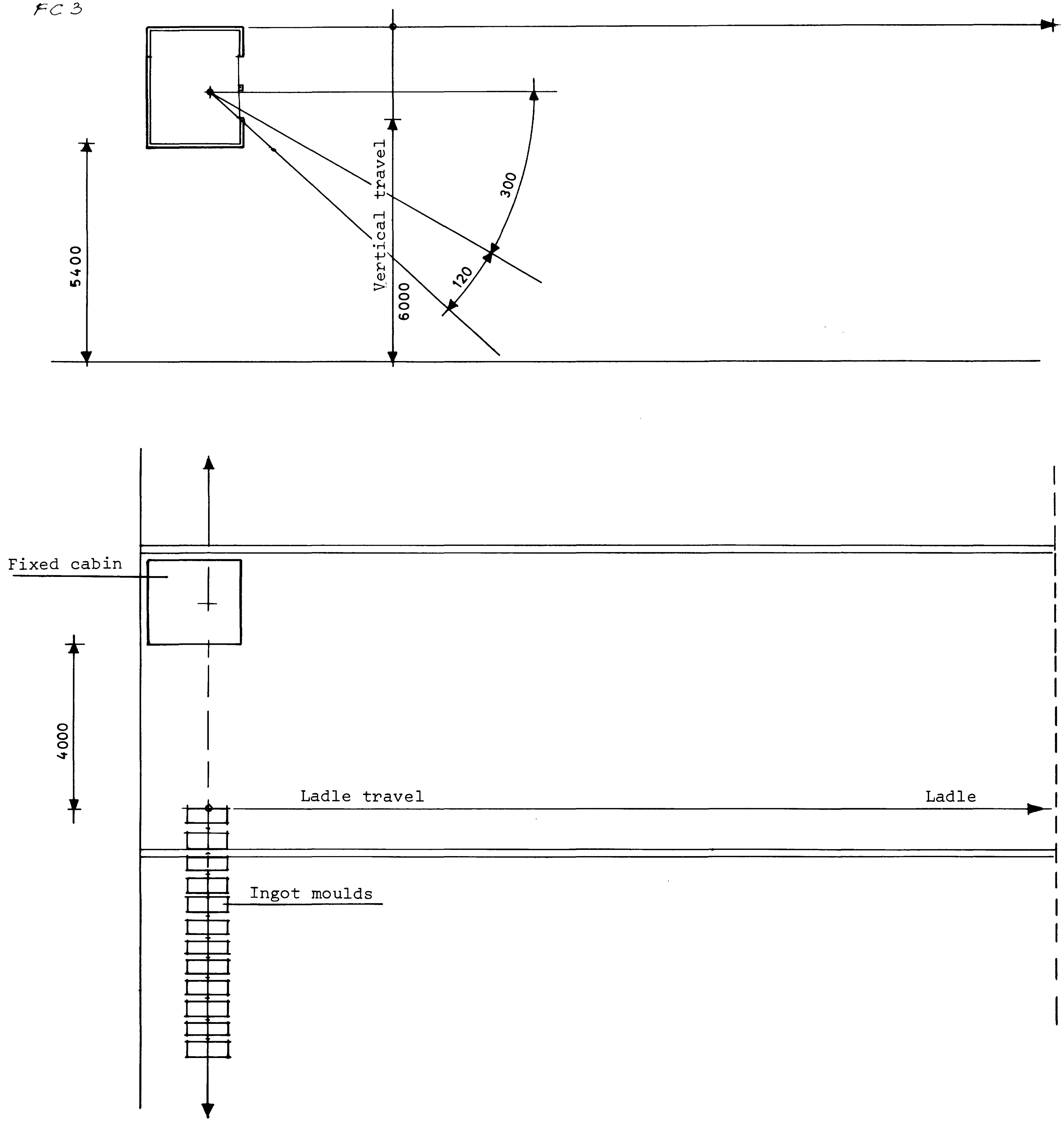
Cabin dimensions:

H edge of cabin windows cm

H cabin windows cm



FC 3


5400
Vertical travel
6000
300
120
Fixed cabin
4000
Ladle travel
Ladle
Ingot moulds

SECTION	CRANE TYPE	LOCATION
APR	ZOPPA	Zone M12

A - vertical travel of grab (distance between upper and lower travel limits) 22.10 m

B - grab traversing 87.70 m

C - longitudinal travel : grab 250.00 m

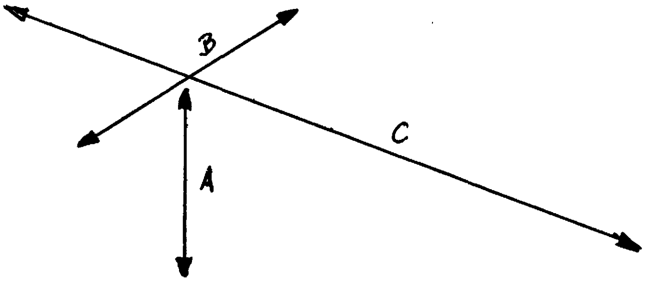
H cabin level above ground 24.80 m

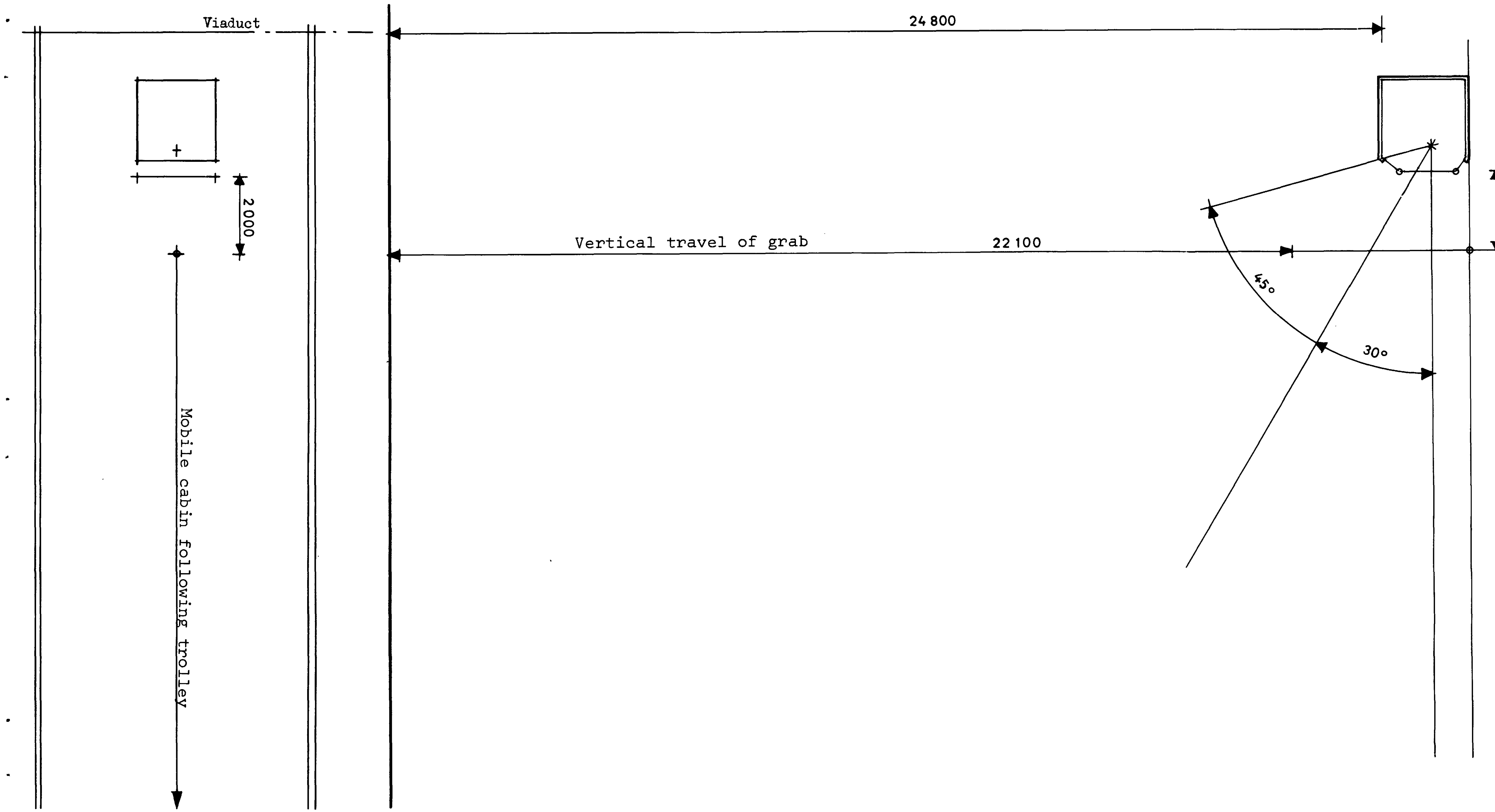
H max. at upper travel limit - grab open : 21.76 m

H max. at upper travel limit - grab closed : 22.10 m

☒ Operator seated

☐ Operator standing





Viaduct
24 800
2 000
Vertical travel of grab
22 100
2000
45°
30°
Mobile cabin following trolley

Zoppa

SECTION	CRANE TYPE	LOCATION
ACC	LG3	Ingot mould preparation

A - vertical travel of magnet-hook (distance between upper and lower travel limits) = 10.00 m (with ref. to hook)

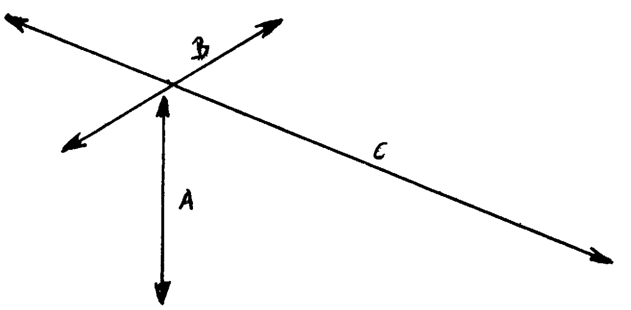
B - magnet-hook traversing : 25.15 m

C - longitudinal travel of grab 272.00 m

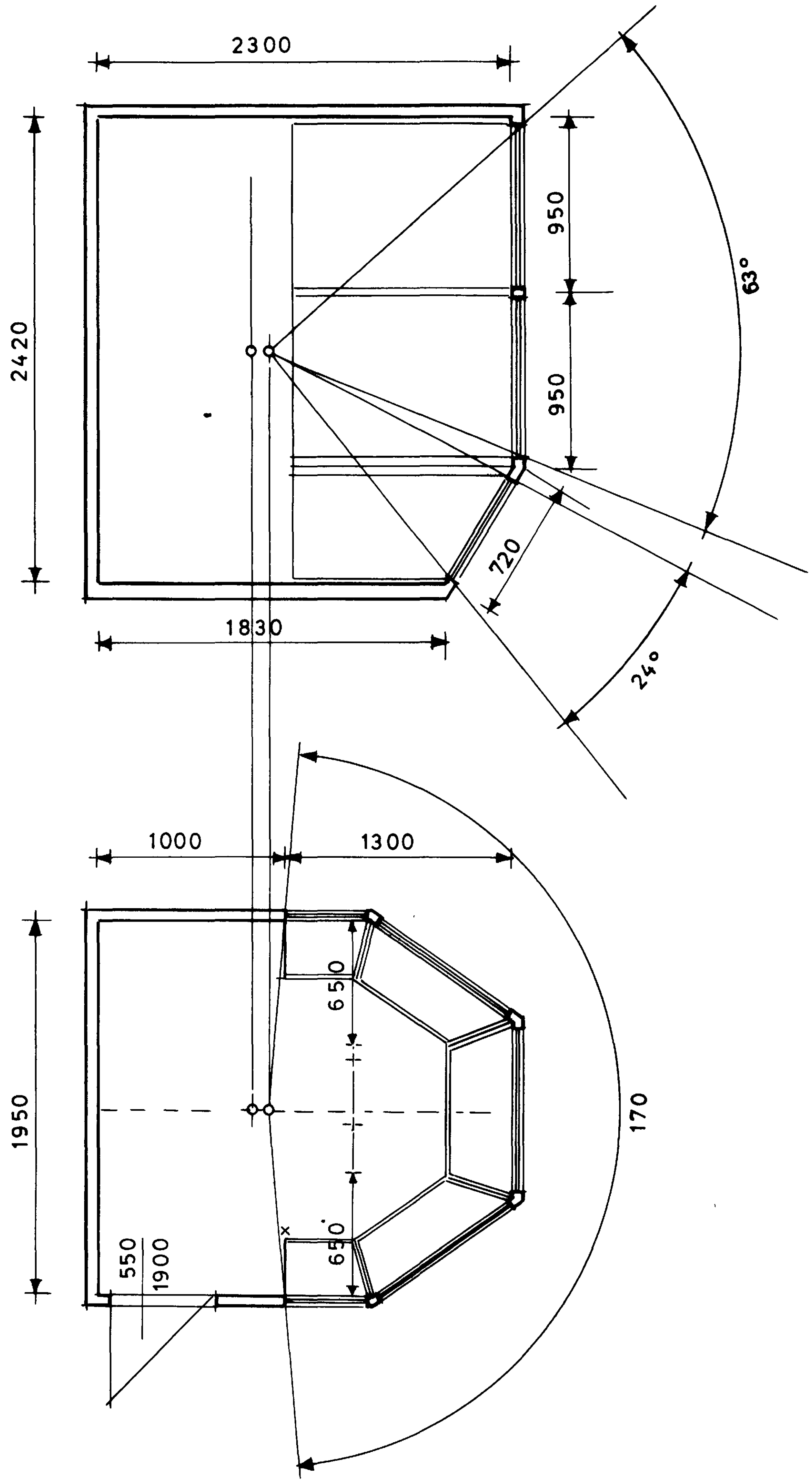
H cabin level above ground 8.10 m

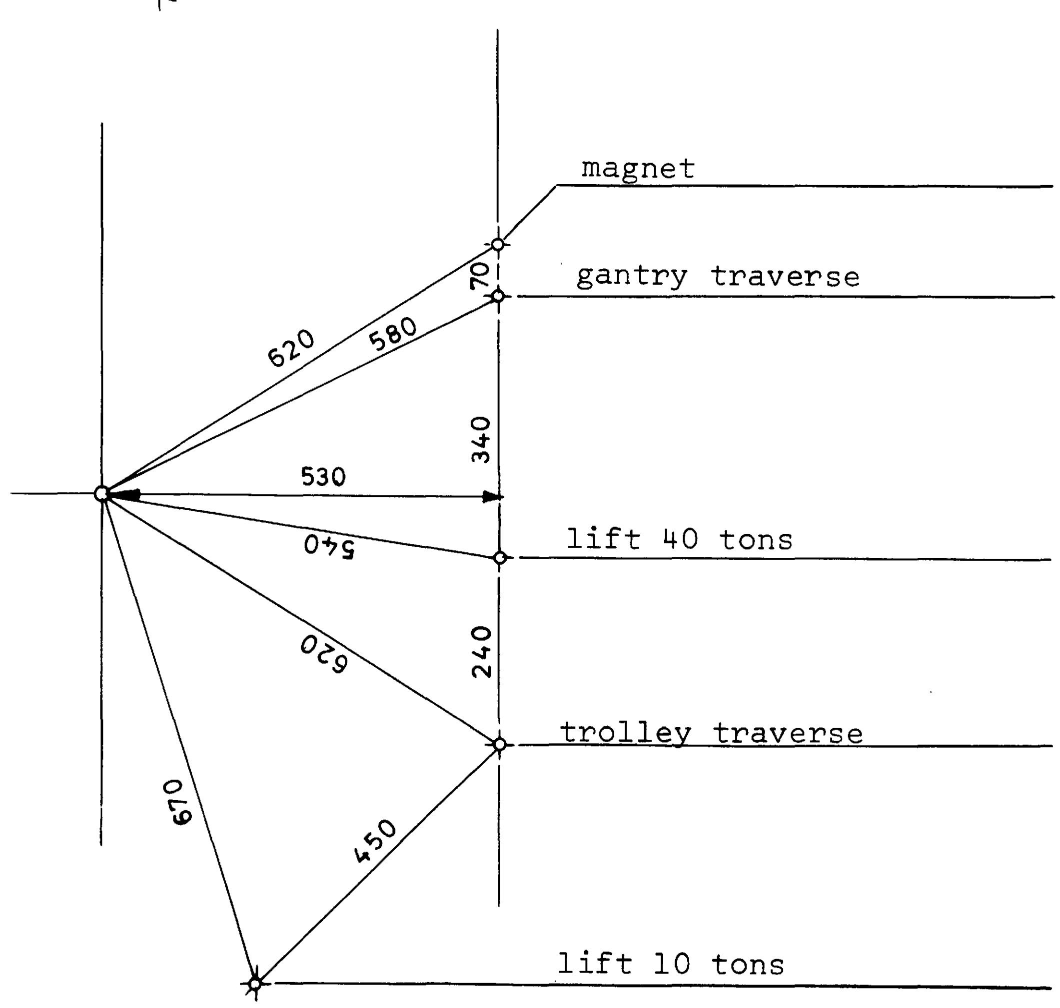
☒ operator seated

☐ operator standing



LG3


2300
2420
950
950
63°
720
1830
24°
1000
1300
1950
650
650
550
1900
170


magnet
gantry traverse
70
620
580
340
530
lift 40 tons
540
620
240
trolley traverse
670
450
lift 10 tons

SECTION	CRANE TYPE	LOCATION
LAC	FL1	

A - vertical travel of magnet (distance between upper and lower travel limits) 8.00 m

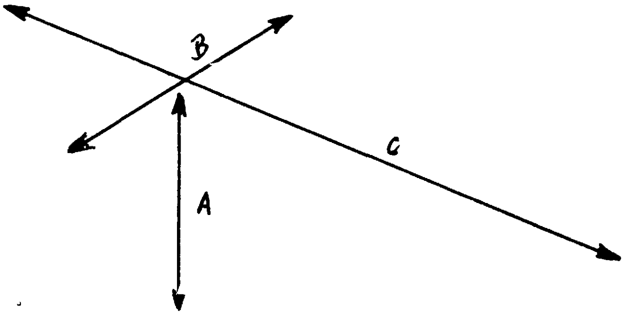
B - traversing 35.00 m

C - longitudinal travel m

H cabin level above ground 7.40 m

☒ operator seated

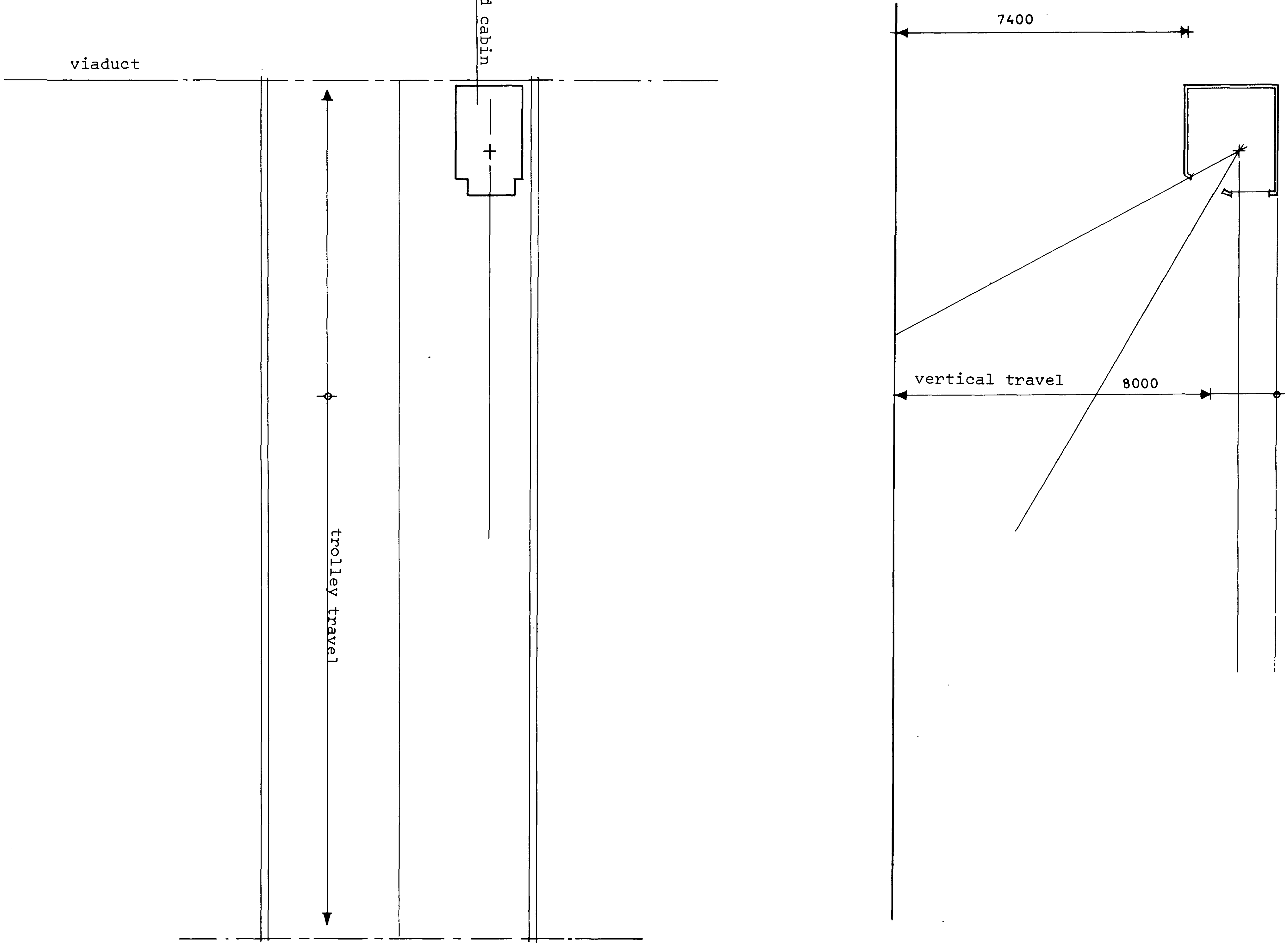
☐ operator standing



H edge of cabin windows cm

H cabin windows cm

FL 1


viaduct
fixed cabin
trolley travel
7400
vertical travel
8000

SECTION	CRANE TYPE	LOCATION
LAC	DB2	Slab store

A - vertical travel 2 independent hooks (distance between upper and lower travel limits) 9.40 m

