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