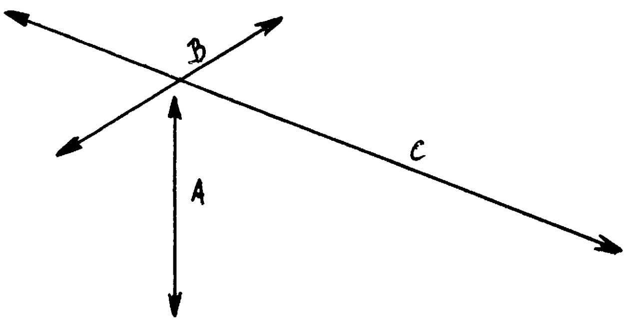
B - traversing 35.00 m

C - longitudinal travel 150.00 m

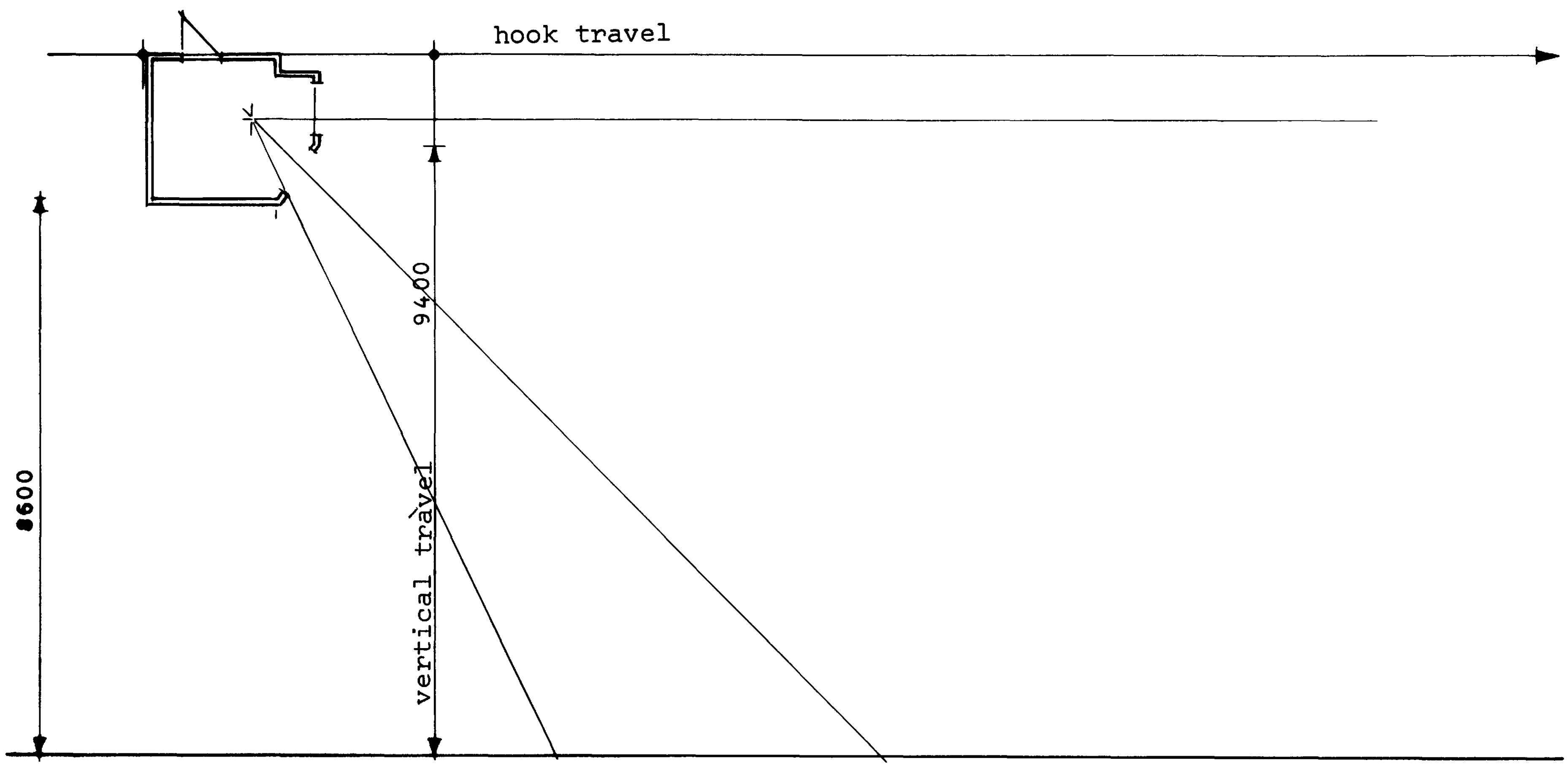
H cabin level above ground 8.60 m

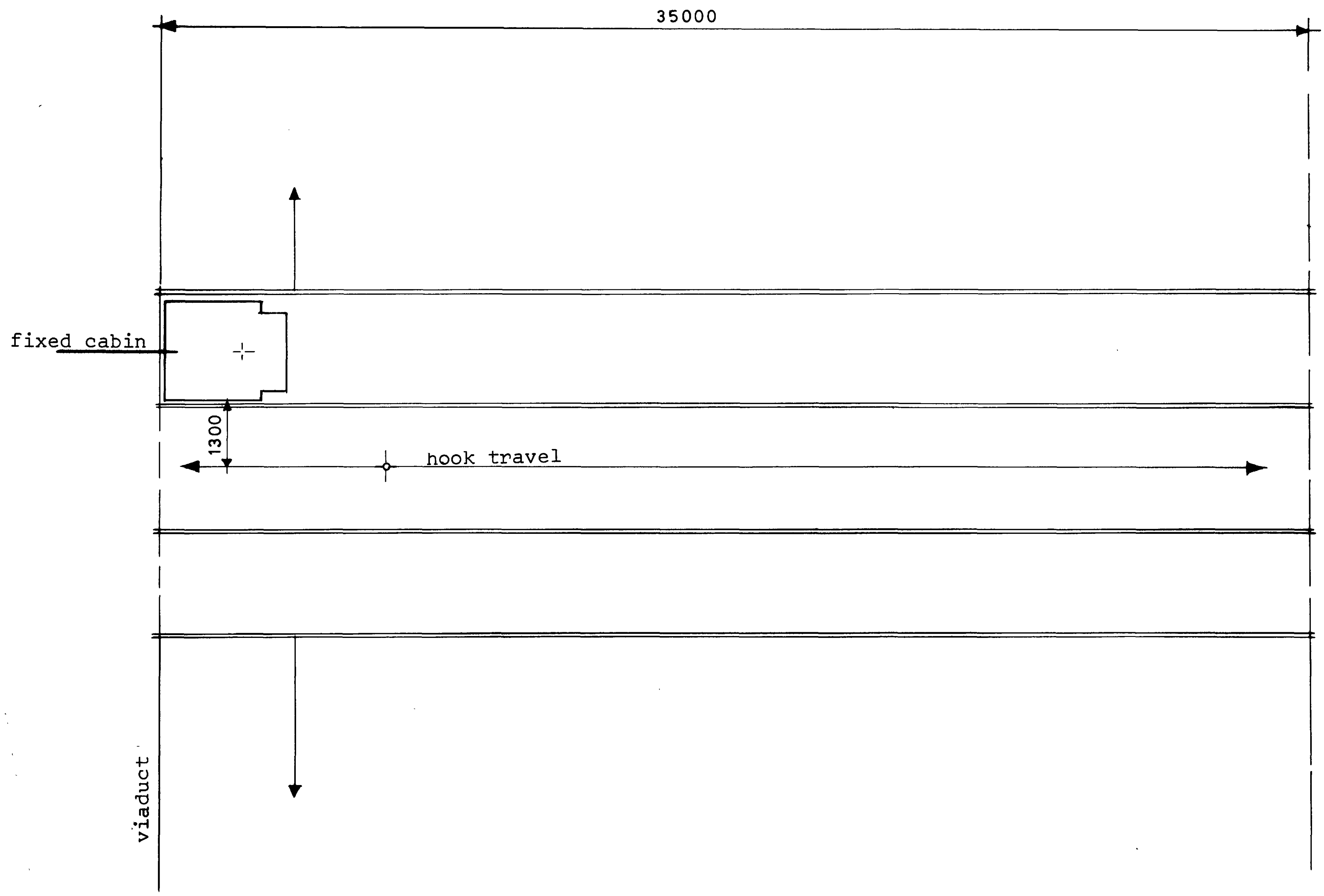
☒ operator seated

☐ operator standing



DB2


hook travel
9400
8600
vertical travel


35000
fixed cabin
1300
hook travel
viaduct

SECTION	CRANE TYPE	LOCATION
ACC	CG3	Molten cast iron zone

A - vertical travel of strap (distance between upper and lower travel limits) 7.50 m

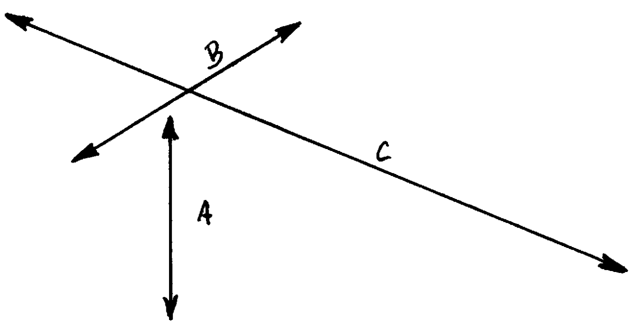
B - traversing 24.05 m

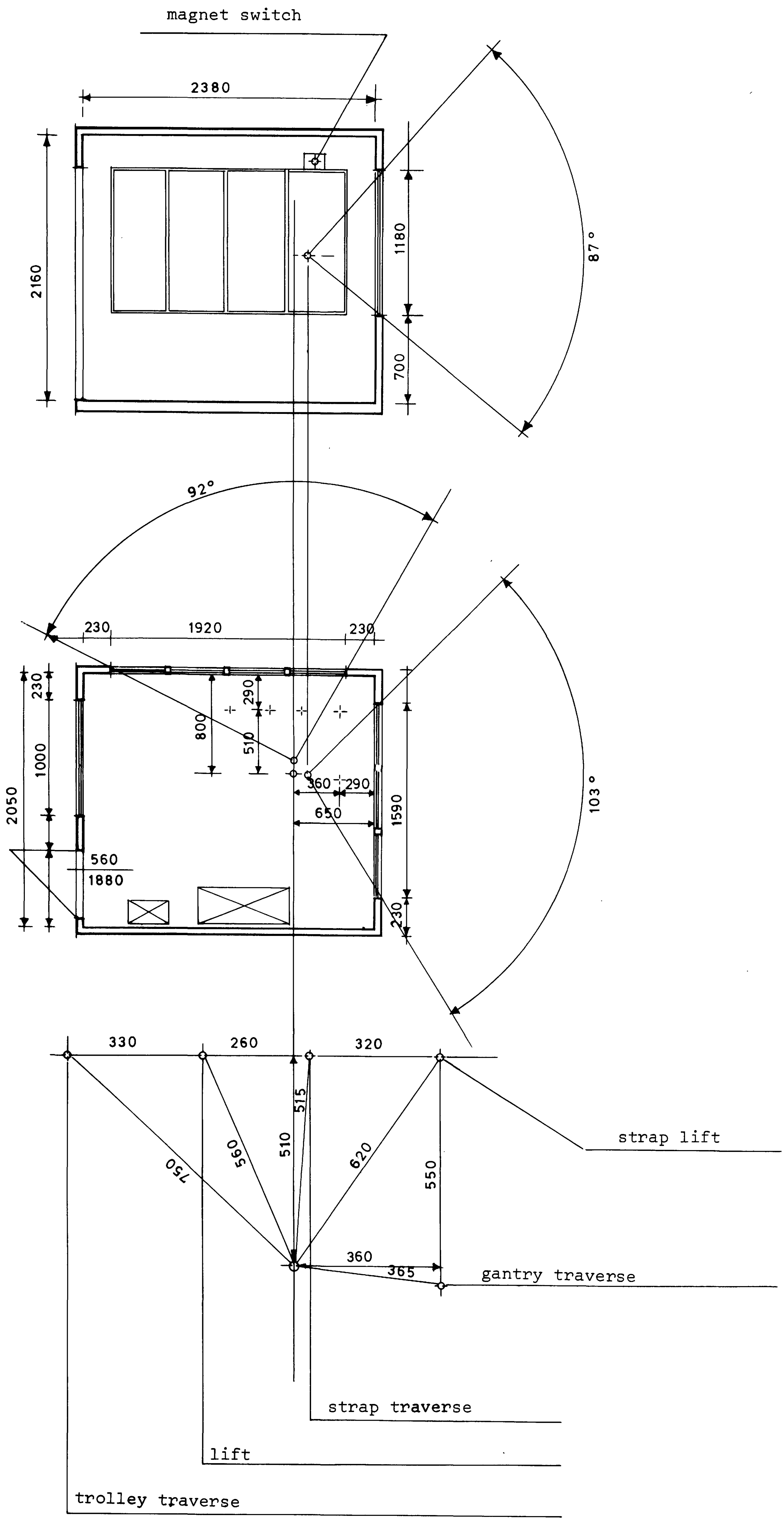
C - longitudinal travel 340.00 m

H cabin level above ground 6.90 m

☒ operator seated

☐ operator standing





magnet switch
2380
2160
1180
700
87°
92°
230
1920
230
2050
1000
230
800
290
510
360
290
650
1590
230
103°
560
1880
330
260
320
515
750
560
510
620
550
360
365
strap lift
gantry traverse
strap traverse
lift
trolley traverse

SECTION	CRANE TYPE	LOCATION
COK	CK	Loading zone

A - vertical travel of grab (distance between upper and lower travel limits) 15.00 m

B - grab traversing : 12.00 m (monorail)

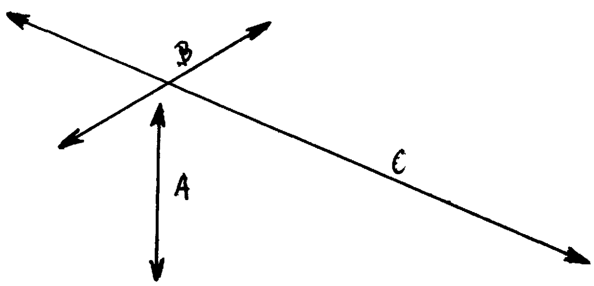
H cabin level above ground:

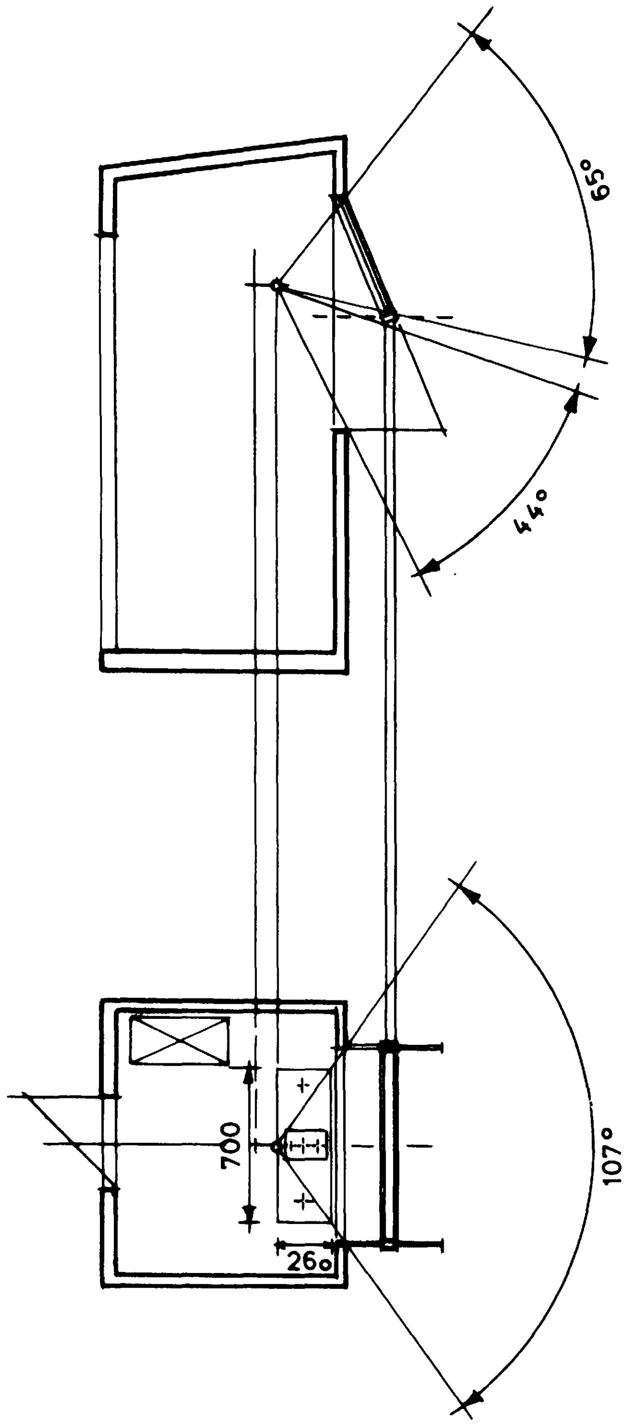
H max. at upper travel limit - grab open : 14.66 m

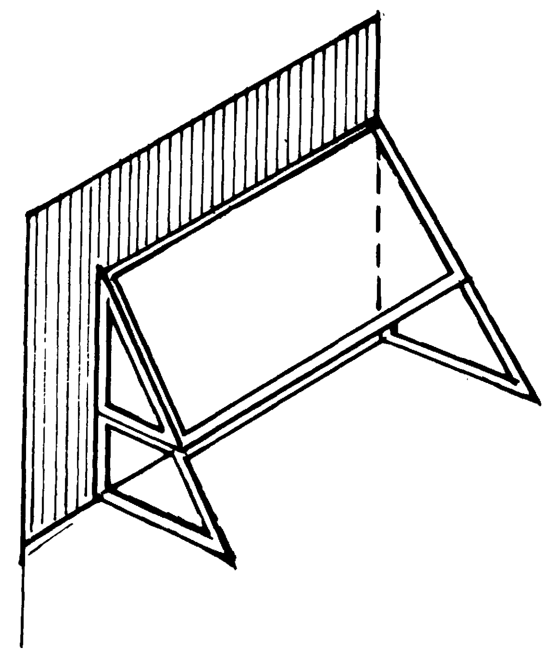
H max. at upper travel limit - grab closed : 15.00 m

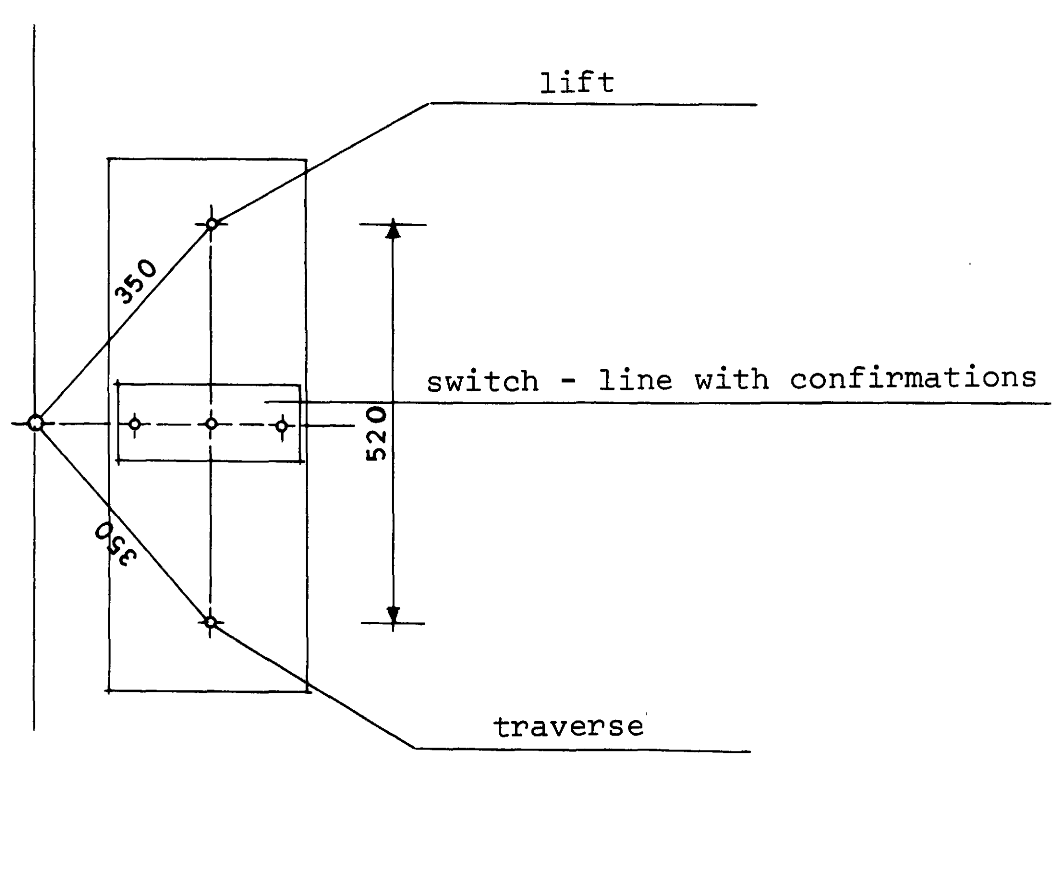
☐ operator seated

☒ operator standing




65°
44°
700
26o
107°




lift
350
switch - line with confirmations
520
350
traverse

SECTION	CRANE TYPE	LOCATION
ACC	PR6	Scrap metal yard

A - vertical travel of hook (distance between upper and lower travel limits) : 18.00 m

B - hook traversing : 31.62 m

C - longitudinal travel of grab : 200.00 m

H cabin level above ground : 15.75 m from lower limit of hook travel

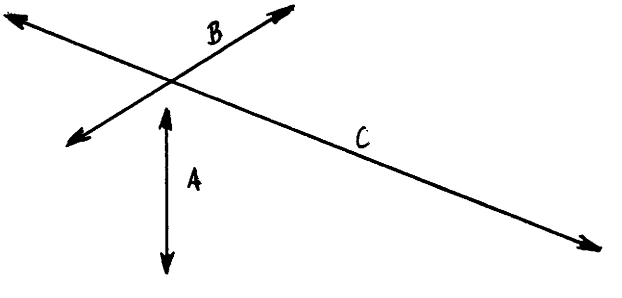
☒ operator seated

☐ operator standing

Distance between controls and axis of driver when seated = cm

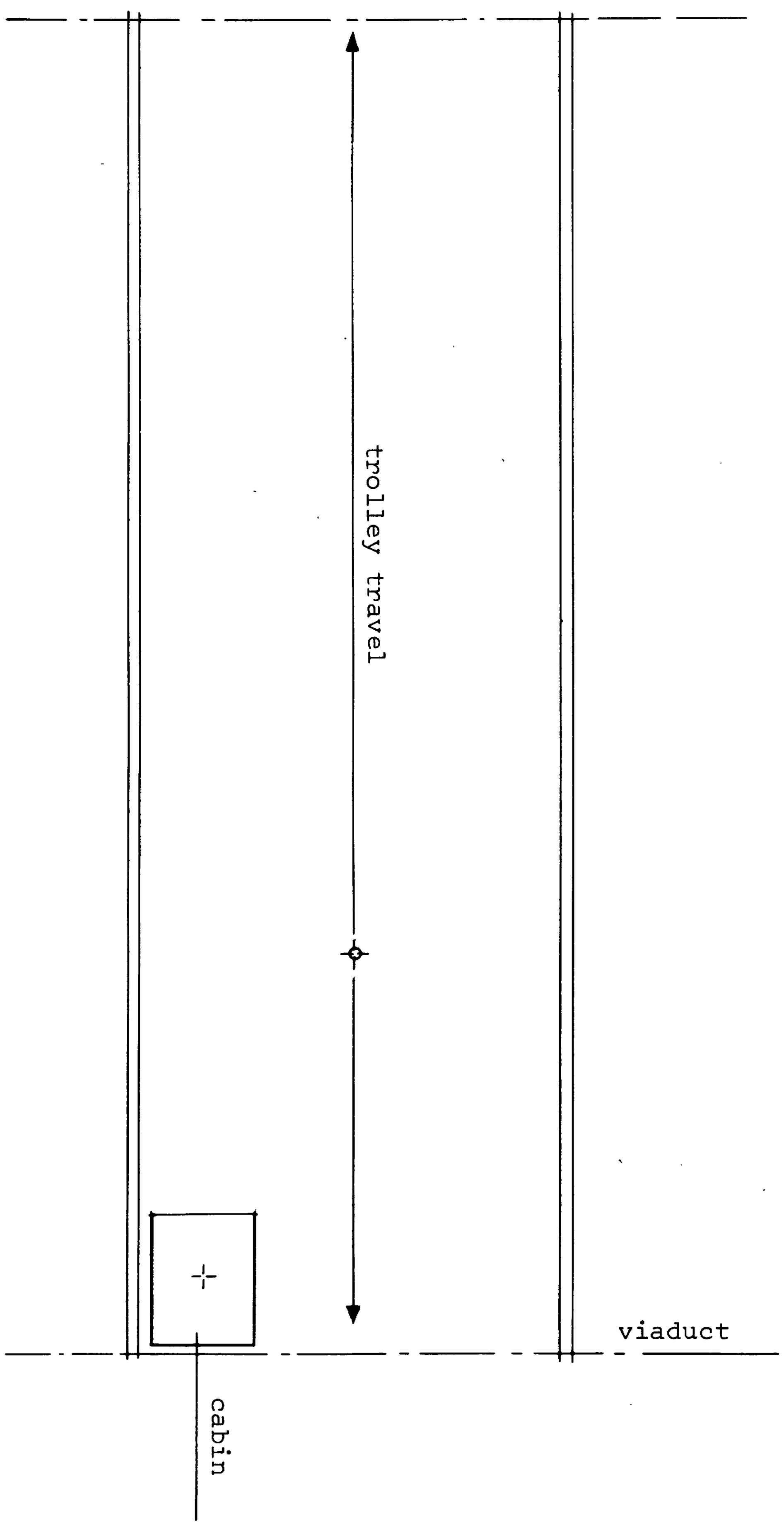
Cabin dimensions :

section at top 1995 x 1610 mm
section at bottom 1635 x 1500 mm
min. height 2370 mm

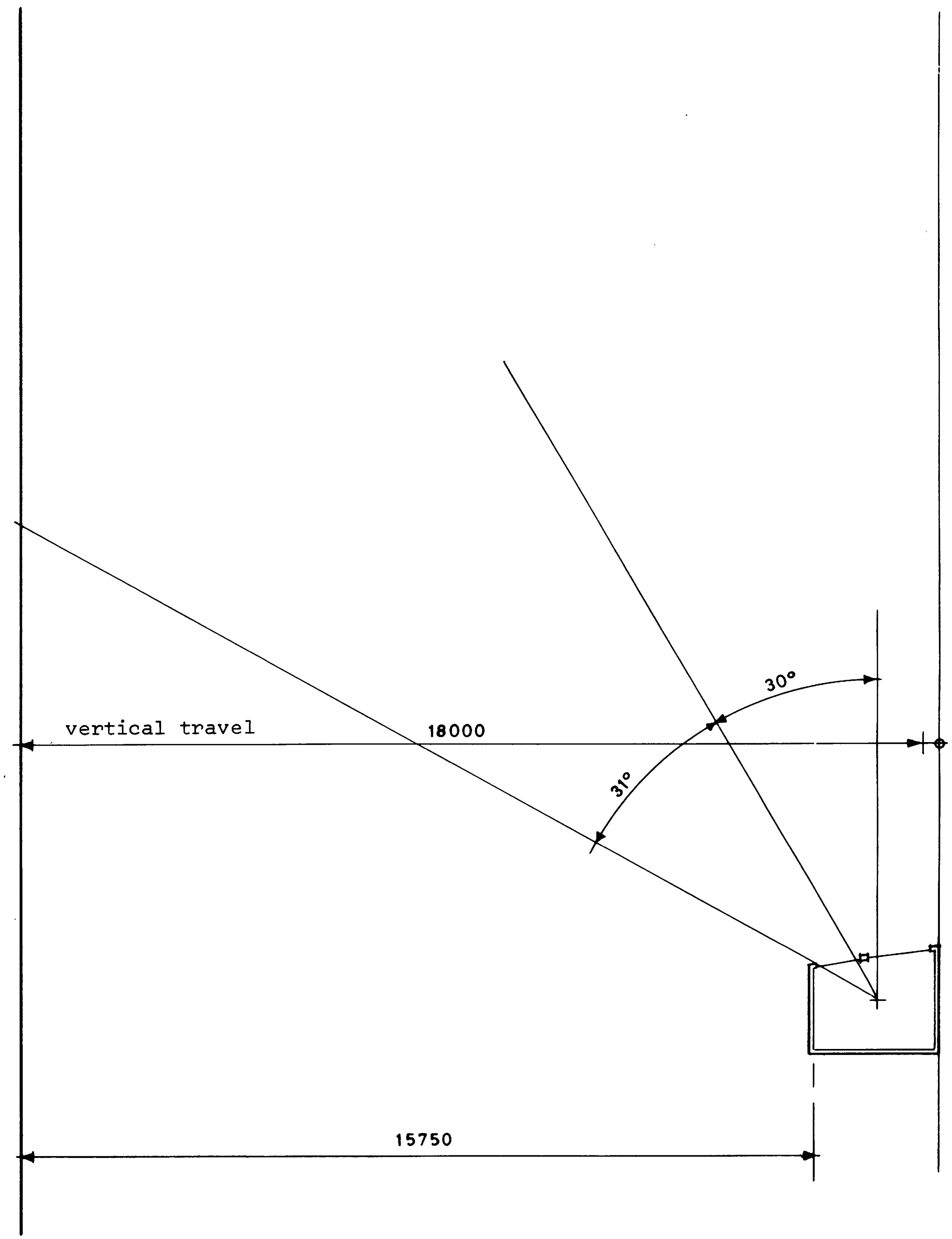


H start of cabin windows = 5 cm
H cabin windows = 99 cm for lower windows and 85 cm for upper, with 10 cm intervening space

PK6



trolley travel
viaduct
cabin



vertical travel
18000
30°
31°
15750

SECTION	CRANE TYPE	LOCATION
ACC	PR1	Scrap metal yard

A - vertical travel magnet (distance between upper and lower travel limits) : 12 m

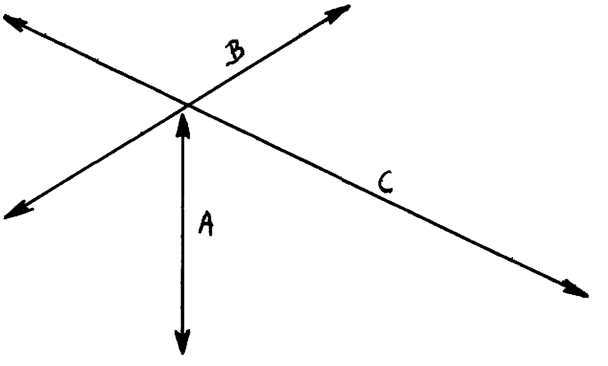
B - magnet traversing : 35 m

C - longitudinal travel of magnet : 320 m

H cabin level above ground 13.40 m

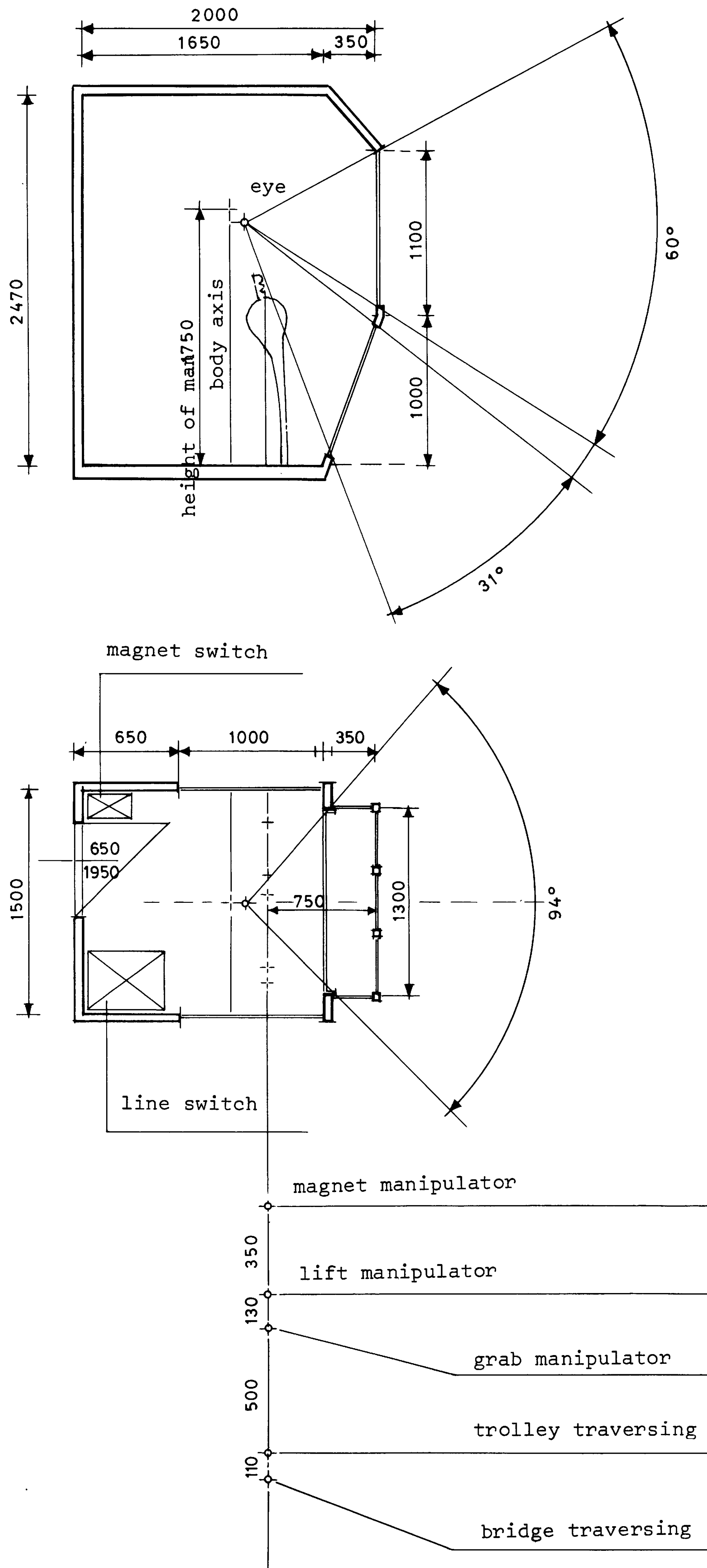
☐ operator seated

☒ operator standing



N.B. the grab is rarely used.

PR1



N.B. All dimensions are internal

SECTION	CRANE TYPE	LOCATION
LAC	FP1	Pit furnace

A - vertical travel of grab (distance between upper and lower travel limits) 7 m

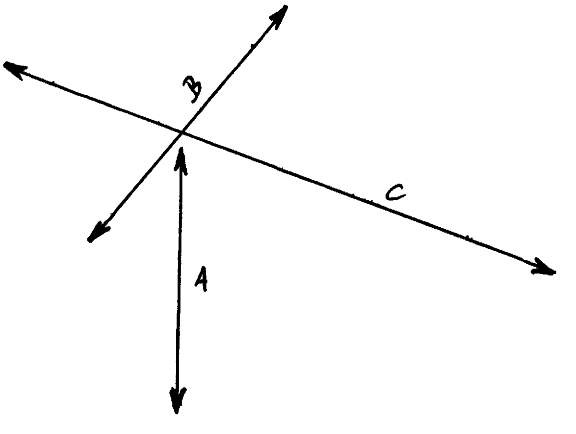
B - grab traversing 30 m

C - longitudinal travel m

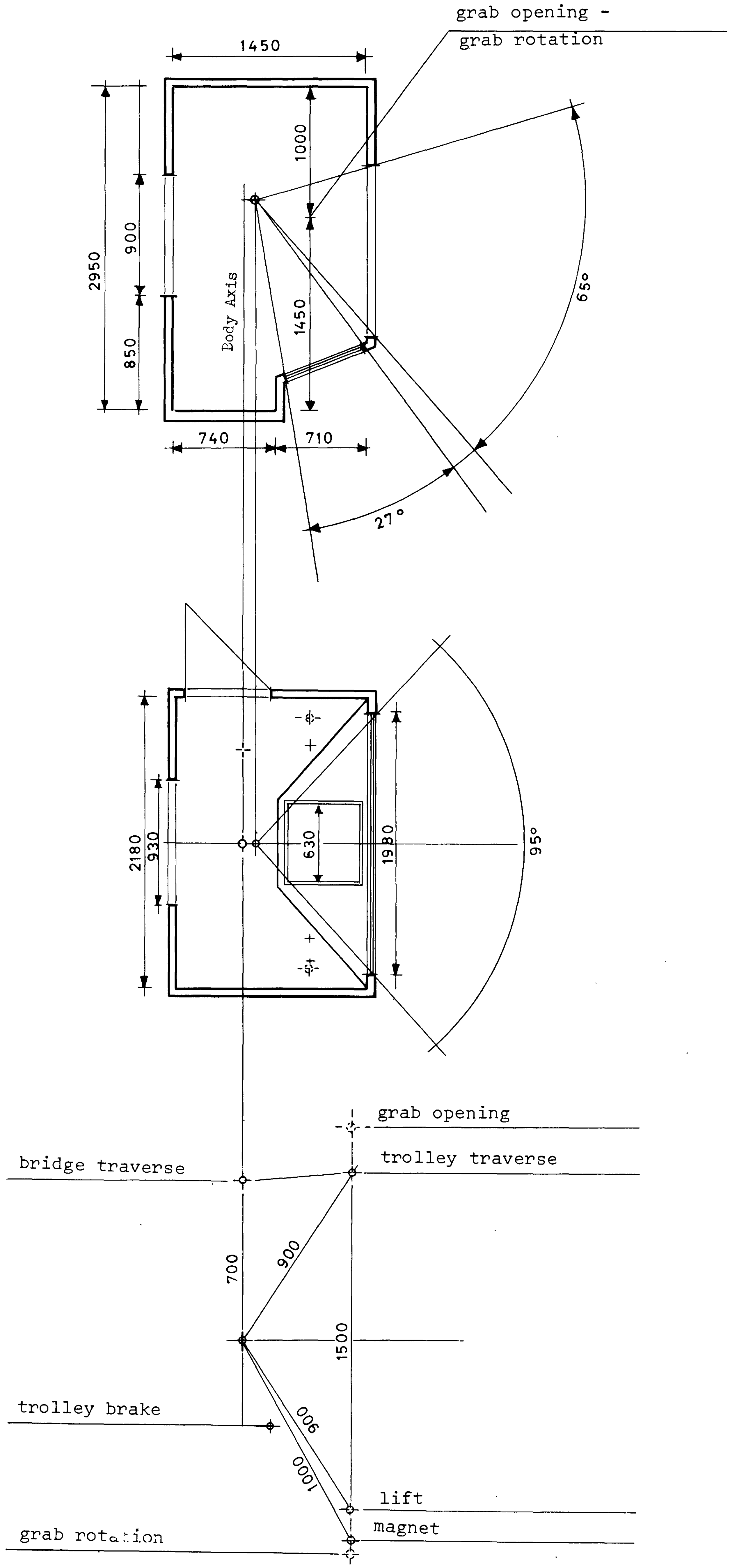
H cabin level above ground 8 m

☐ operator seated

☒ operator standing



FP1


grab opening -
grab rotation
1450
2950
900
850
1000
1450
Body Axis
740
710
65°
27°
2180
930
630
1980
95°
grab opening
bridge traverse
trolley traverse
700
900
1500
trolley brake
900
1000
lift
magnet
grab rotation

SECTION	CRANE TYPE	LOCATION
LAC-LAF-LAF	TC1-TF1-DR1	Cylinder change material movement

A - vertical travel magnet and hook (distance between upper and lower travel limits) 10.50 m

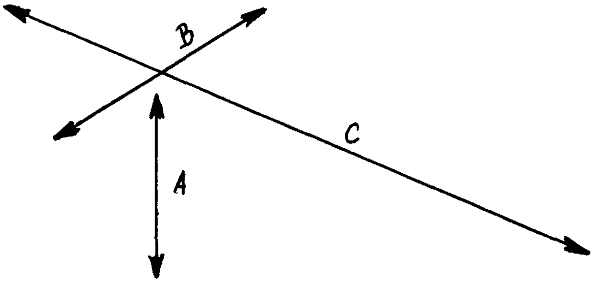
B - magnet and hook traversing 35 m

C - longitudinal travel, magnet and hook m

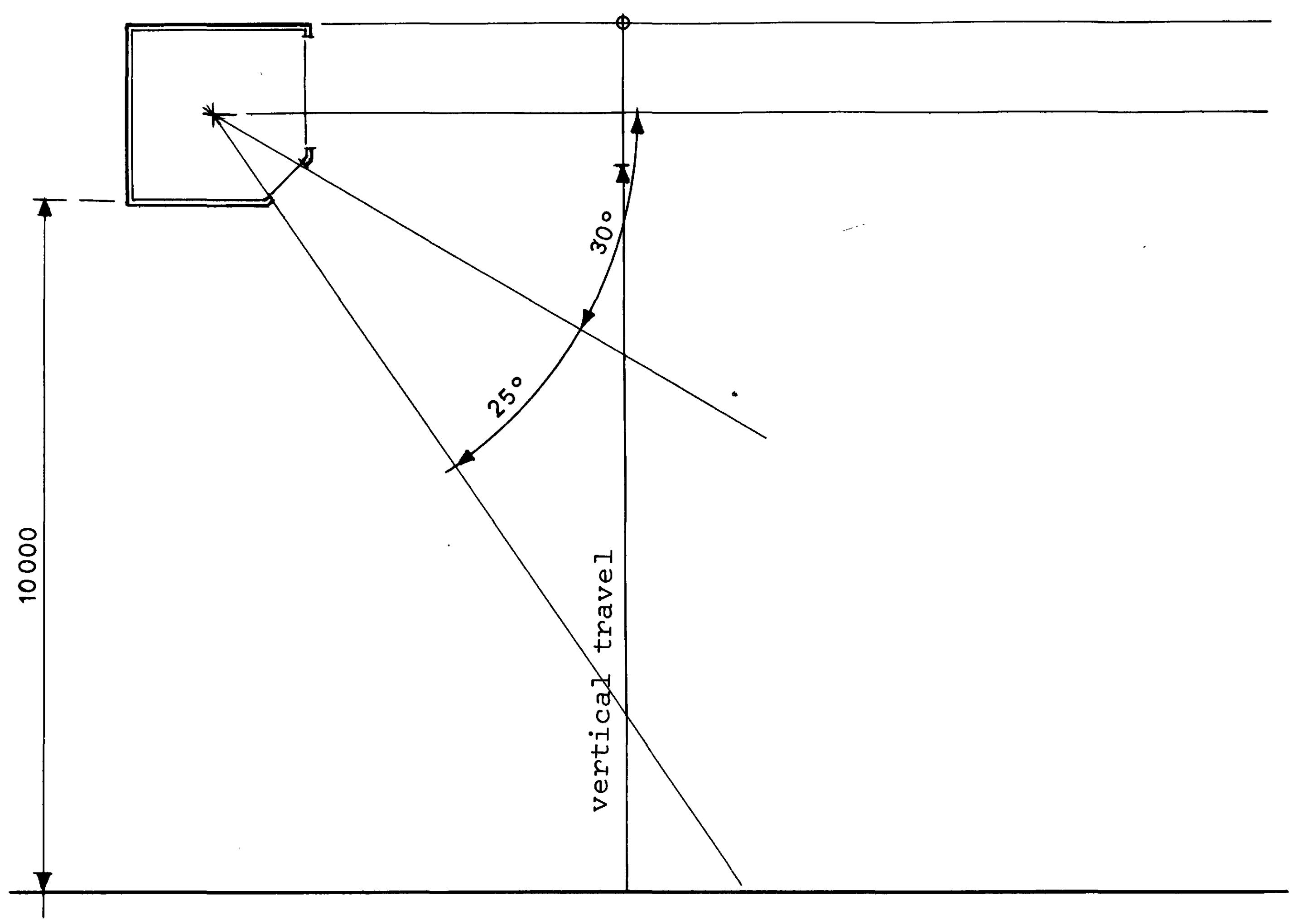
H cabin level above ground 10 m

☒ operator seated

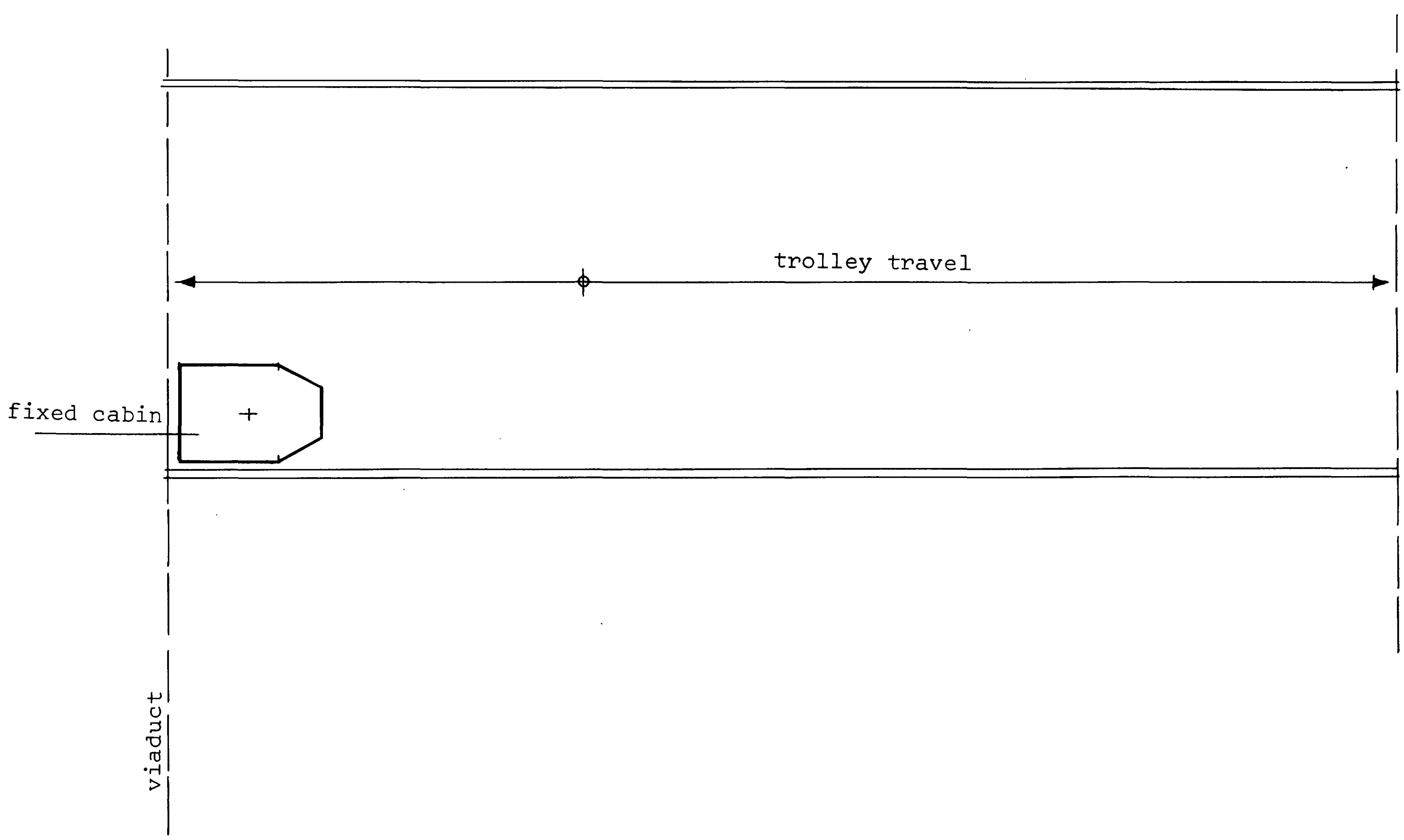
☐ operator standing



TC1-TF1-DR1



30°
25°
10000
vertical travel



trolley travel
fixed cabin
viaduct

SECTION	CRANE TYPE	LOCATION
LAF	FR1	Annealing Bay

A - vertical travel hook (distance between upper and lower travel limits) : 12 m

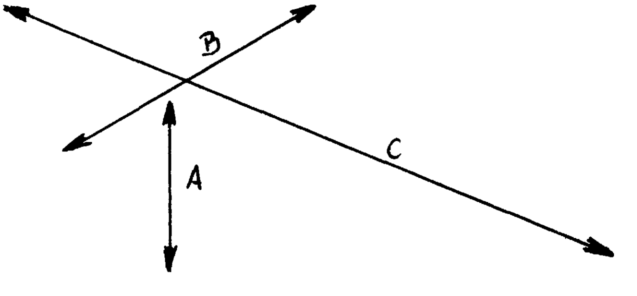
B - hook traversing : 35 m

C - longitudinal travel of hook : 100 m

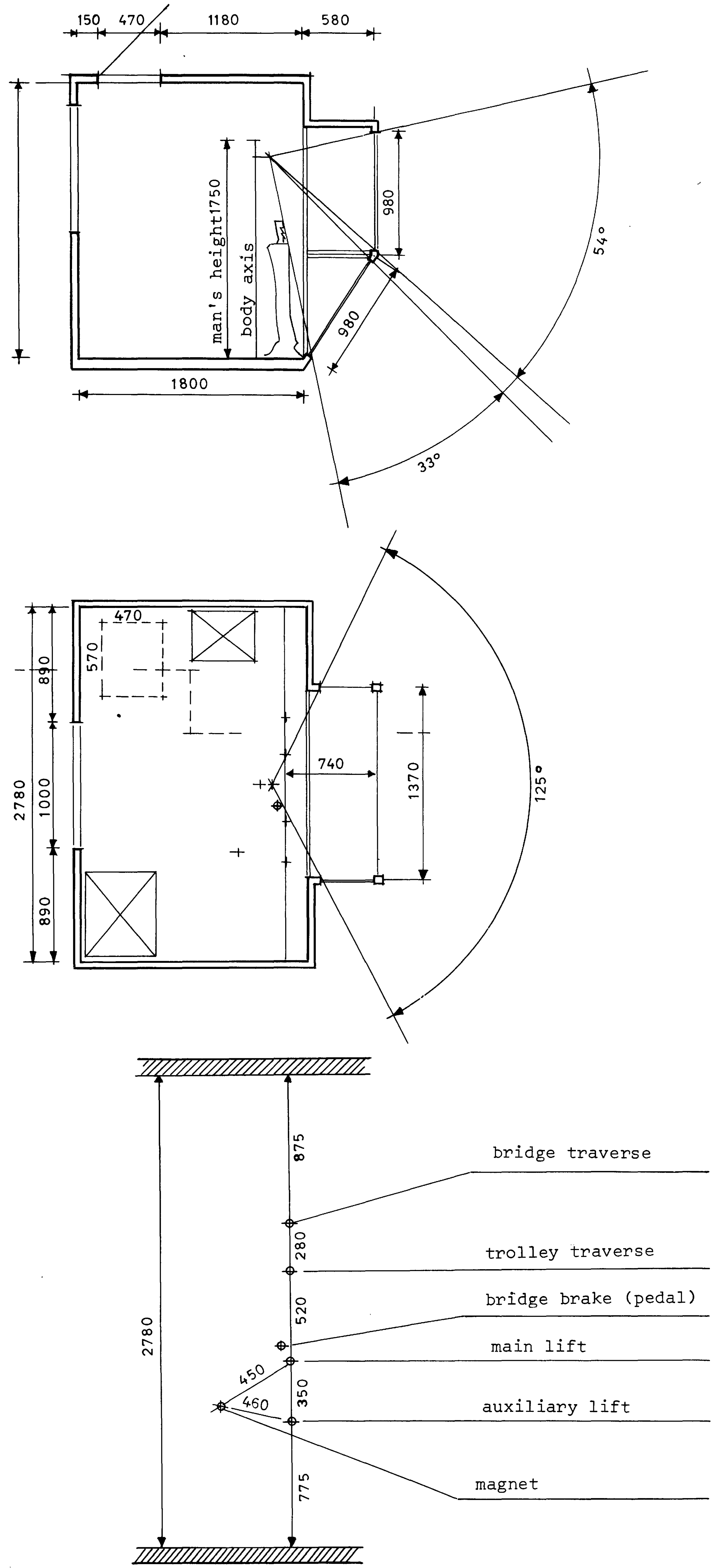
H cabin level above ground : 10.90 m

☒ operator seated

☐ operator standing



FR1



150
470
1180
580
man's height1750
body axis
980
980
54°
33°
1800
470
570
890
1000
890
2780
740
1370
125°
875
280
520
350
775
2780
450
460
bridge traverse
trolley traverse
bridge brake (pedal)
main lift
auxiliary lift
magnet

SECTION	CRANE TYPE	LOCATION
ACC	PR4 - PR5	Scrap metal yard

A - vertical travel of magnet (distance between upper and lower travel limits) : 12 m

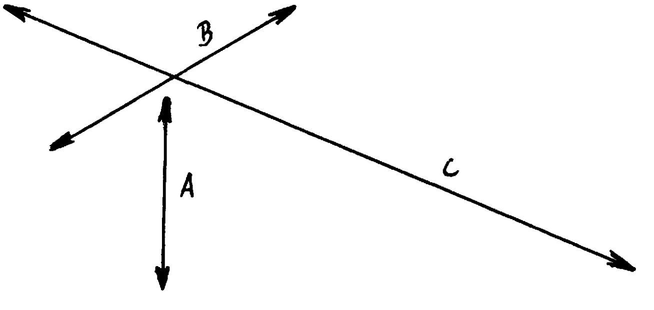
B - magnet traversing : 35 m

C - longitudinal travel of magnet : 320 m

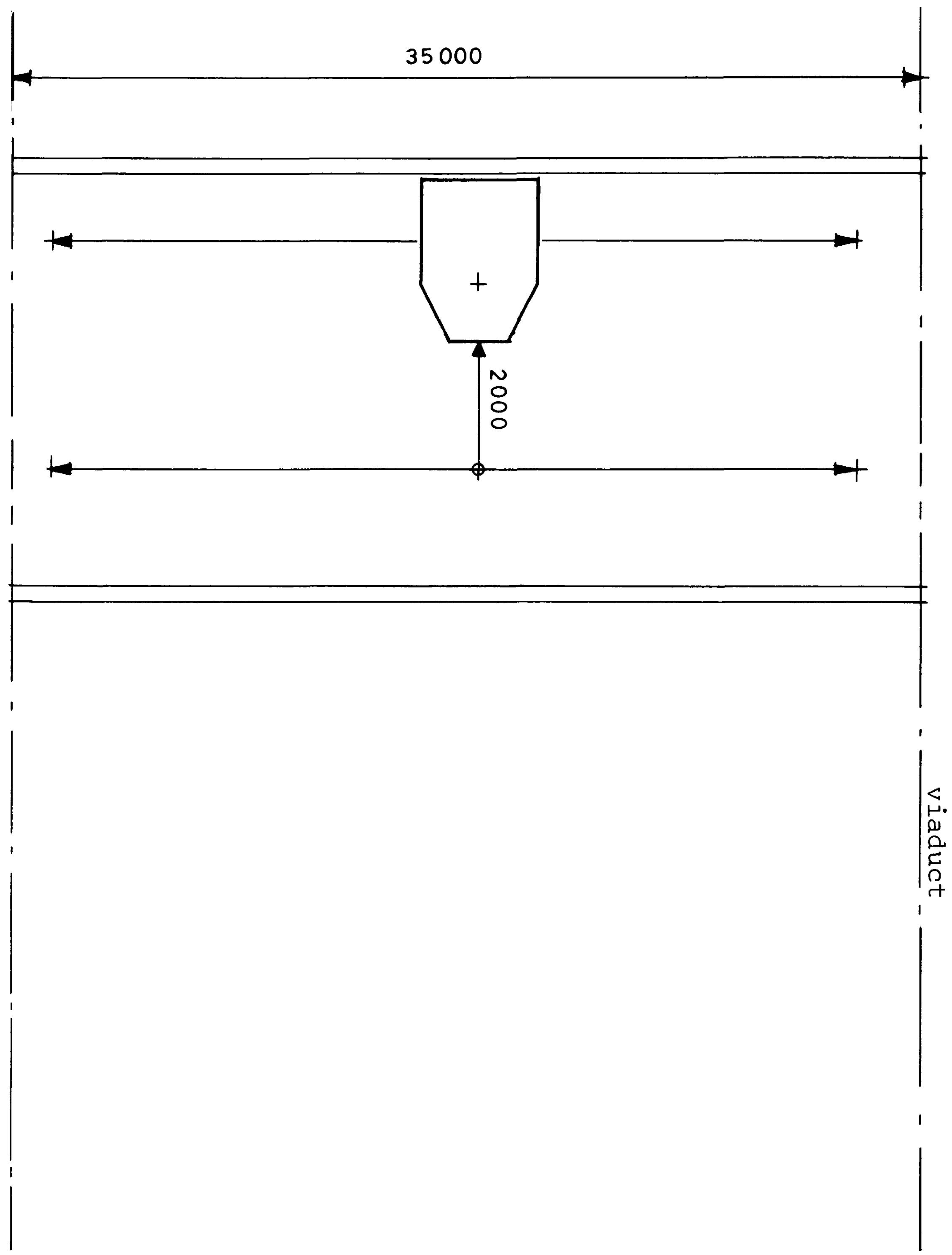
H cabin level above ground : 13.40 m

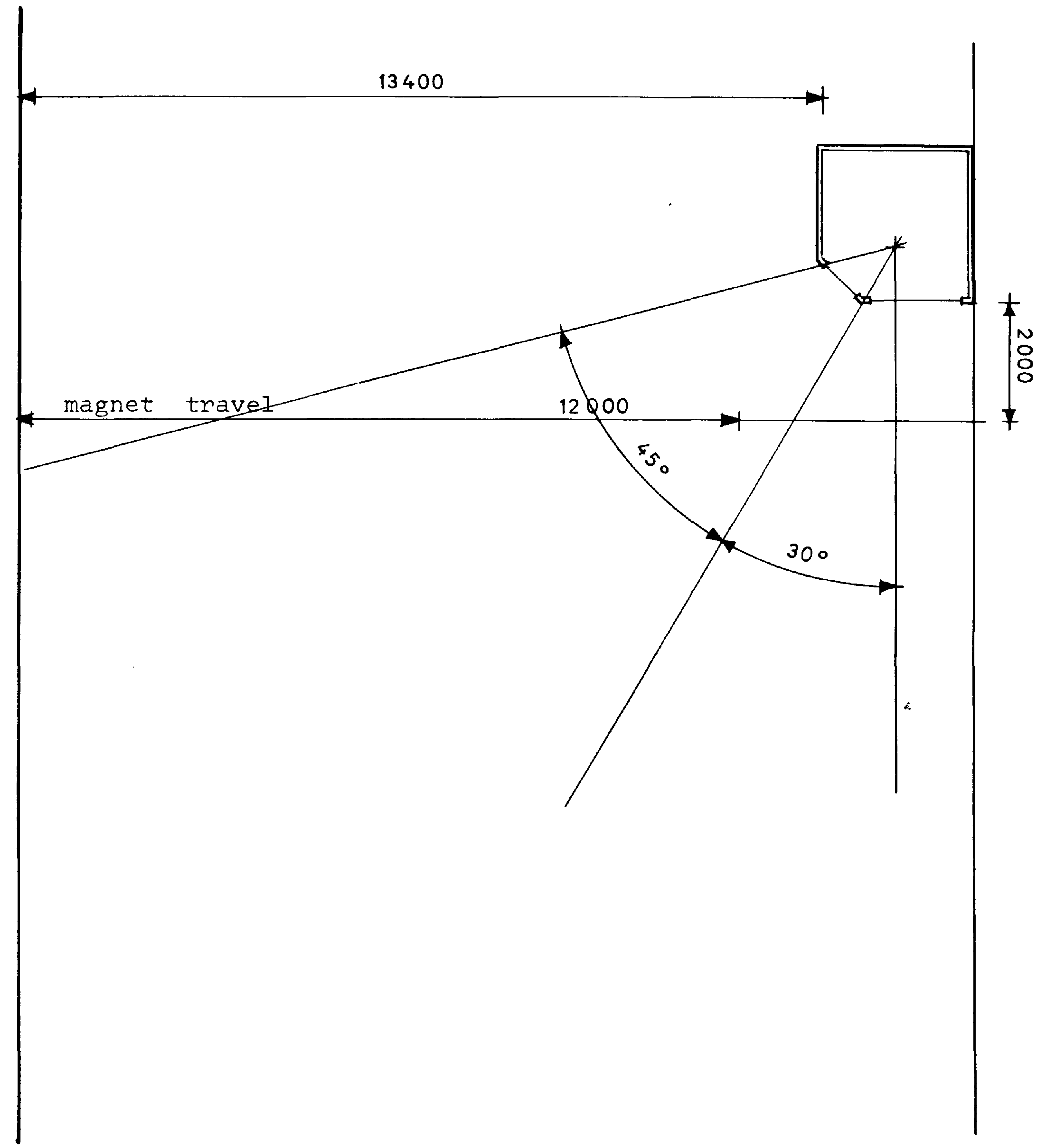
☒ operator seated

☐ operator standing



PR4-PR5





SECTION	CRANE TYPE	LOCATION
SES	SB1 - SB2	Quay area

A - vertical travel of grab (distance between upper and lower travel limits): 36.4 m

B - grab traversing : 34.65 m

C - longitudinal travel of grab : 500 m

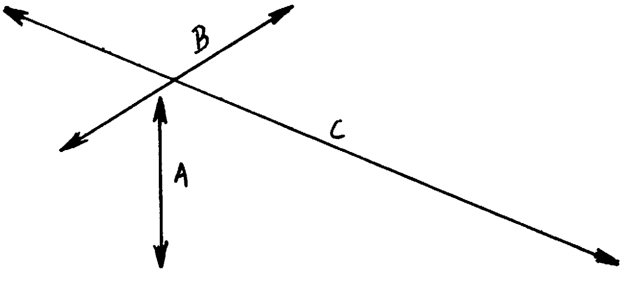
H cabin level above ground : 21.30 m above sea level (0.00)

H max., grab open, at upper travel limit : 36.06 m

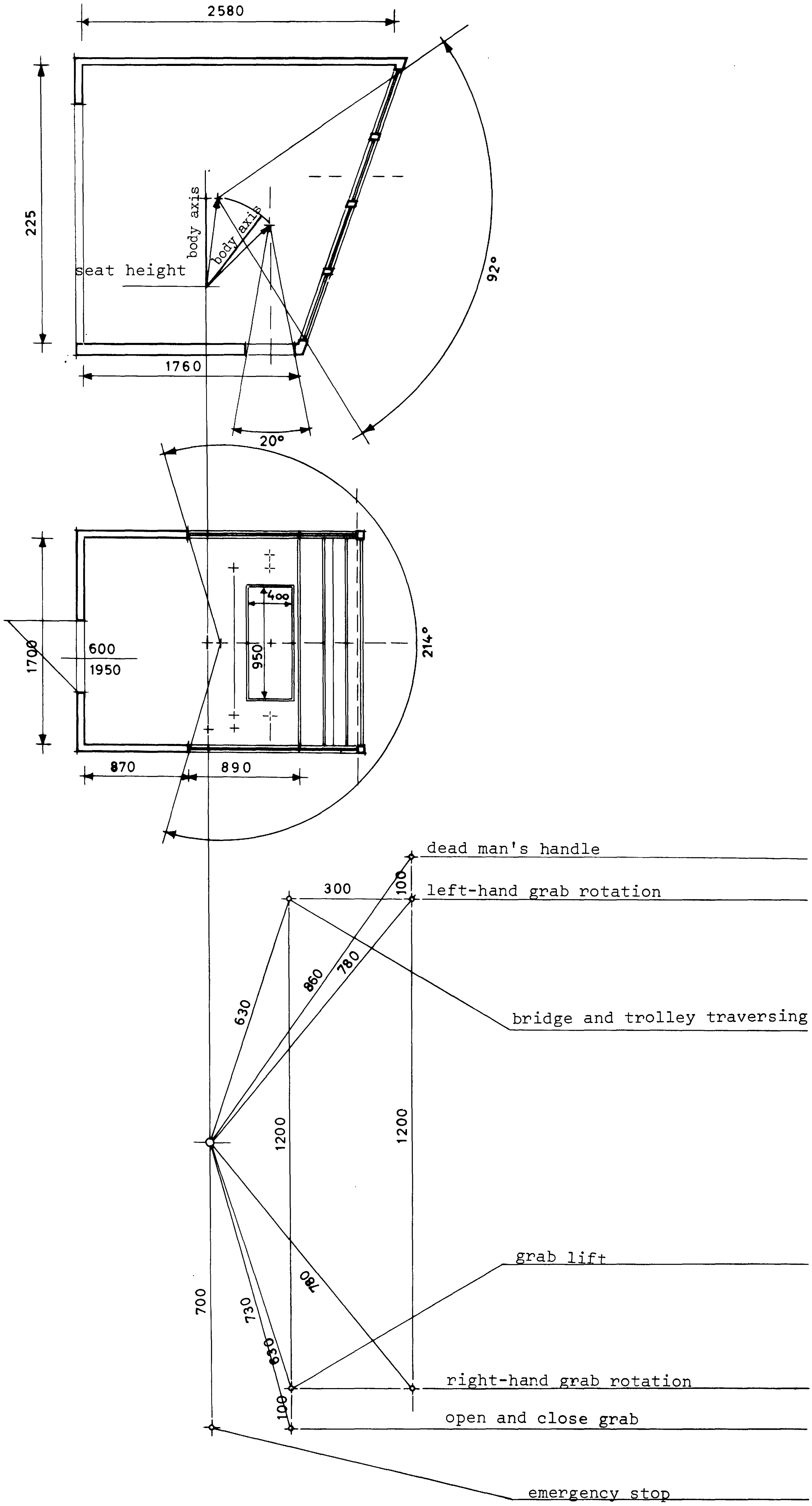
H max., grab closed, at upper travel limit : 36.40 m

☒ operator seated

☐ operator standing



SB1 - SB2


2580
225
1760
body axis
body axis
seat height
92°
20°
214°
1700
600
1950
400
950
870
890
dead man's handle
left-hand grab rotation
bridge and trolley traversing
grab lift
right-hand grab rotation
open and close grab
emergency stop
300
100
860
780
630
1200
1200
700
730
630
780
100

SECTION	CRANE TYPE	LOCATION
SES	SB4 - SB3	Quay area

A - vertical travel of grab (distance between upper and lower travel limits) : 36 m

B - rotation with straddle : min. 9.30 m, max. 26.50 m (360° rotation)

C - longitudinal grab travel : 500 m

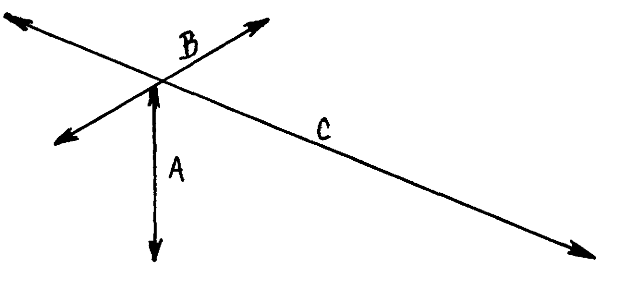
H cabin height above sea level (0.00) : 23.00 m

H max. at upper travel limit - grab open : 35.66 m (from base of ship's hold)

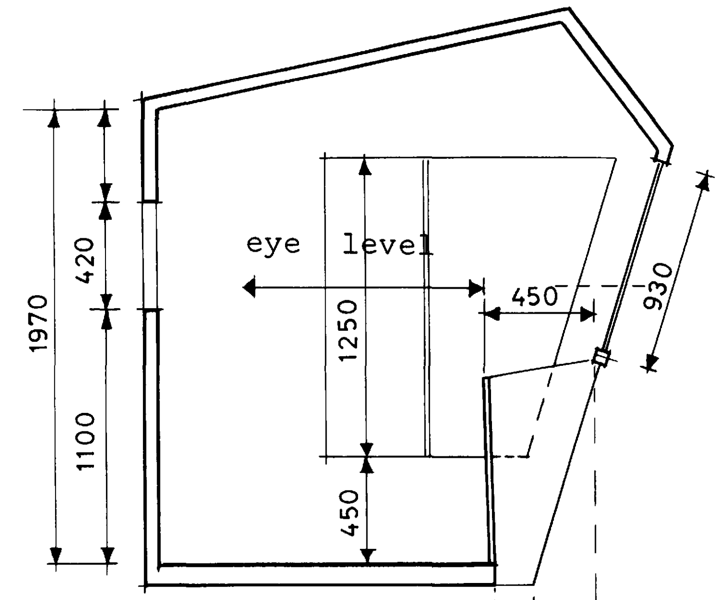
H max. at upper travel limit - grab closed : 36.00 (from base of ship's hold)

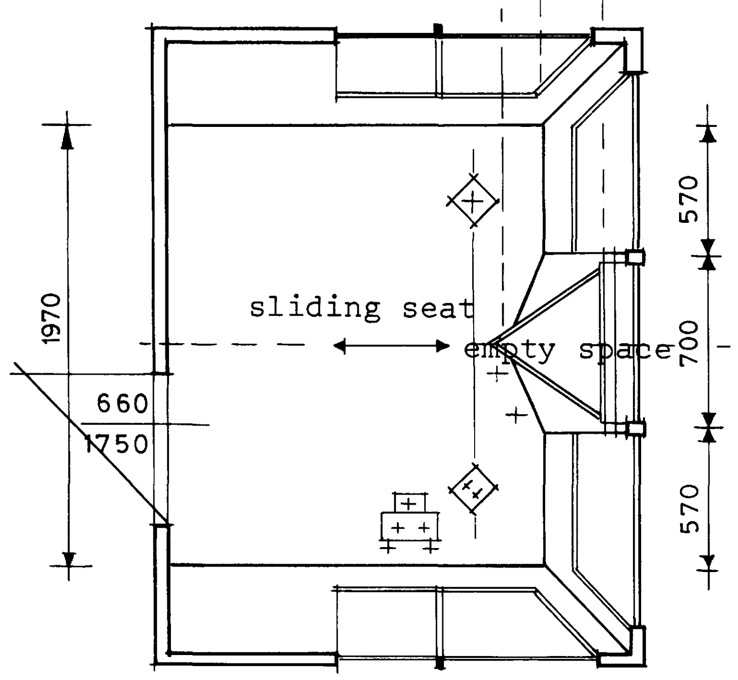
☒ operator seated

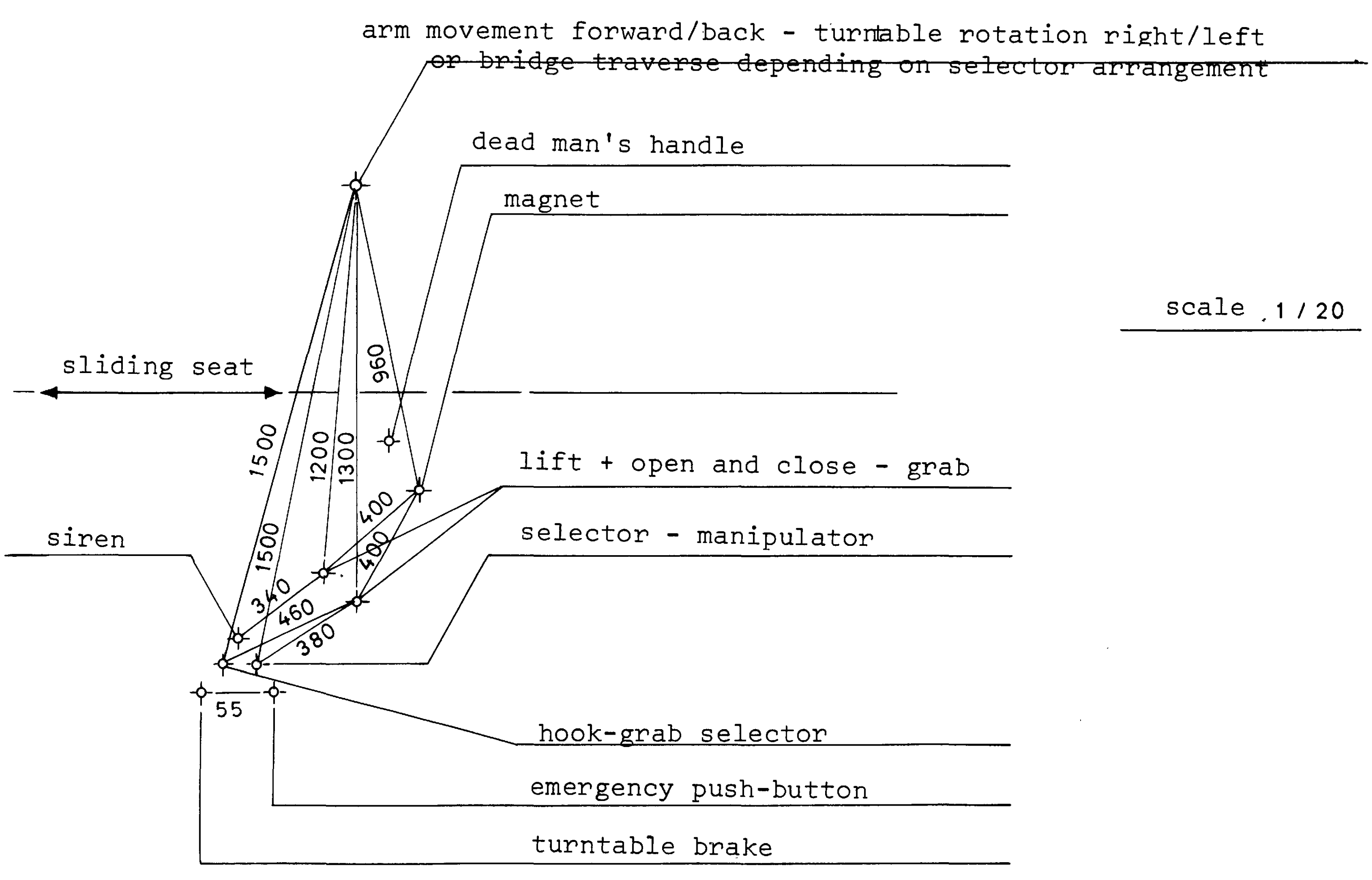
☐ operator standing



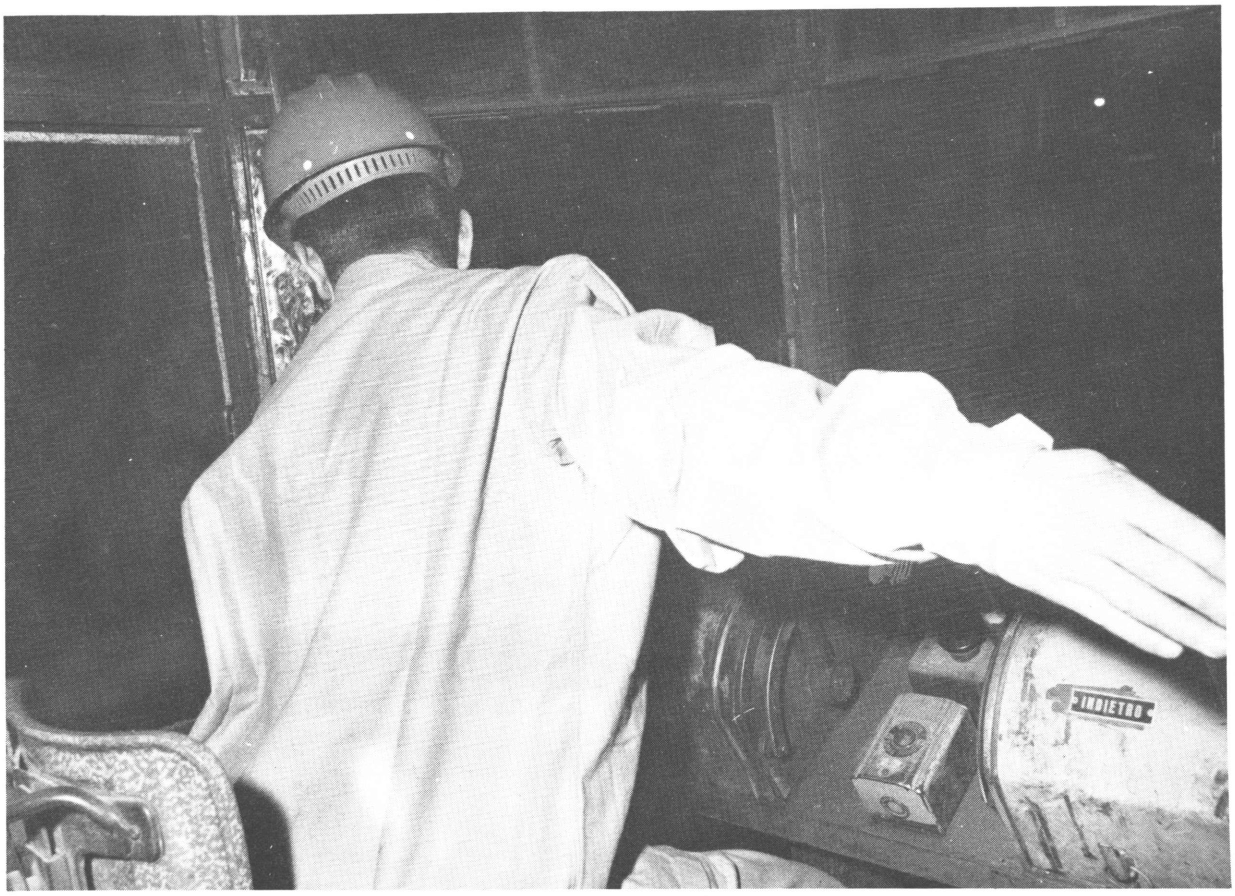
SB4 - SB3





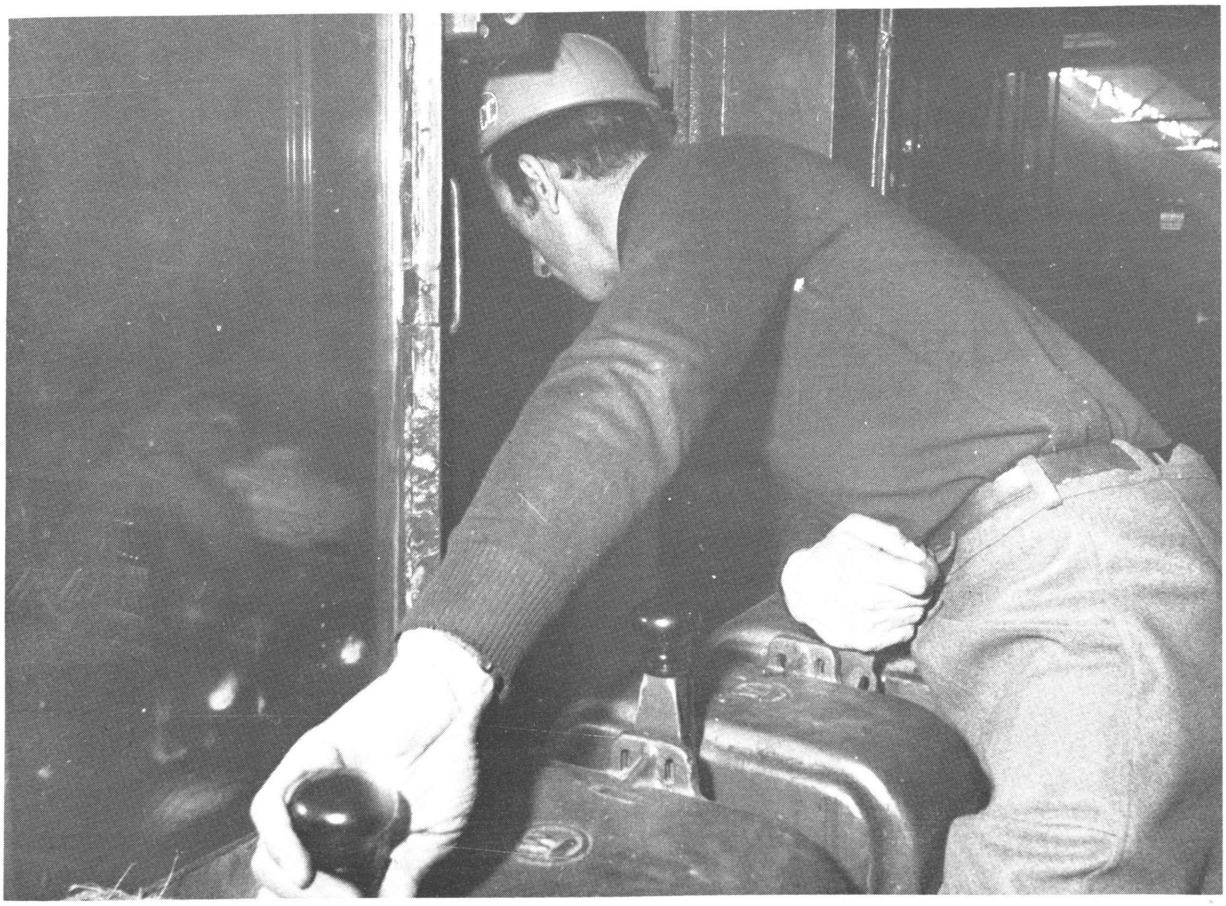


scale 1/20

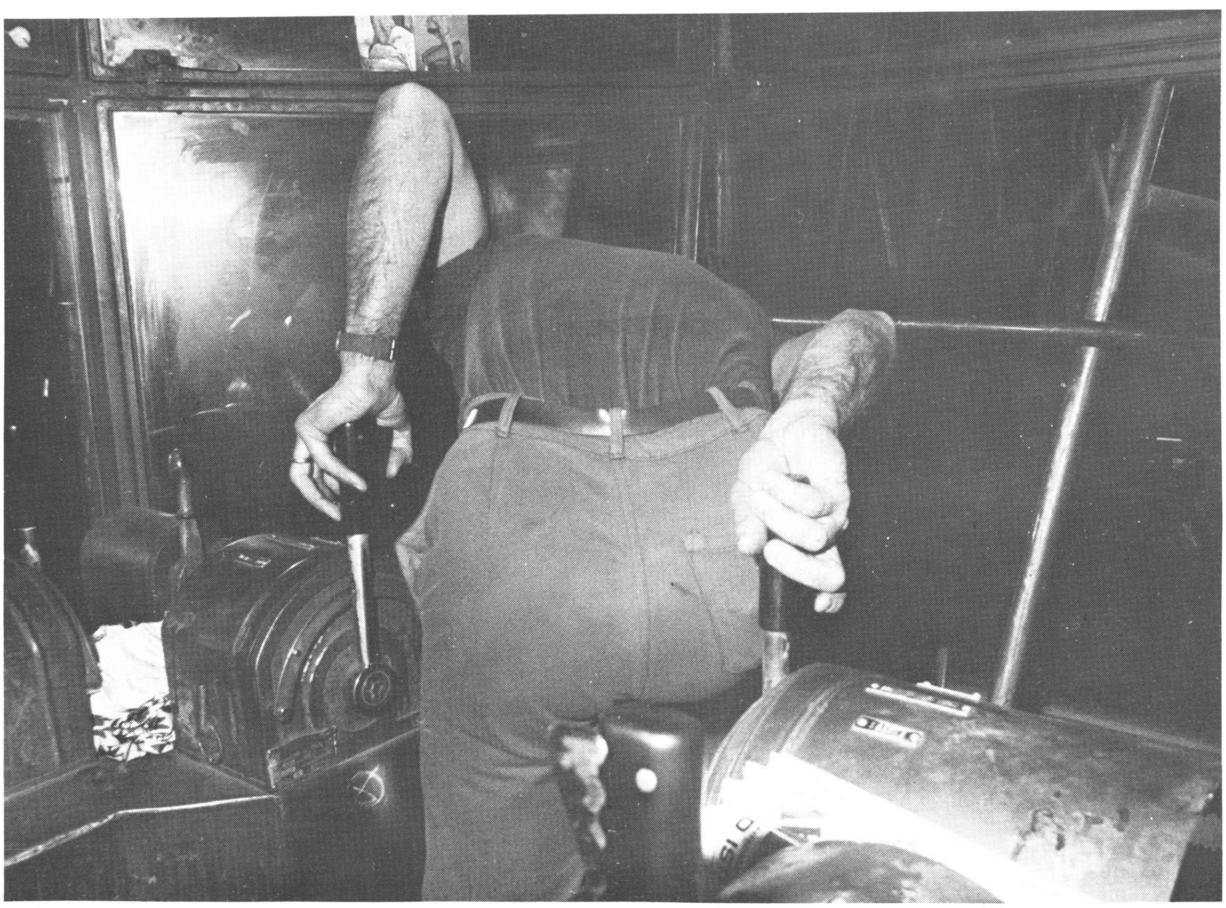


L G 3

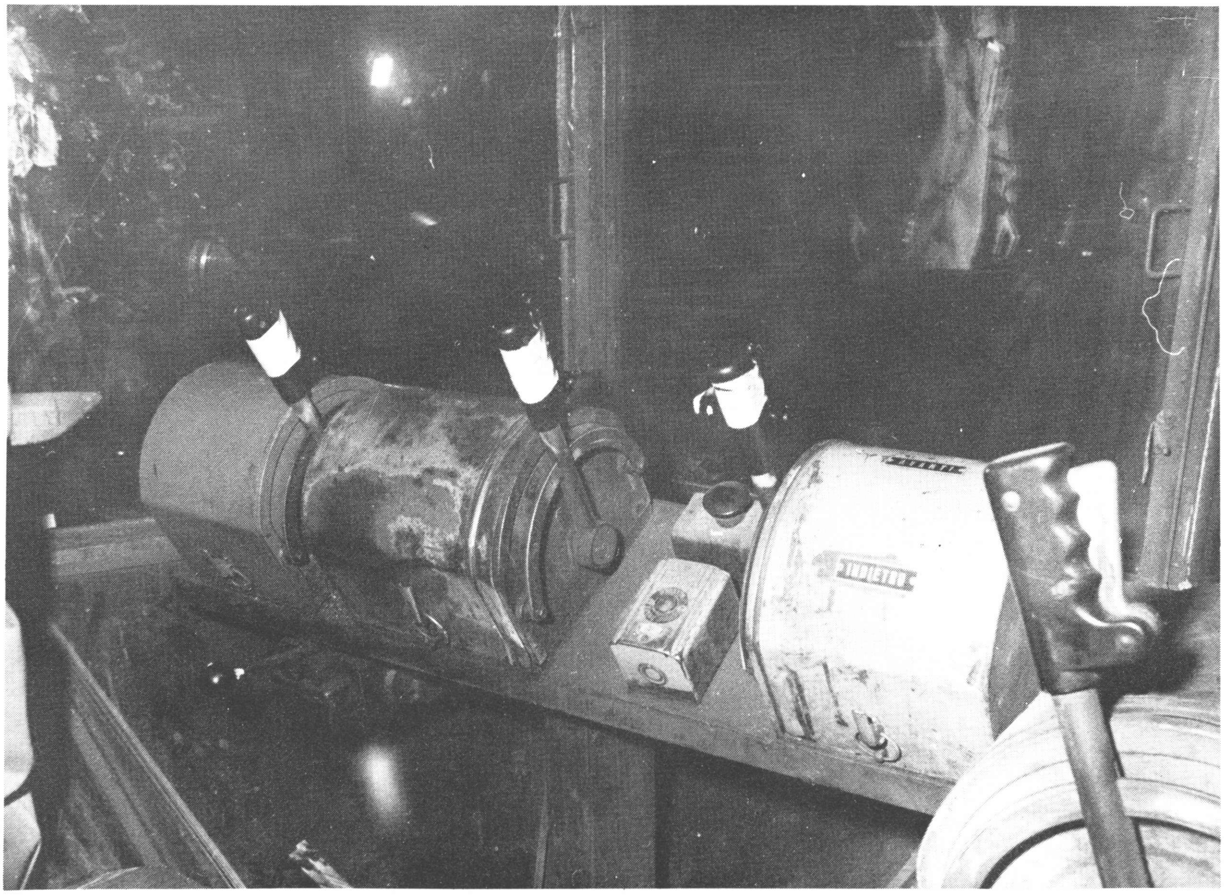
S B 3 - S B 4



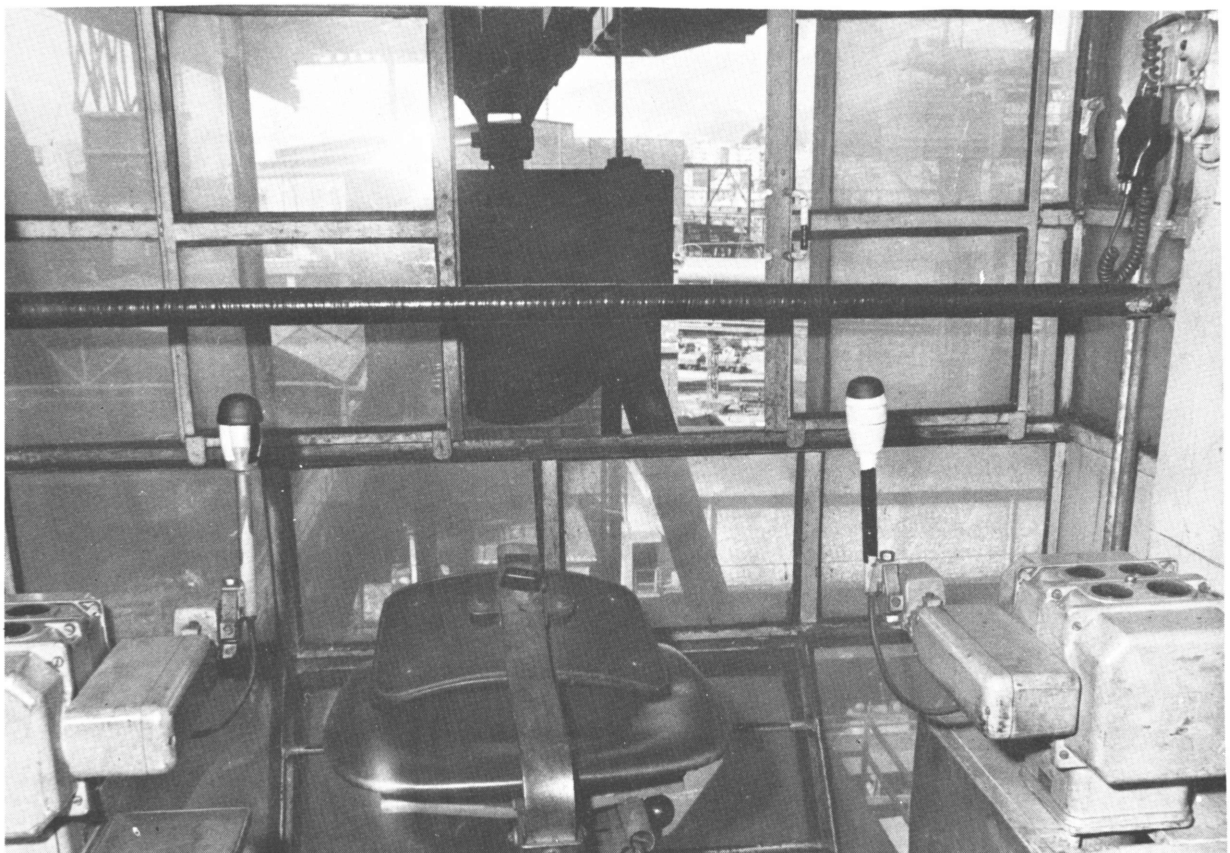
L G 3



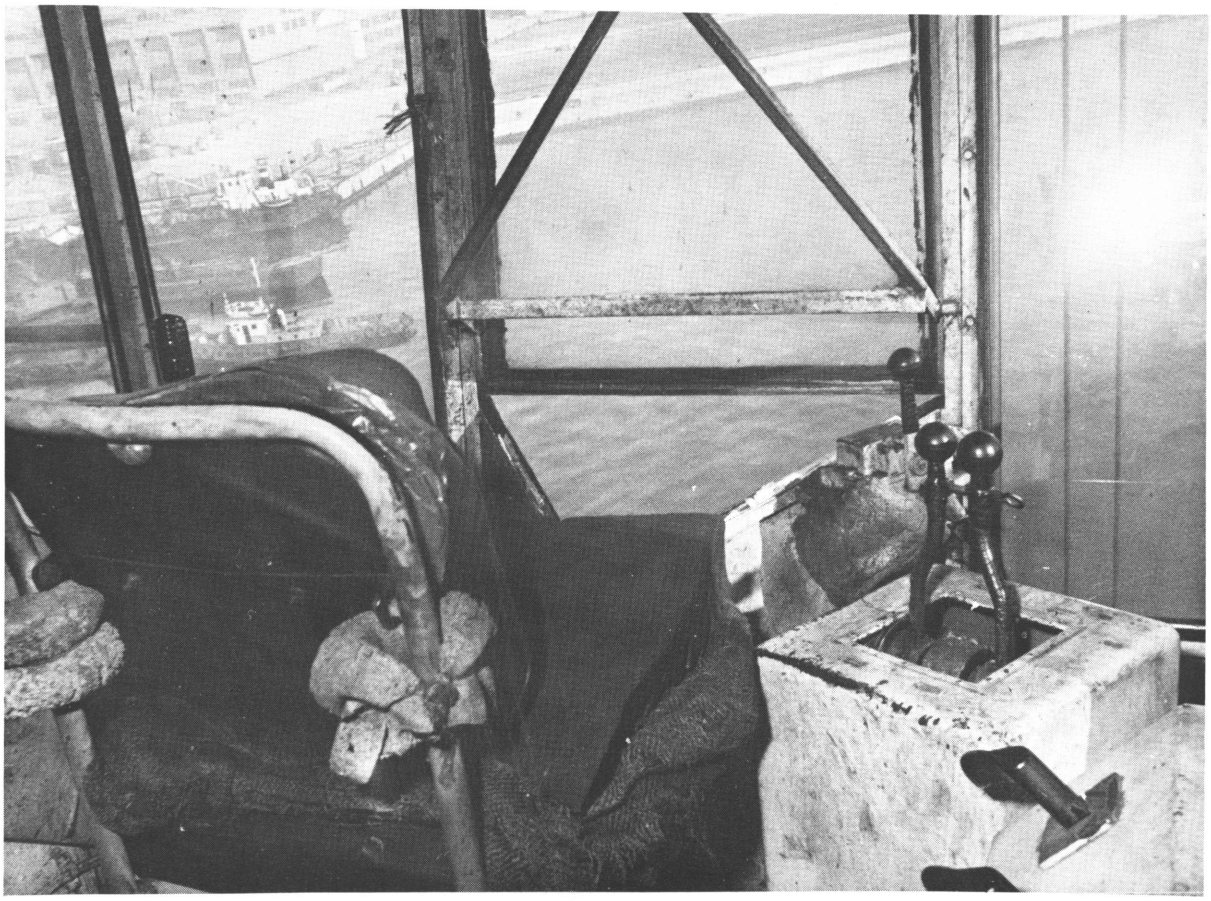
T C 1 - T F 1 - D R 1



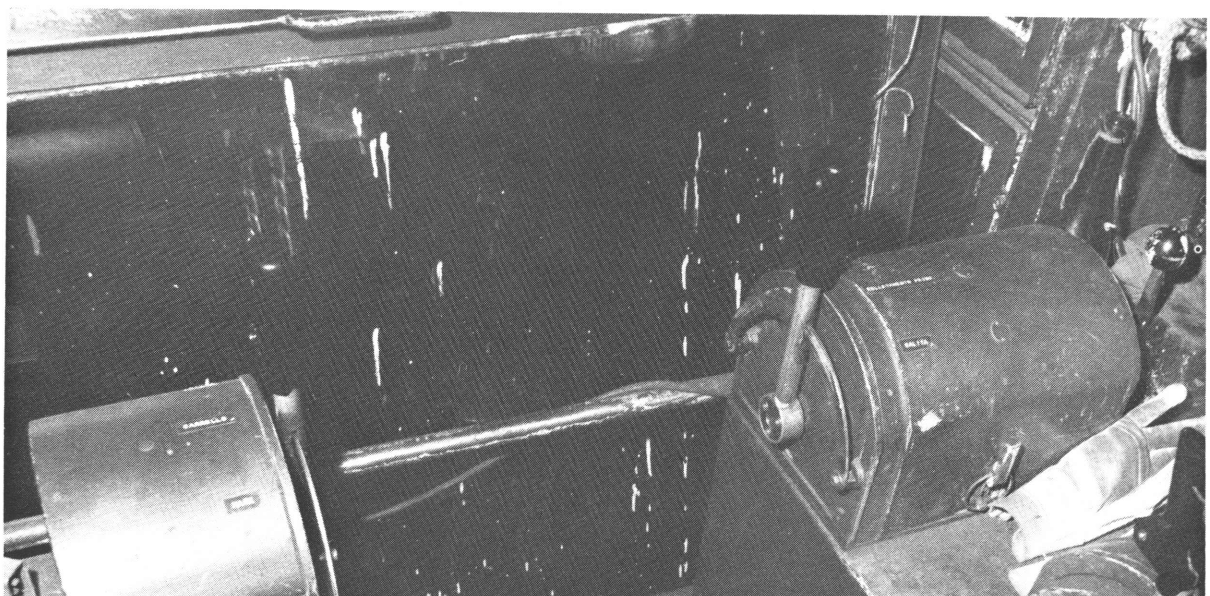
L G 3



Z O P P A



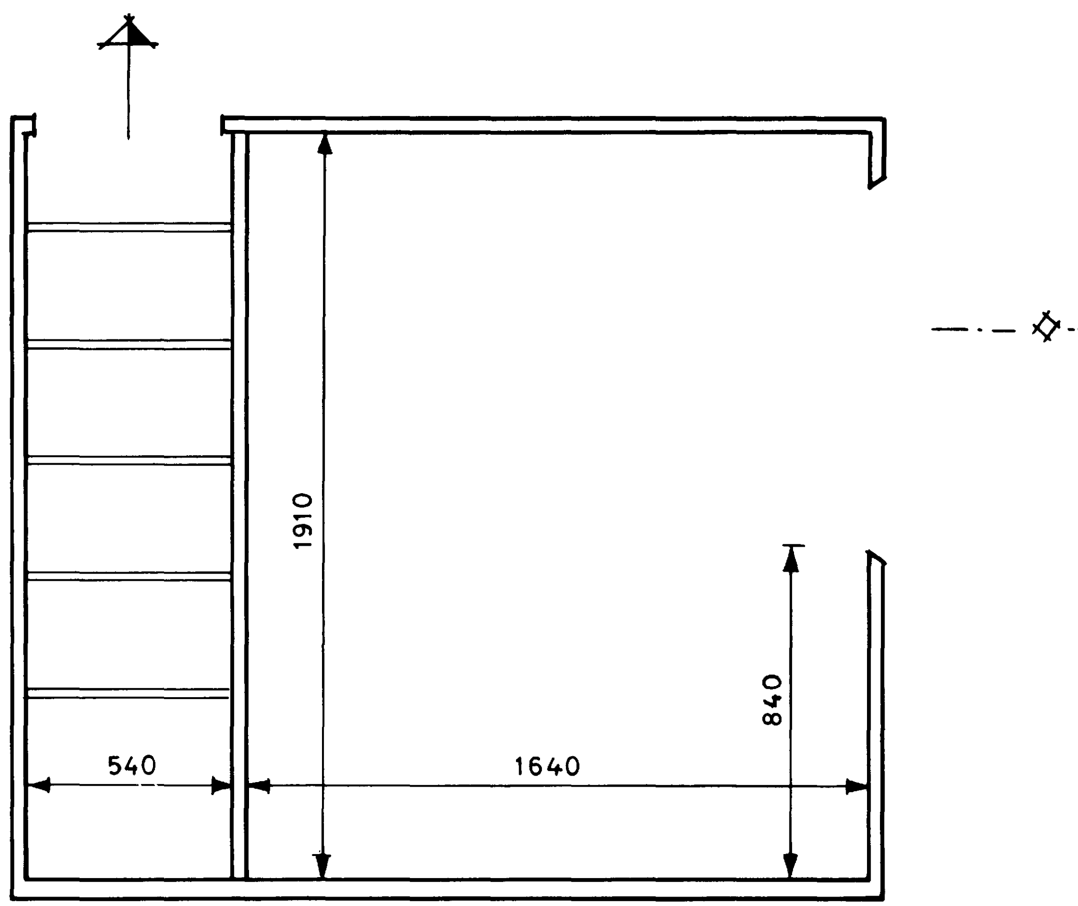
S B 3 - S B 4

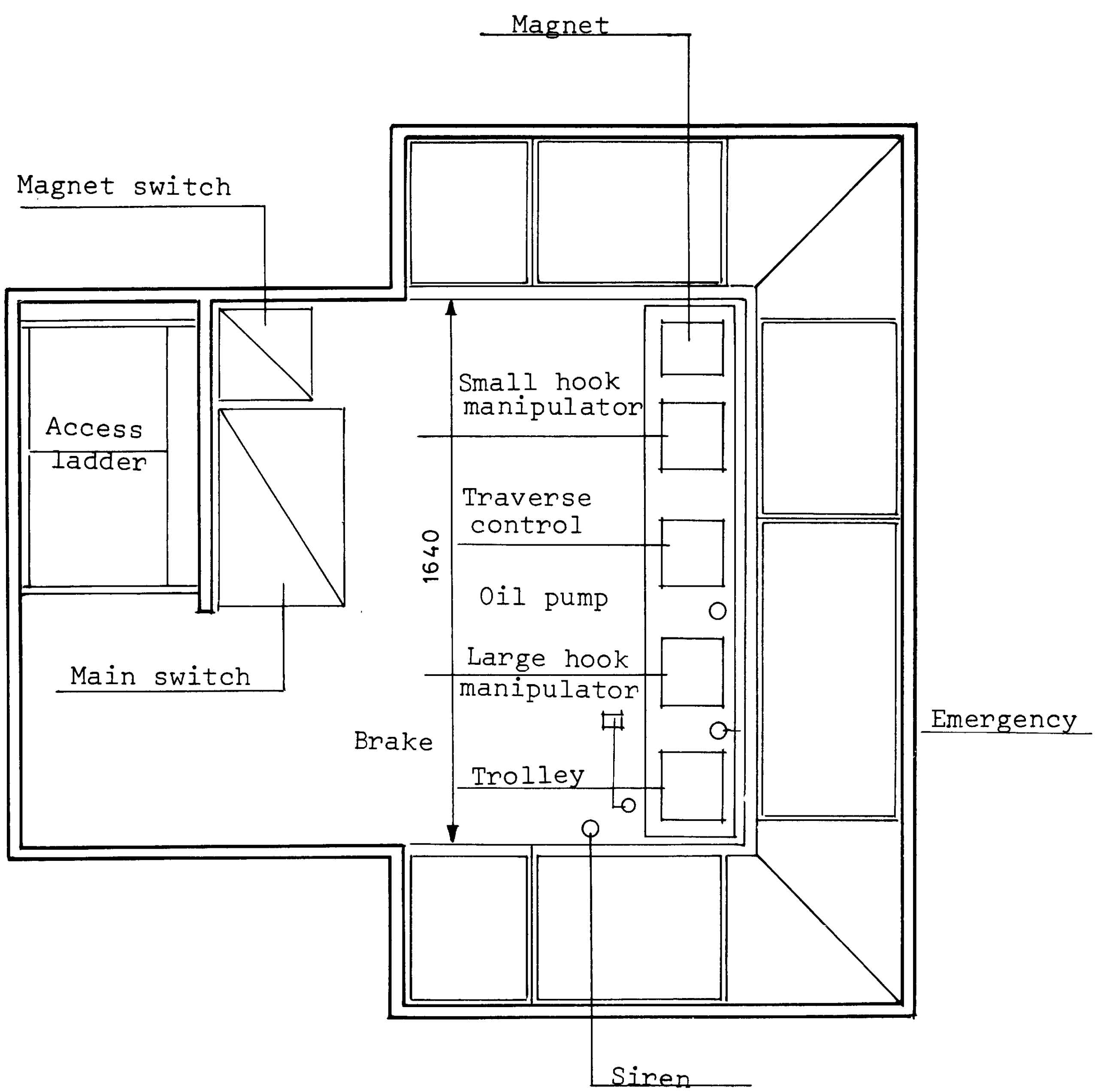


D B 2

LAYOUT OF EXISTING CAB

LG1-LG2





Magnet
Magnet switch
Access
ladder
Small hook
manipulator
Traverse
control
1640
Oil pump
Main switch
Large hook
manipulator
Emergency
Brake
Trolley
Siren

JOB DESCRIPTION

N.B. This description has been included to give a better idea of the plant and general functions with a view to determining the working sectors which the windows of the future cabin should face.

JOB DESCRIPTION

- Move ingot mould trolleys arriving from stripping plant.

  This operation is carried out with the magnet attached to an ingot mould because the train locomotive cannot cover the entire bay. At least two cranes are needed to move the train.

- Remove ingot moulds requiring maintenance (cracks, breakage, corrosion etc.) from incoming train. Appropriate information is given verbally or by hand signals to the crane driver by the operator responsible for ingot mould preparation. After a final decision by the supervisor, rejected ingot moulds are placed on the scrap metal trolleys located at the end of the bay. The ingot moulds are removed with two different attachments:

  - "beam" to raise normal ingot moulds;
  - "piston" to raise cylinder-type ingot moulds.

- Internal cleaning of ingot moulds.

  This operation is effected with a metal brush matching the mould type; the crane driver takes the brushes from a store. The operation consists in inserting the brush in the mould and moving it up and down repeatedly.

- Cleaning the edge of the ingot mould with the magnet.
- Transporting clean ingot moulds to the store or onto clean plates.
- Removing and replacing in store magnets, beams, brushes and pistons.
- Connecting the magnet plug.

  For this operation, the crane driver moves the magnet to the walkway of the ingot mould preparation operator who inserts the plug.
- Cleaning plates with magnet.
- Cleaning trolleys with magnet.
- Cleaning bay with magnet.
- Removing ingot waste and loading on scrap metal trucks.
- Loading new plates on trucks.
- Positioning plates away from work station.
- Ingot moulds containing ingot waste are conveyed to the burner operator who separates the waste with a long cutting torch.
- Conveying new ingot moulds on heat treatment trolleys.

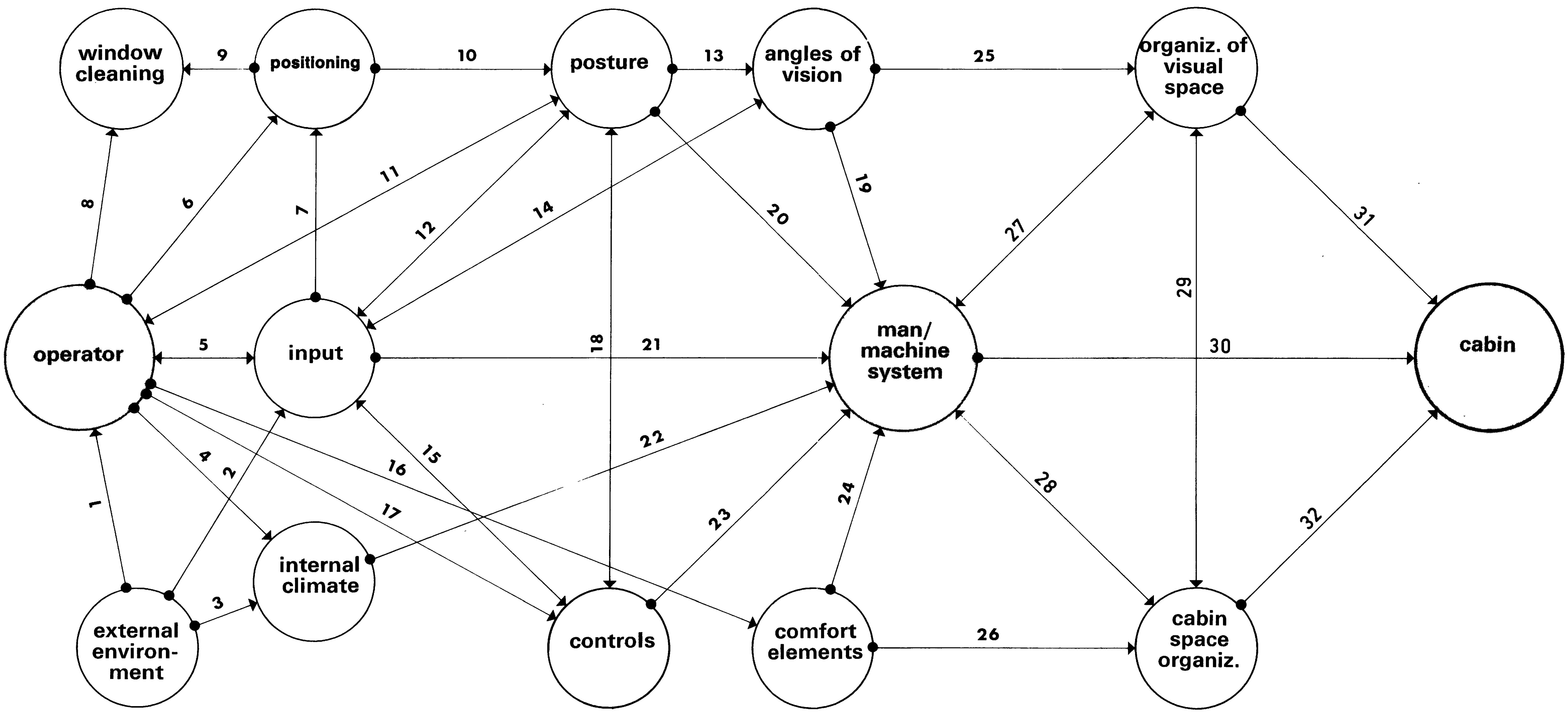
  This operation is carried out by LG 1. LG 1 is also responsible for depositing along the bay the gauge strips to be inserted in the ingot moulds.

- Loading ingot moulds on trolleys to form the train based on the ACC. tapping programme, following instructions given by supervisor.

- Supply of aluminium to hopper for casting pit.

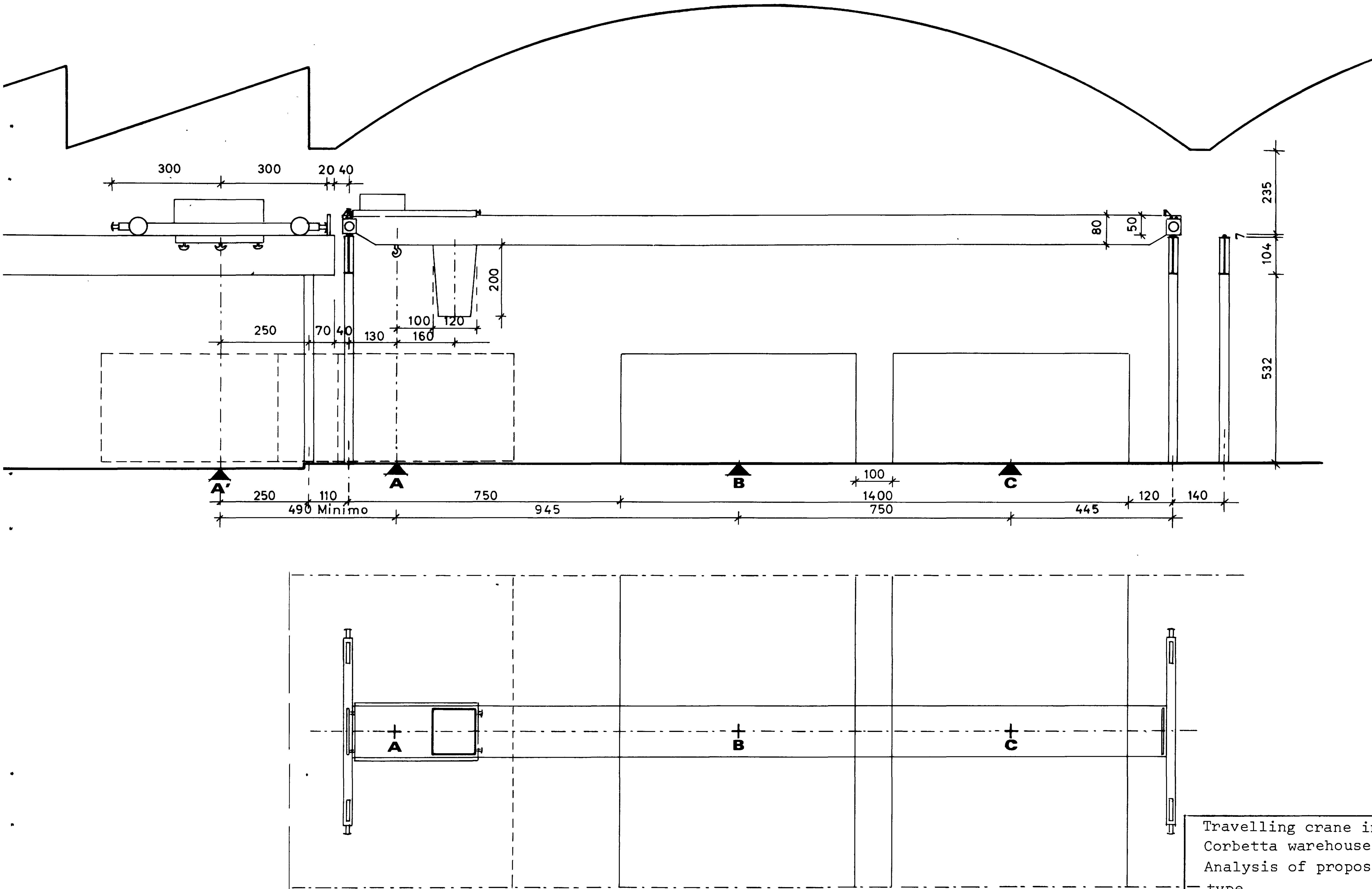
DESIGN MODEL

DESIGN MODEL FOR CABINS LG1 - LG2



ANNEX N. 8

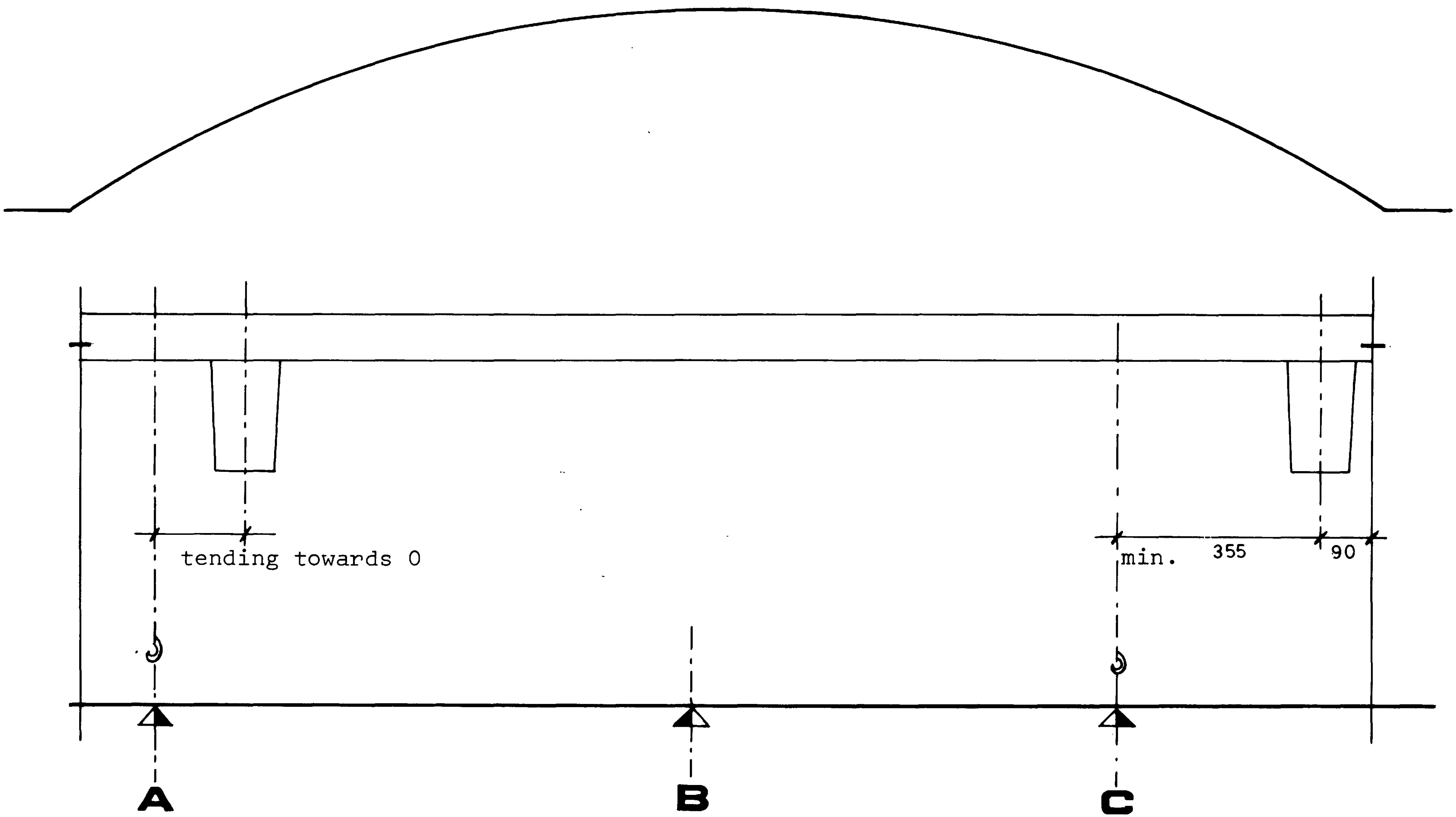
DESIGN OF TRAVELLING CRANE FOR COLD WORKED TUBE WAREHOUSE



Travelling crane in
Corbetta warehouse.
Analysis of proposed
type.

Plan and sectional views

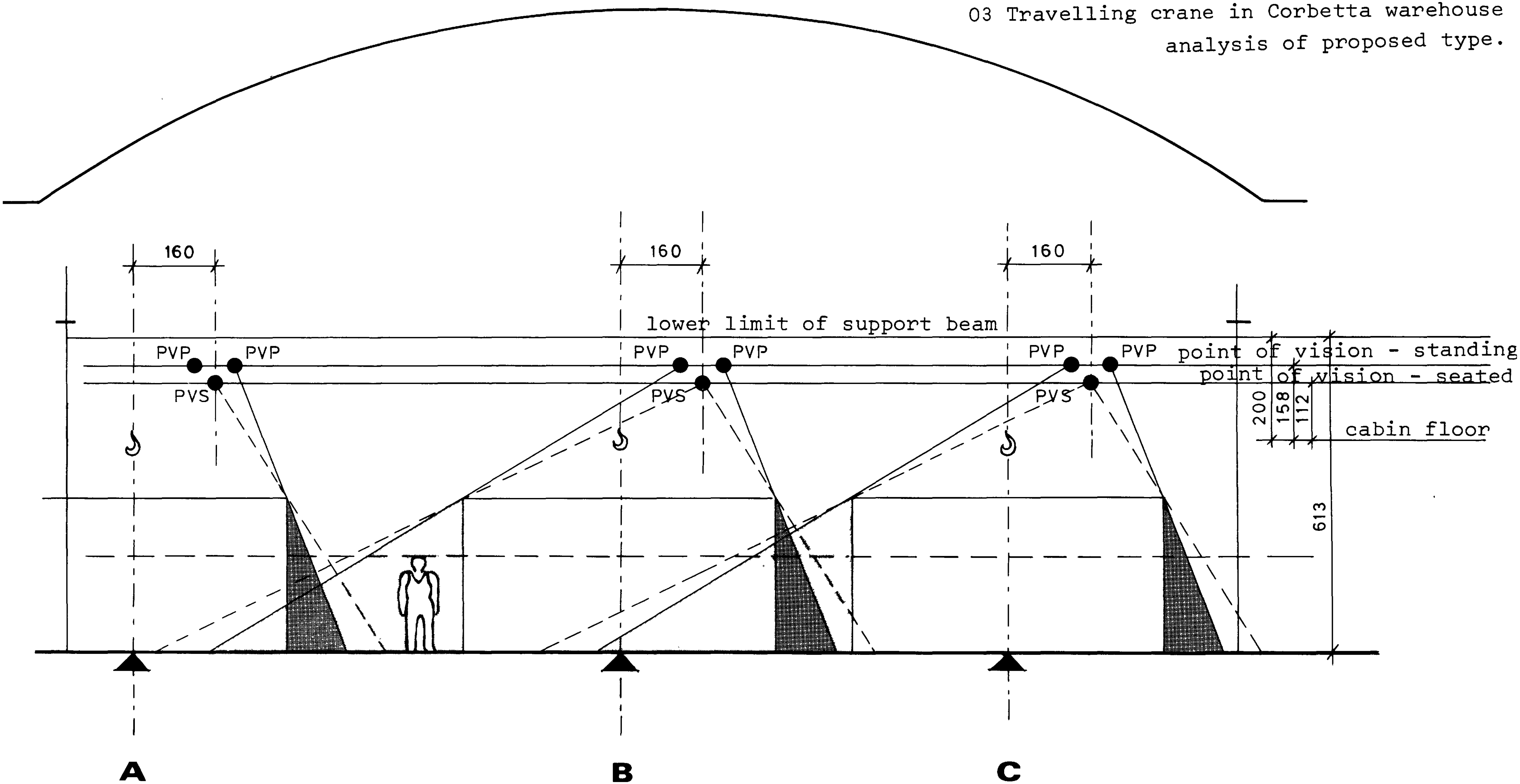
Scale 1:50 1450 01



02 Travelling crane in Corbetta warehouse.
Analysis of proposed type.

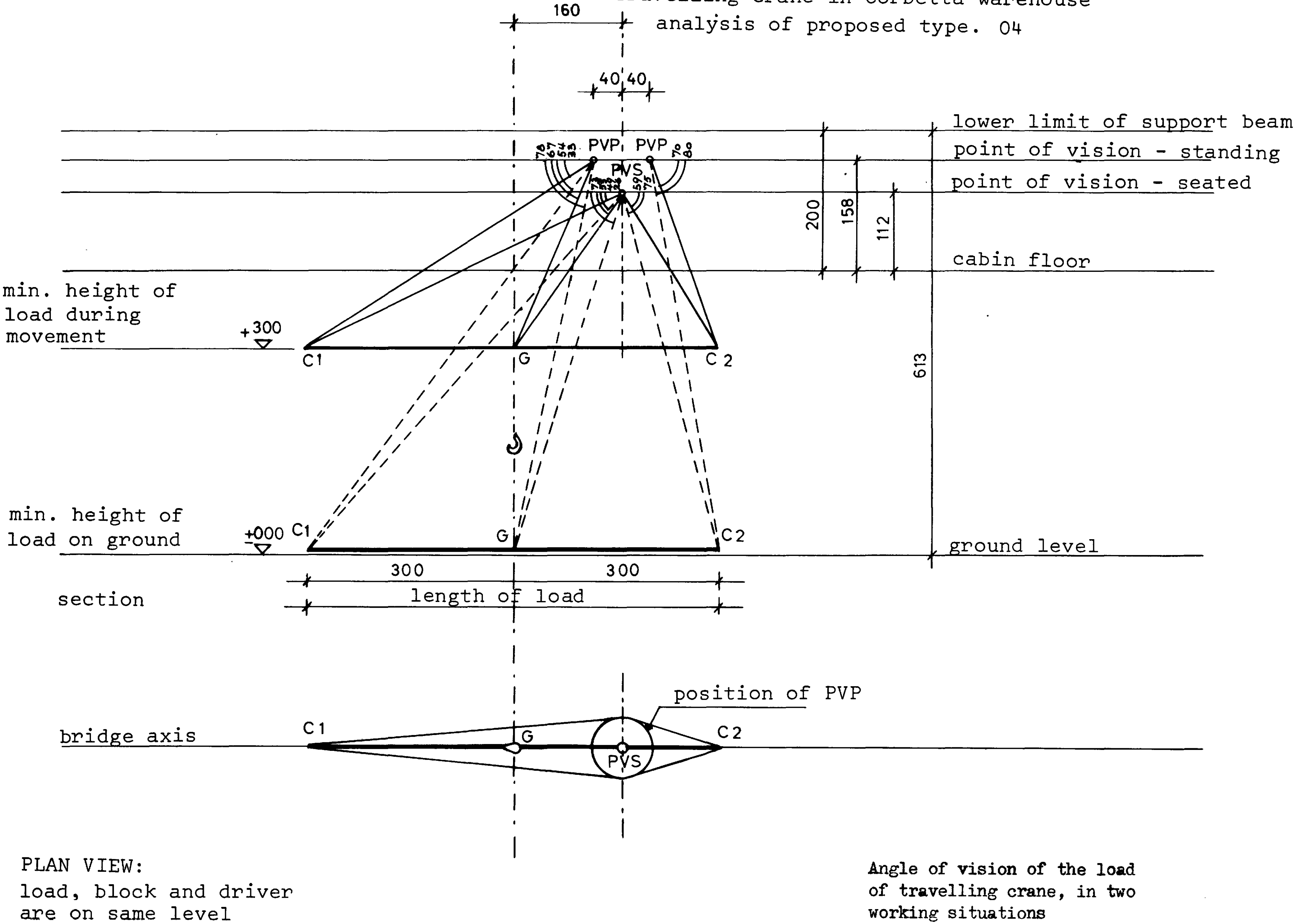
EVALUATION OF MIN. AND MAX.
DISTANCE BETWEEN BLOCK AND CABIN
AS A FUNCTION OF LAYOUT.

03 Travelling crane in Corbetta warehouse
analysis of proposed type.



ZONES VISIBLE AND INVISIBLE DURING OPERATIONS AT A (MOBILE STORAGE UNIT), B AND C (FIXED STORAGE UNITS°.

Travelling crane in Corbetta warehouse
analysis of proposed type. 04



Angle of vision of the load of travelling crane, in two working situations

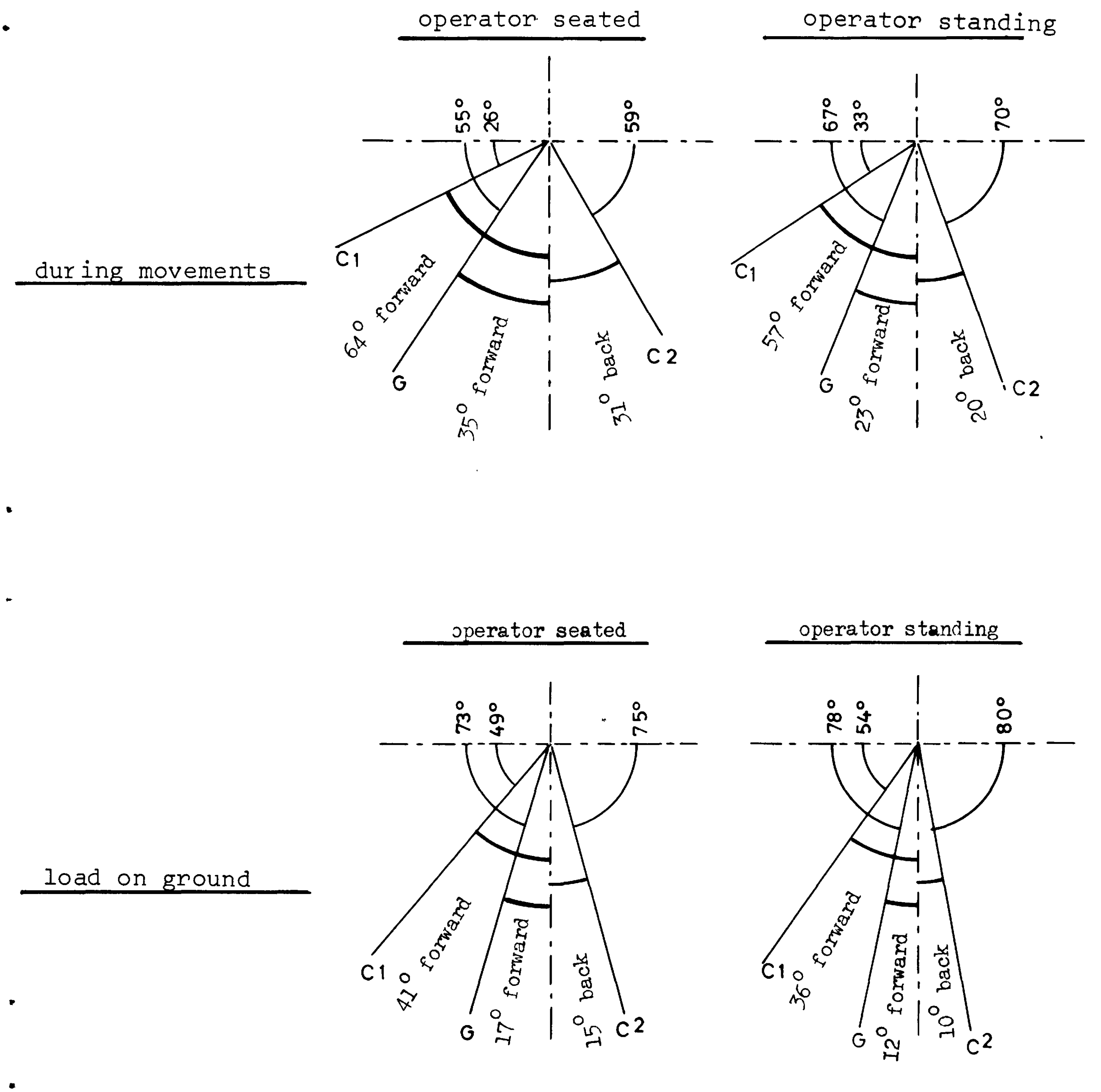
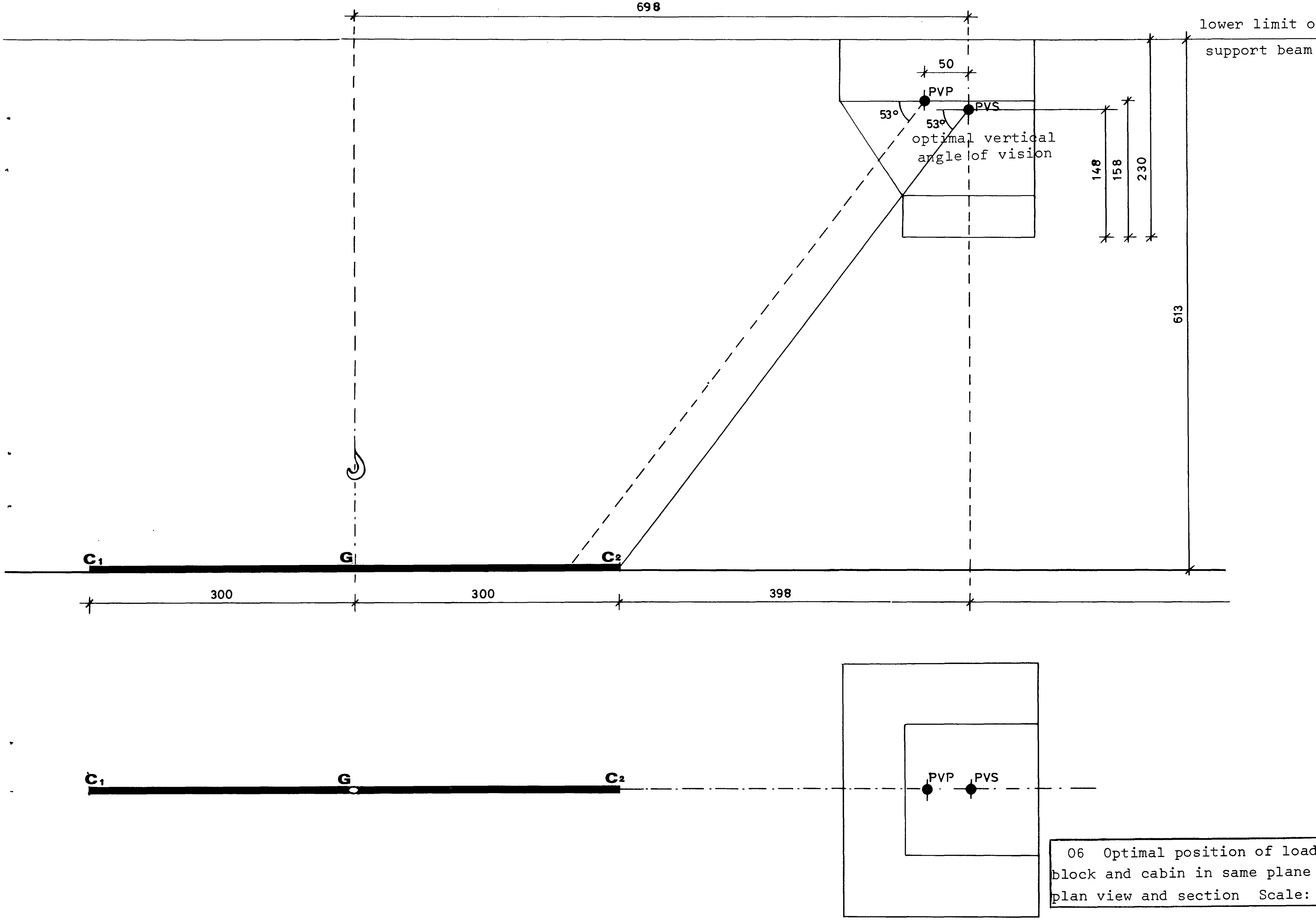
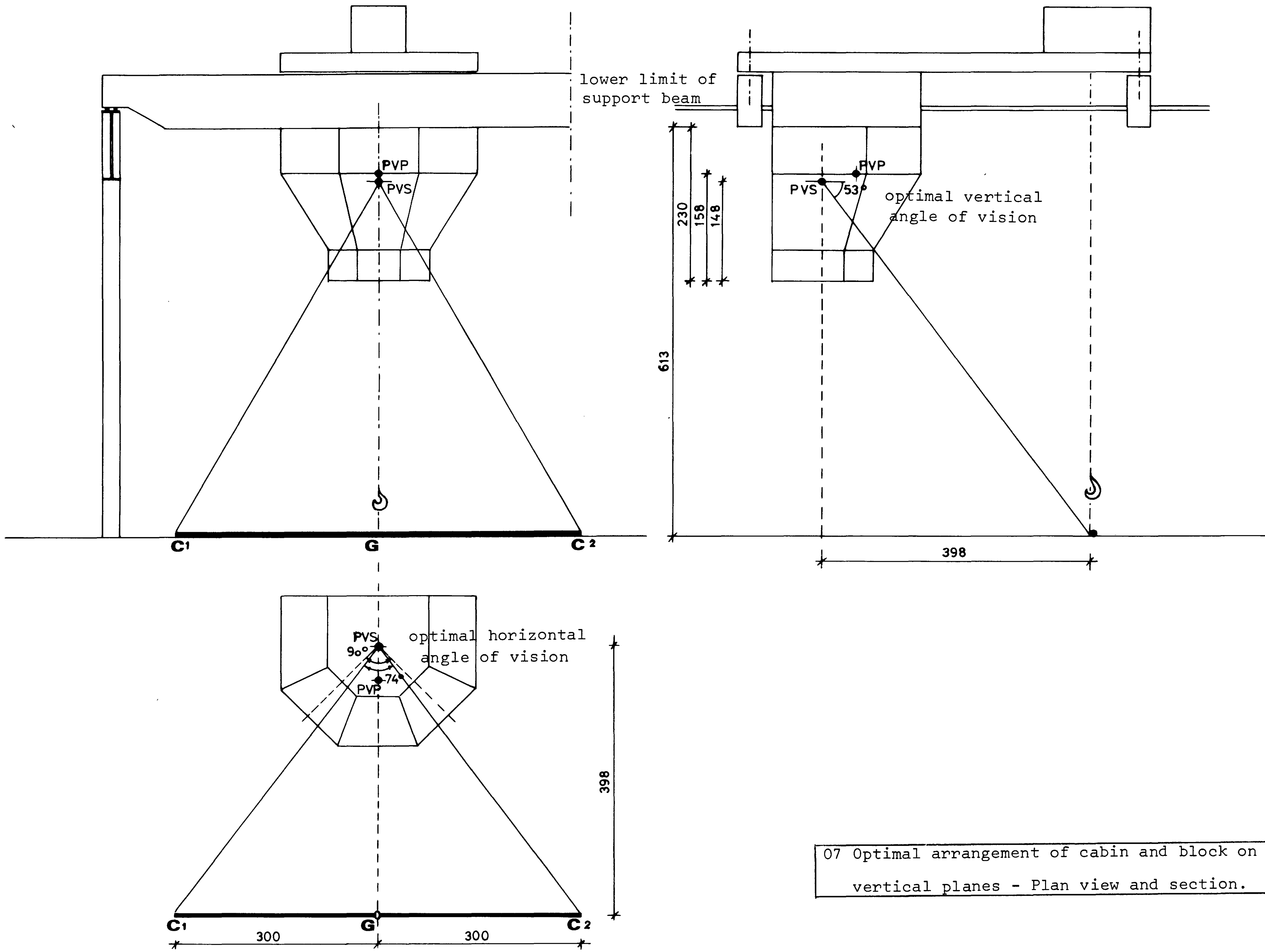


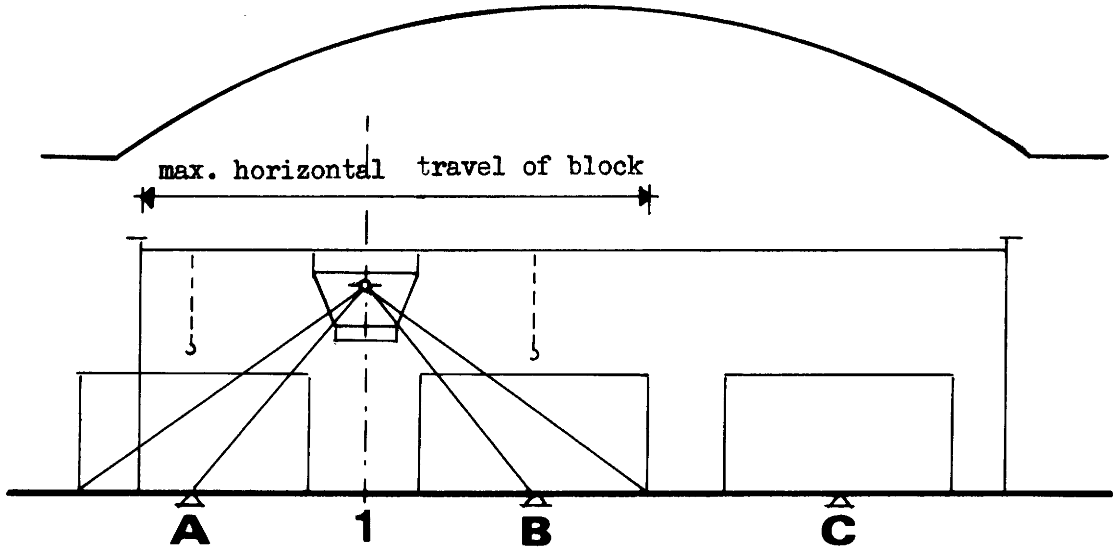
diagram summarizing angles of vision in two working situations and with operator seated or standing



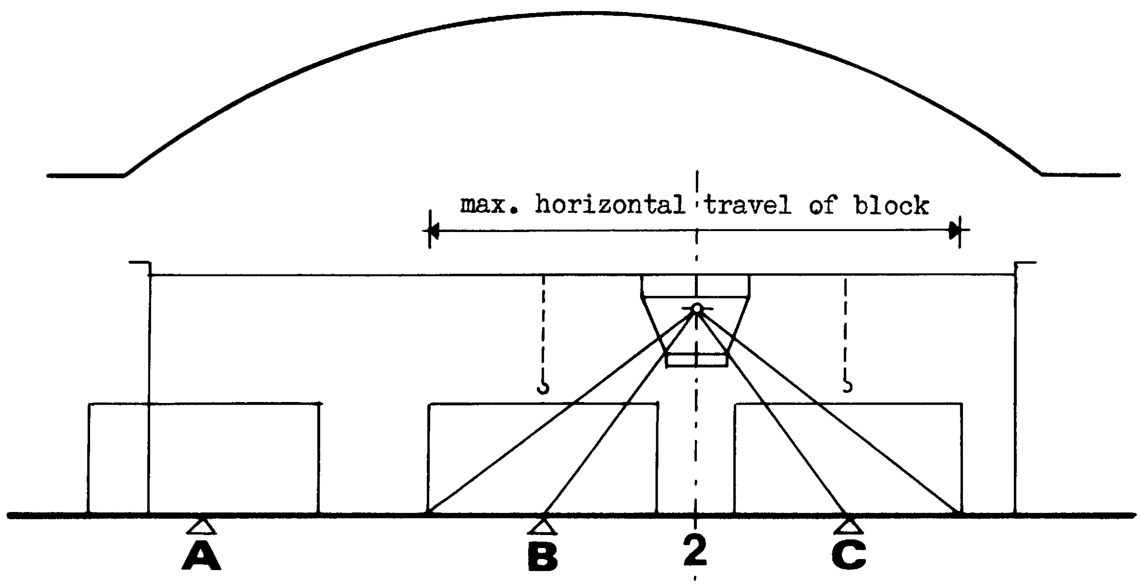
06 Optimal position of load, block and cabin in same plane plan view and section Scale: 1:20



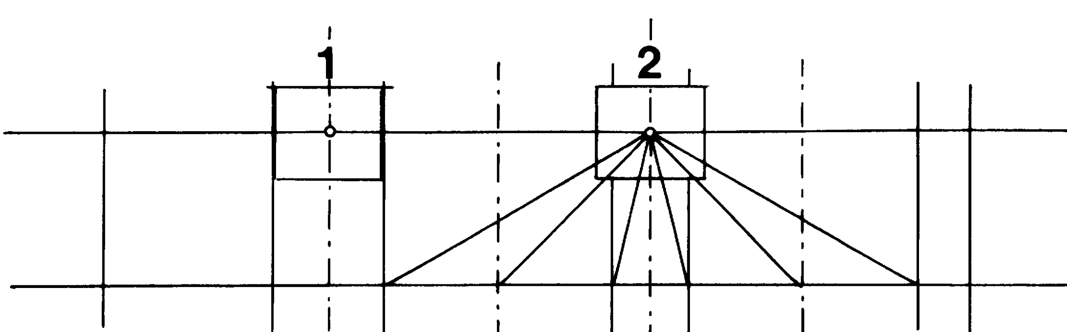
07 Optimal arrangement of cabin and block on different vertical planes - Plan view and section. Scale 1:20



stowing tubes from production line



loading motor vehicles

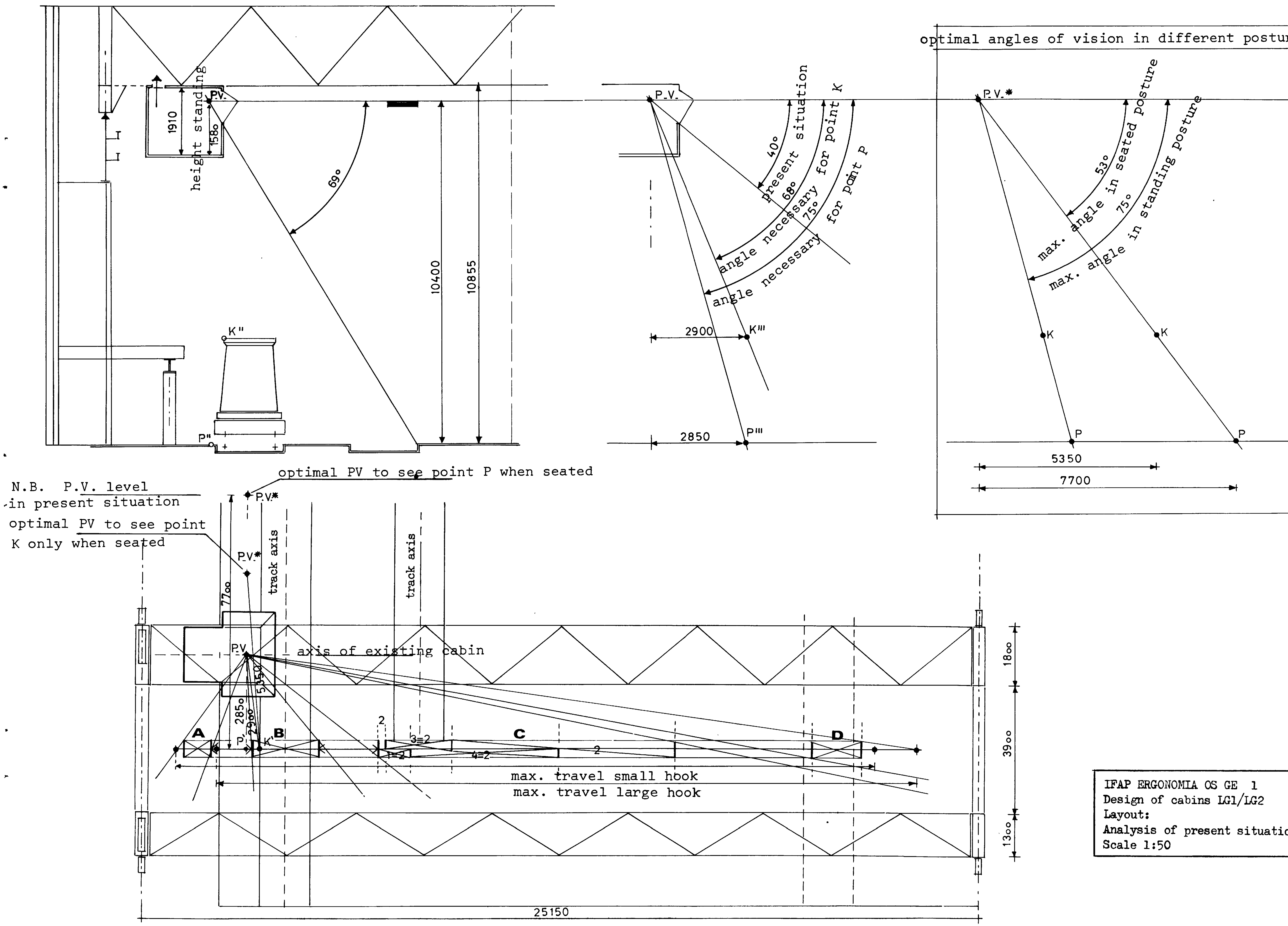


plan

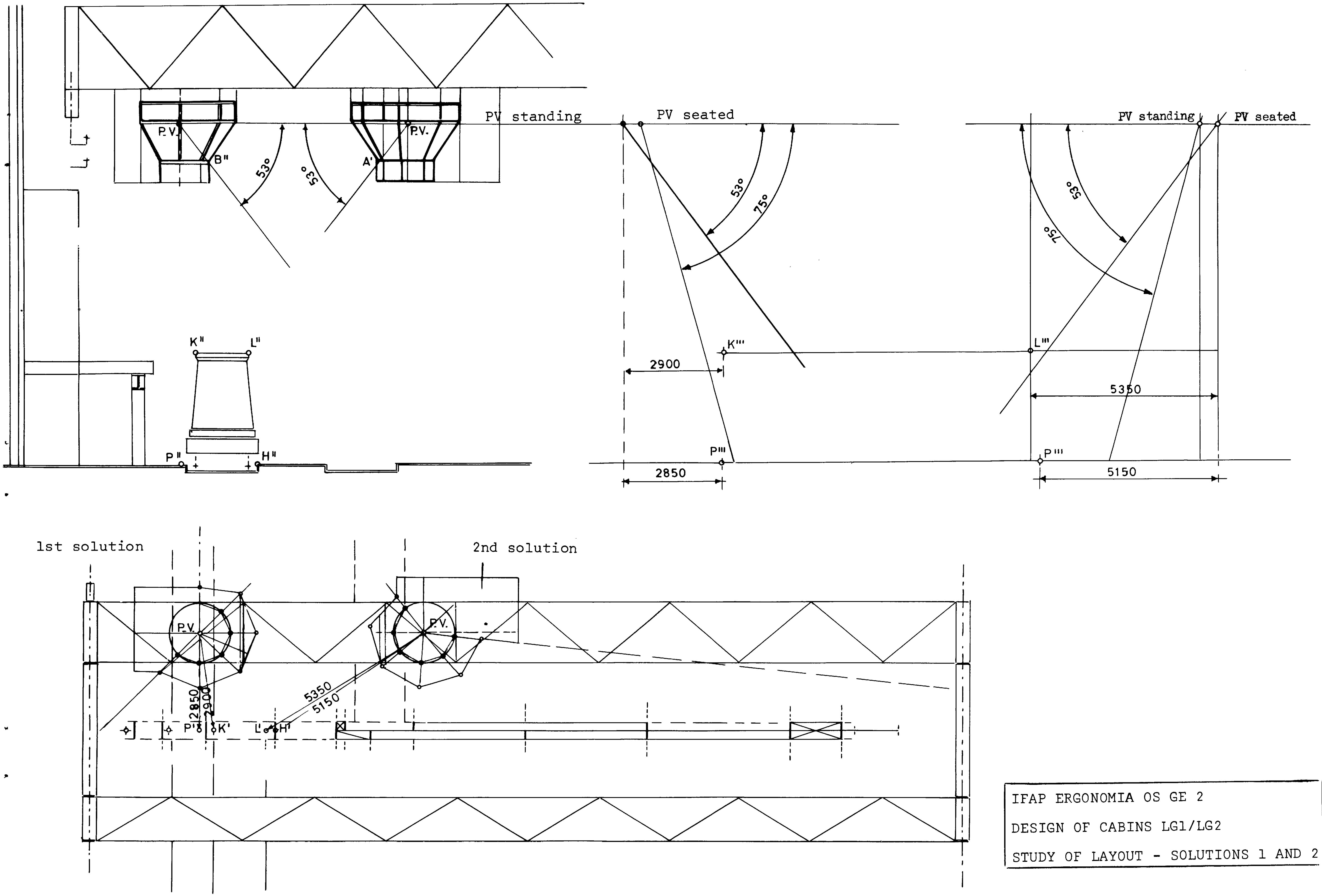
Q8 Travelling crane in Corbetta warehouse

- Final proposal -

D R A W I N G S



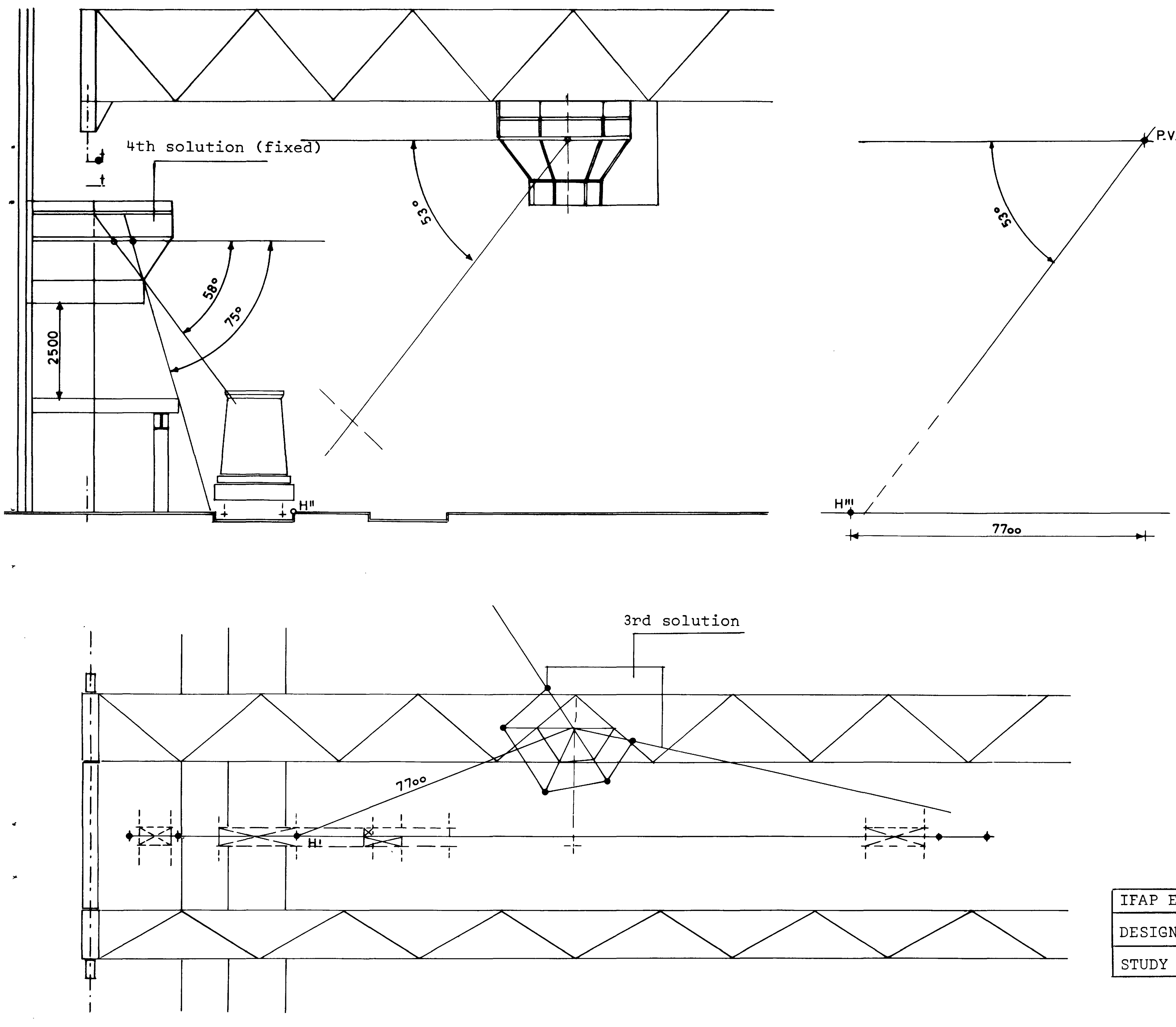
IFAP ERGONOMIA OS GE 1
Design of cabins LG1/LG2
Layout:
Analysis of present situation
Scale 1:50



IFAP ERGONOMIA OS GE 2

DESIGN OF CABINS LG1/LG2

STUDY OF LAYOUT - SOLUTIONS 1 AND 2

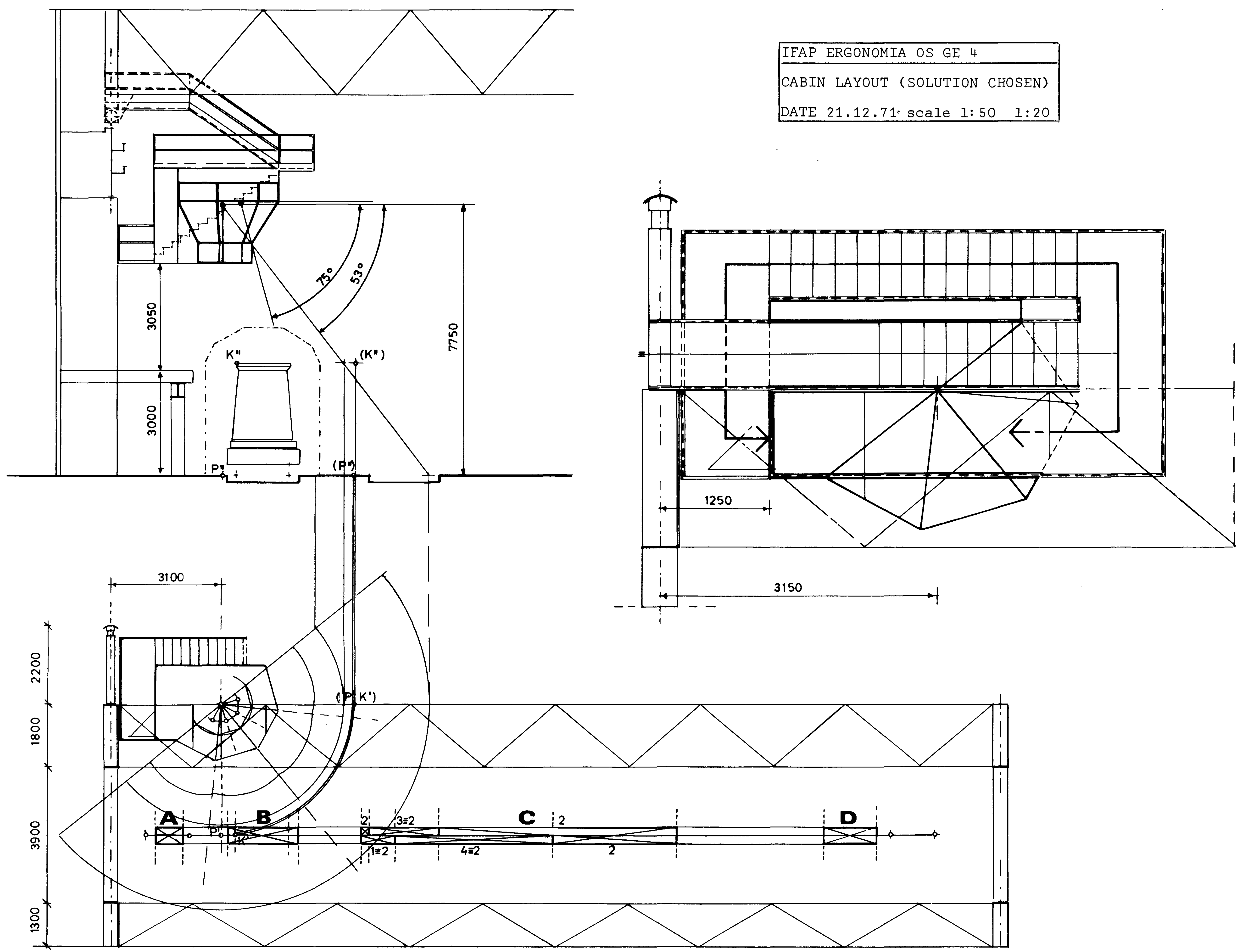


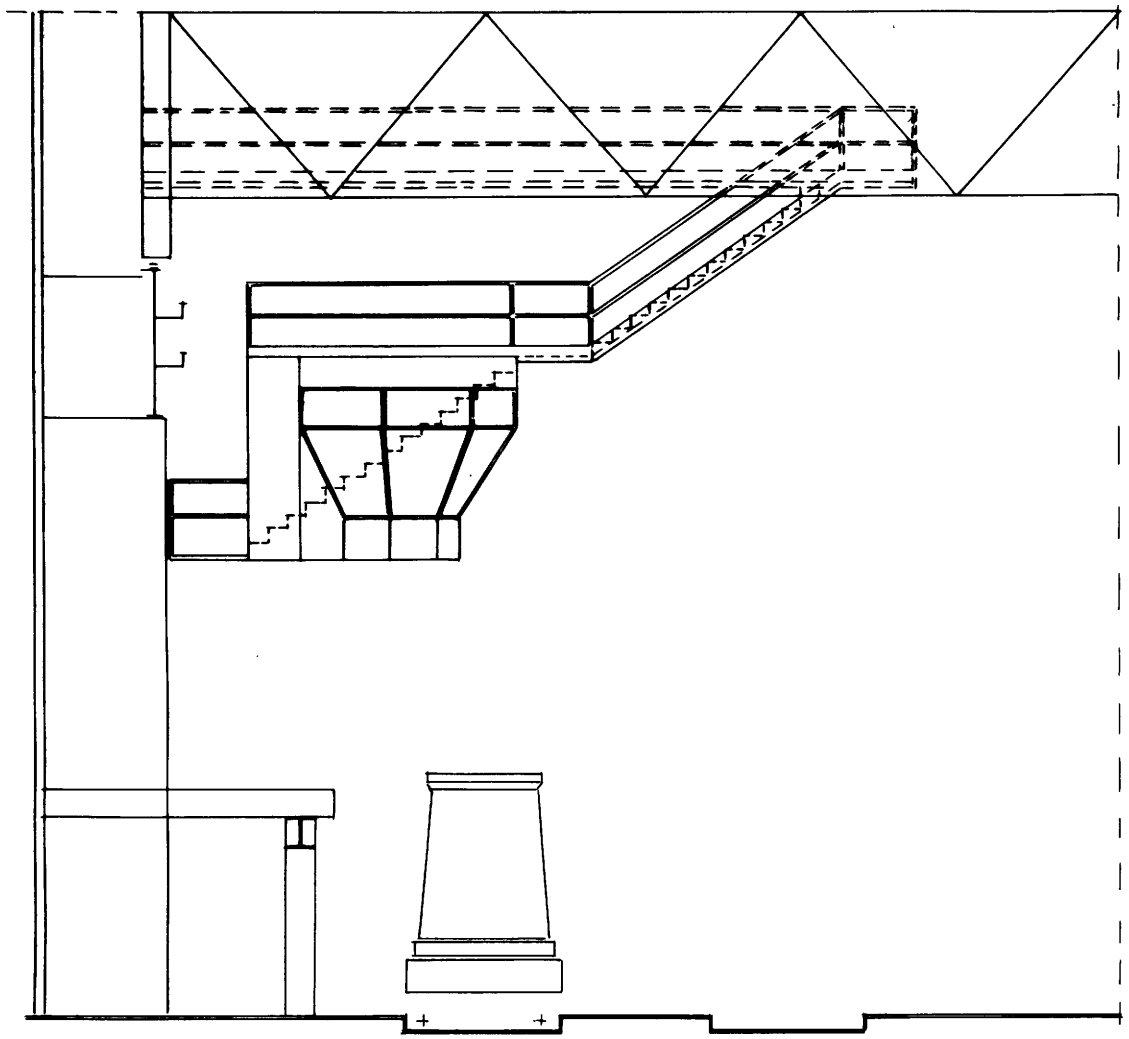
IFAP ERGONOMIA OS GE 3
DESIGN OF CABINS LG1/LG2 - 1/50 -
STUDY OF LAYOUT - SOLUTIONS 3 AND 4

IFAP ERGONOMIA OS GE 4

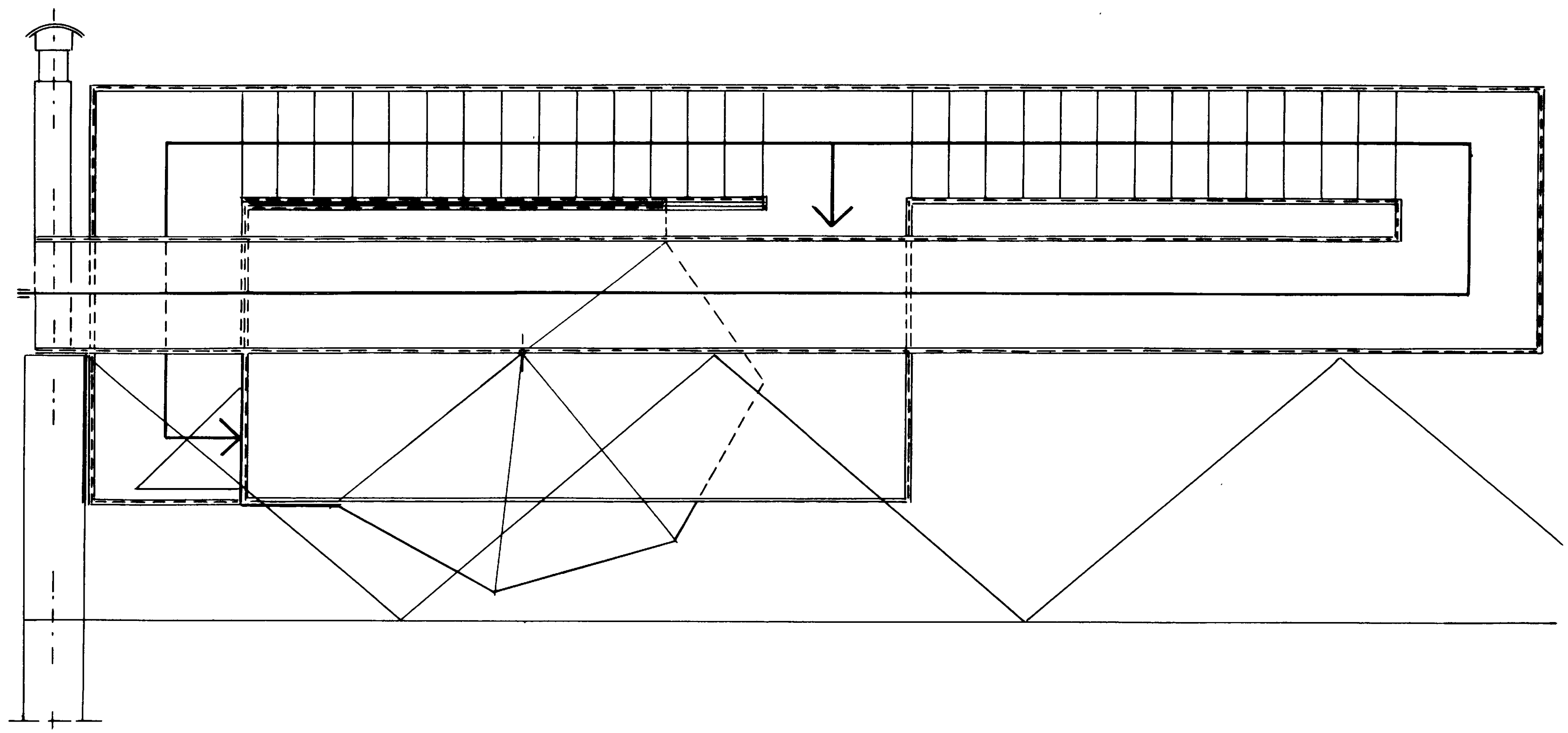
CABIN LAYOUT (SOLUTION CHOSEN)

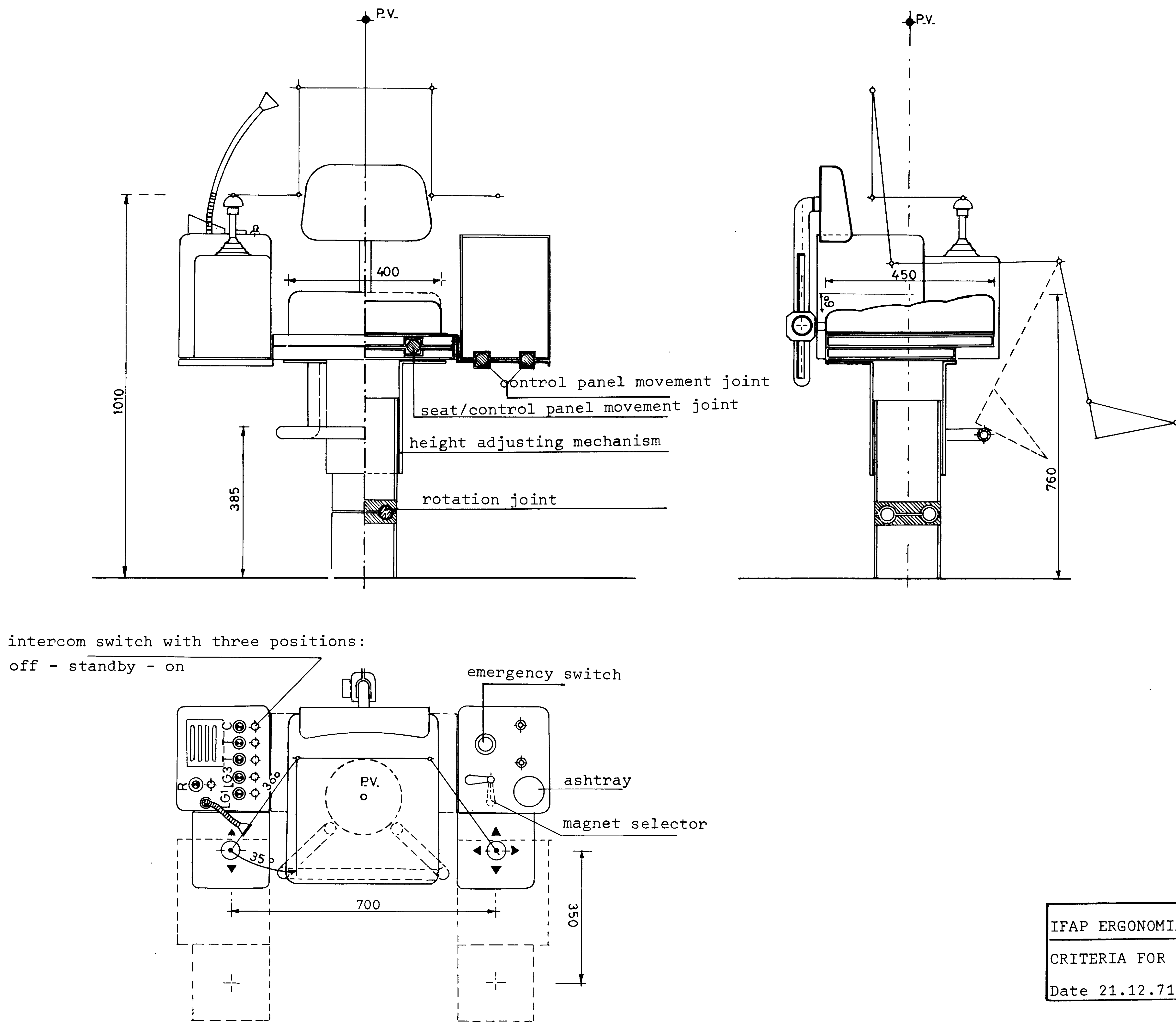
DATE 21.12.71 scale 1:50 1:20



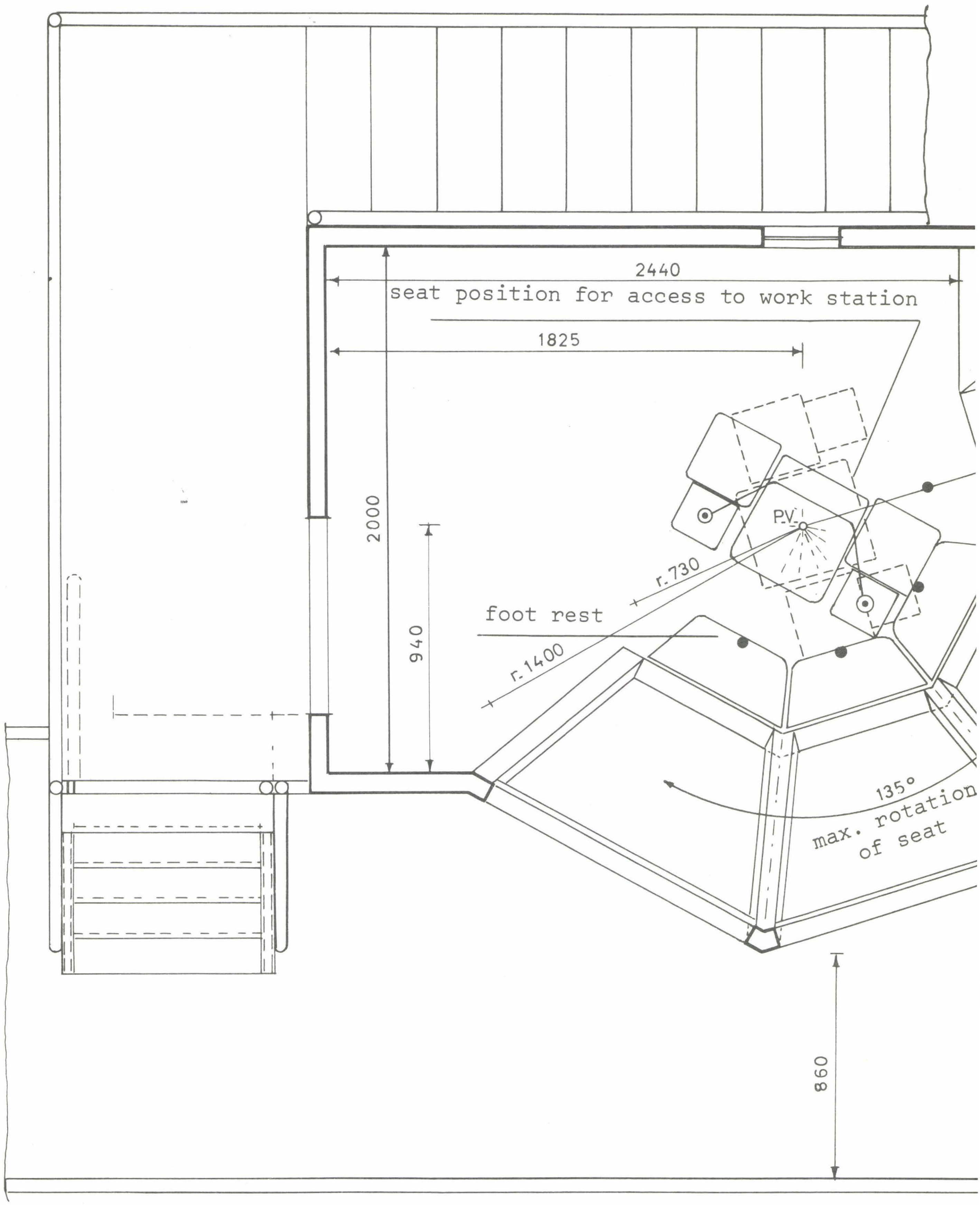


IFAP ERGONOMIA OS GE 5
ACCESSIBILITY - ALTERNATIVE TO DRAWING 4
DATE 21.12.71 scale 1:50 1:20

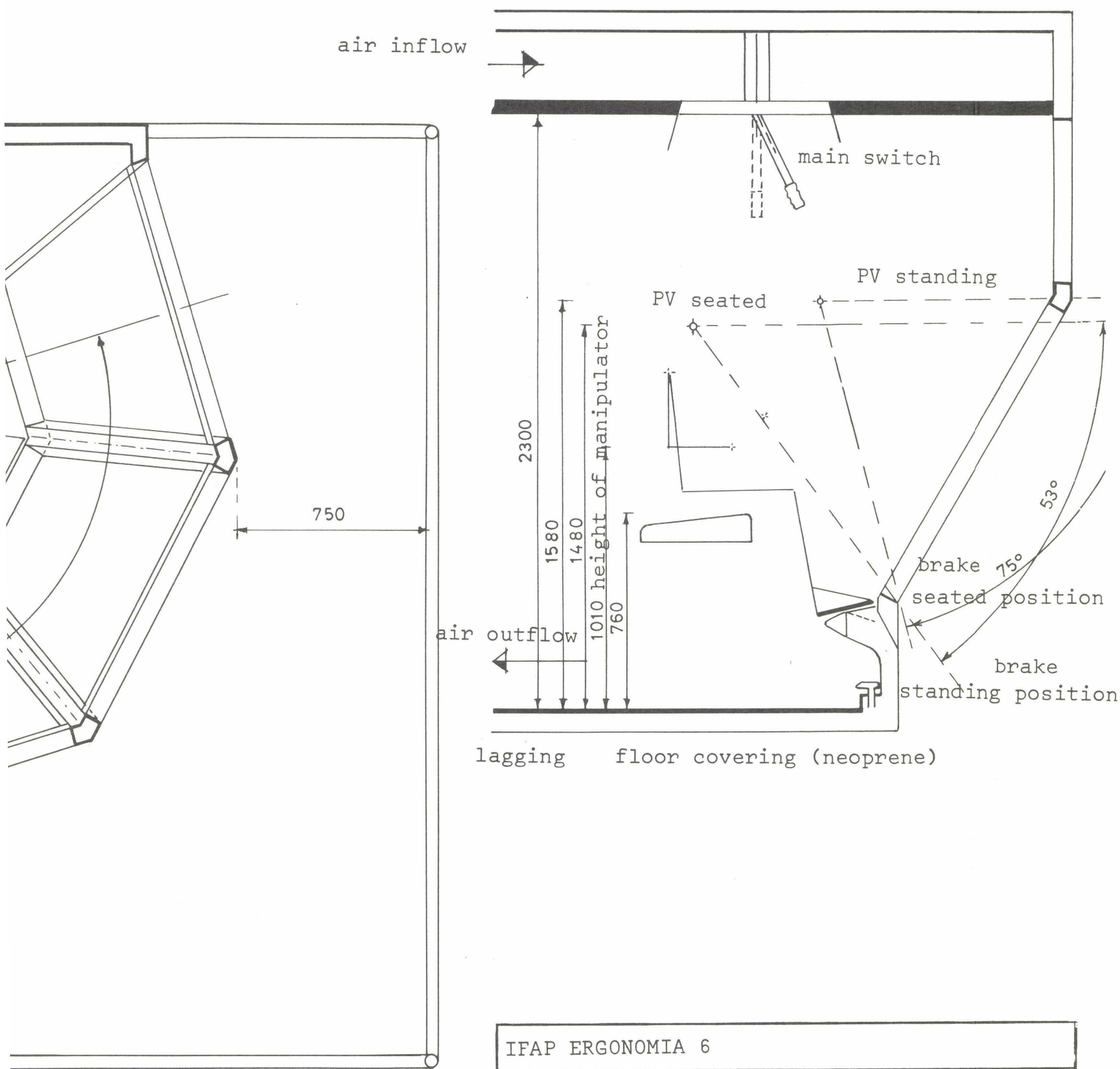




IFAP ERGONOMIA 7 GE 7
CRITERIA FOR SEAT DESIGN
Date 21.12.71 scale 1:5



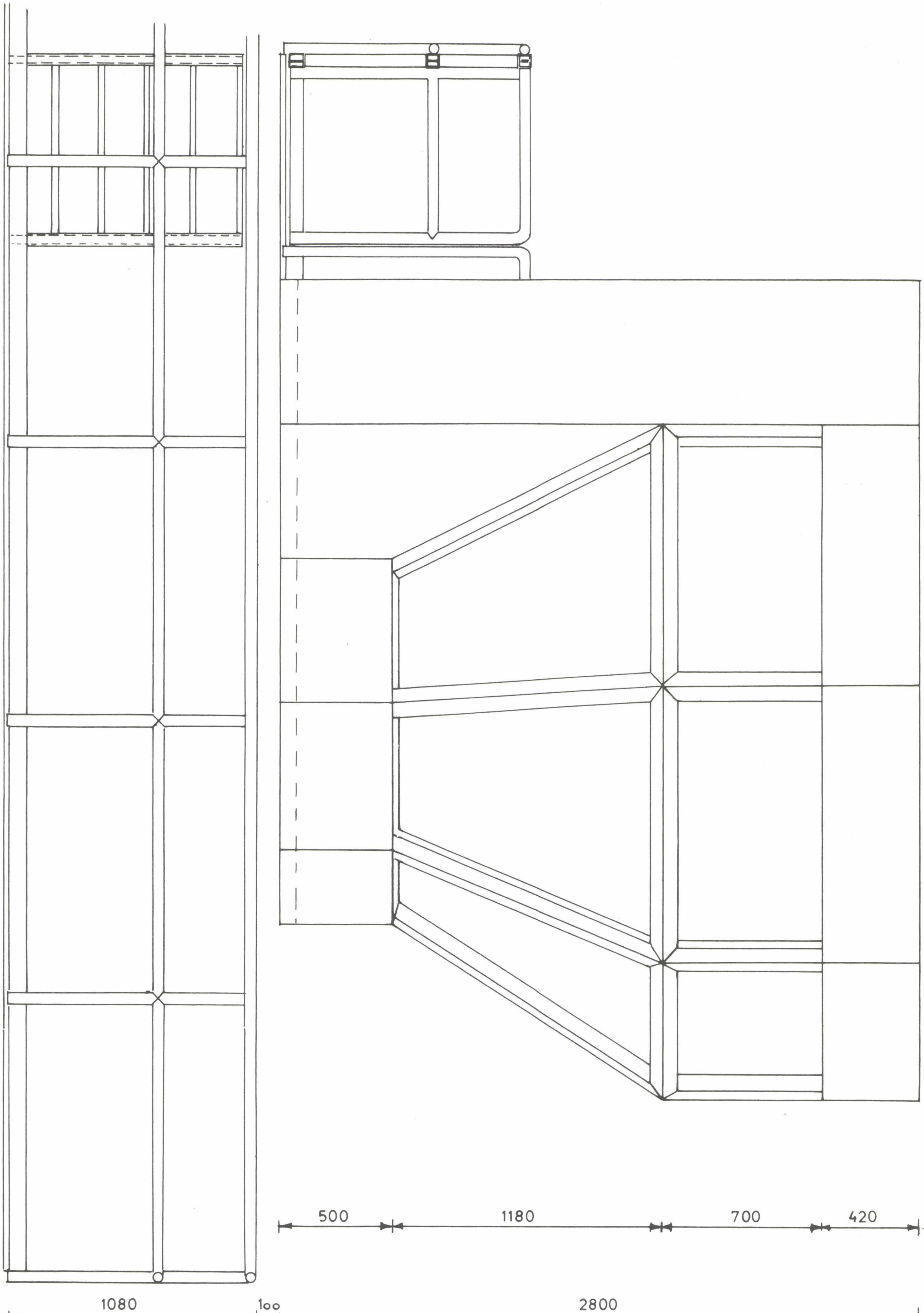
platform for window cleaning

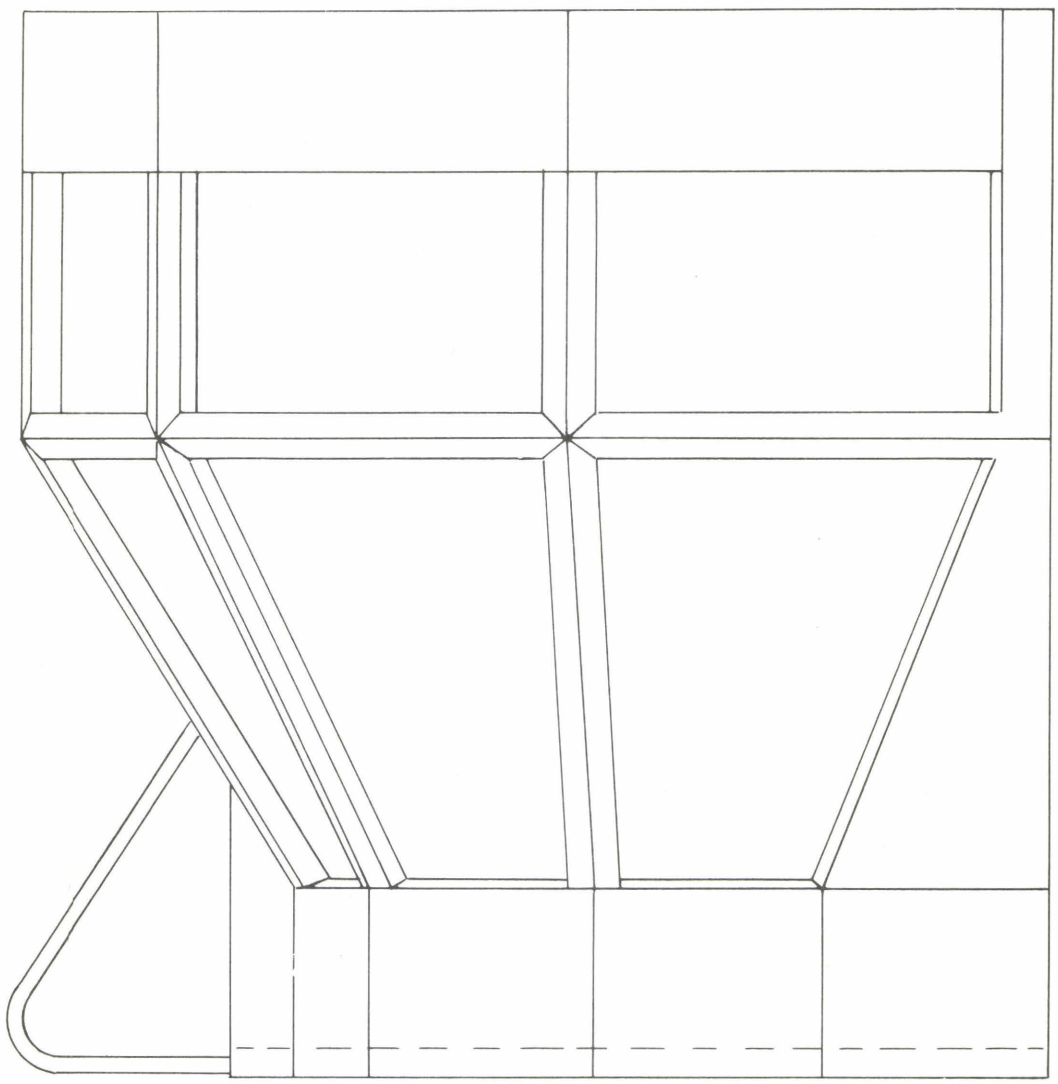


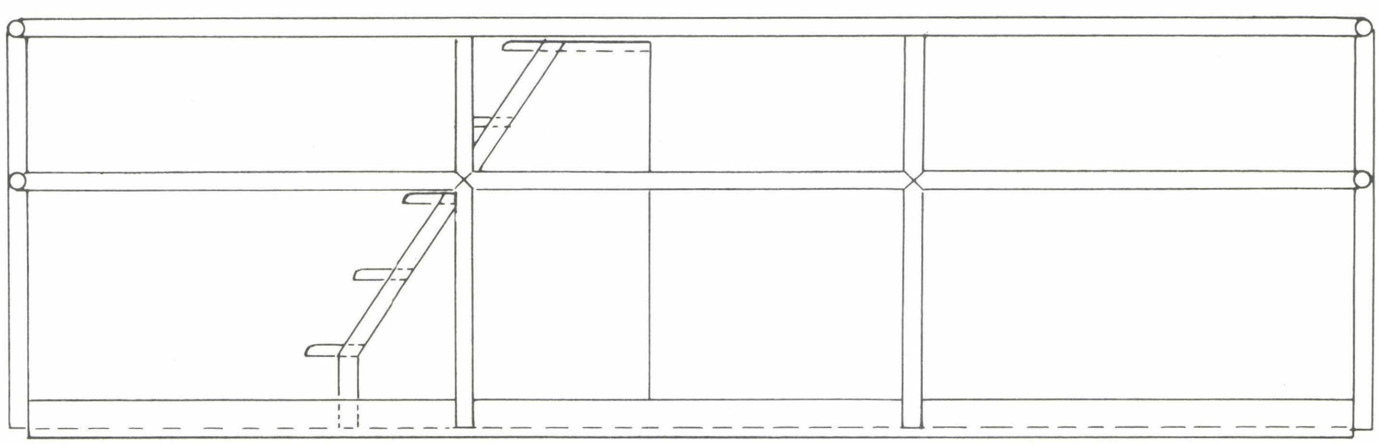
IFAP ERGONOMIA 6

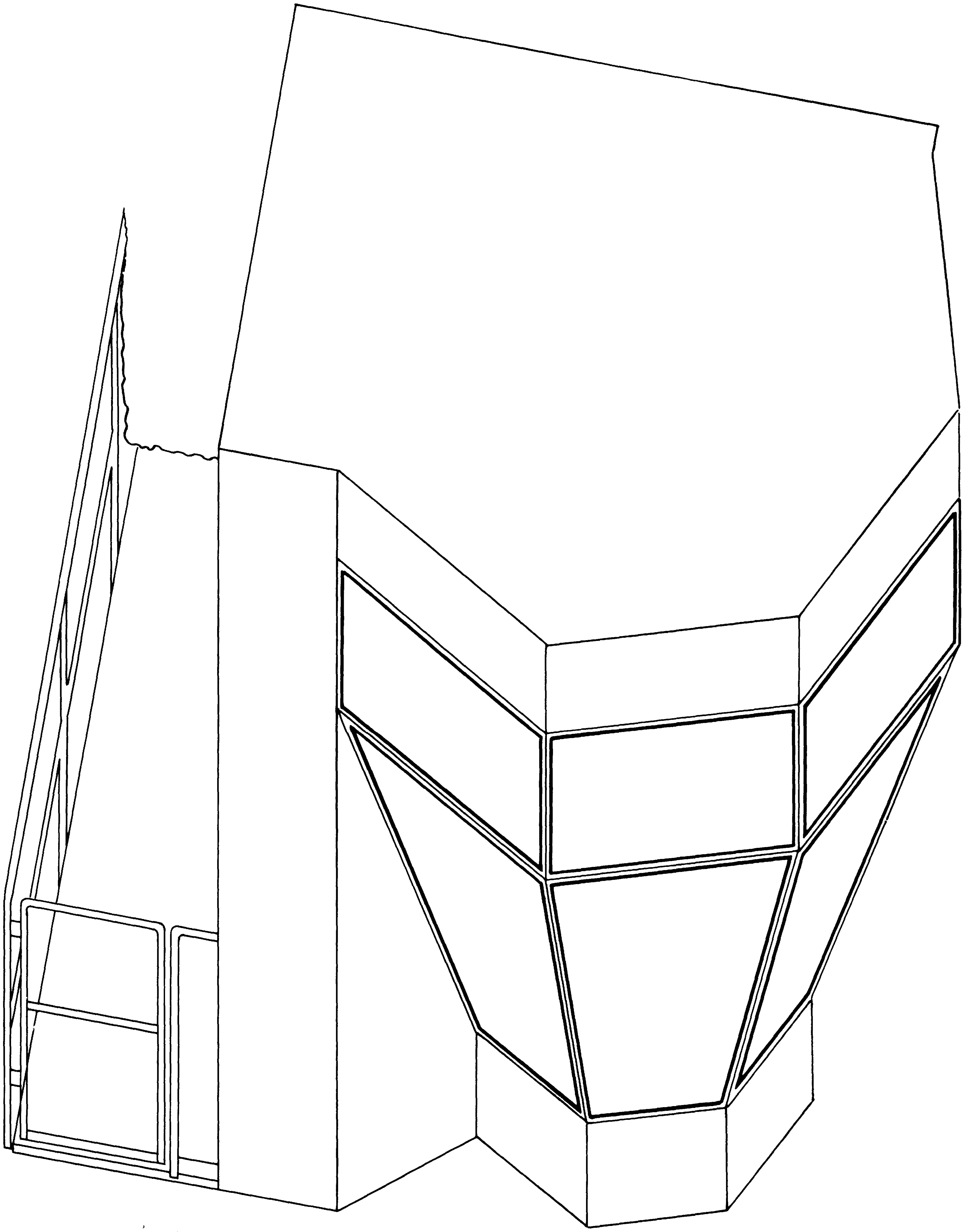
DIMENSIONED DRAWINGS OF CABINS LG1, LG2

Date 21.12.71 scale 1:10


500
1180
700
420
1080
100
2800







ISOMETRIC DRAWING OF CABIN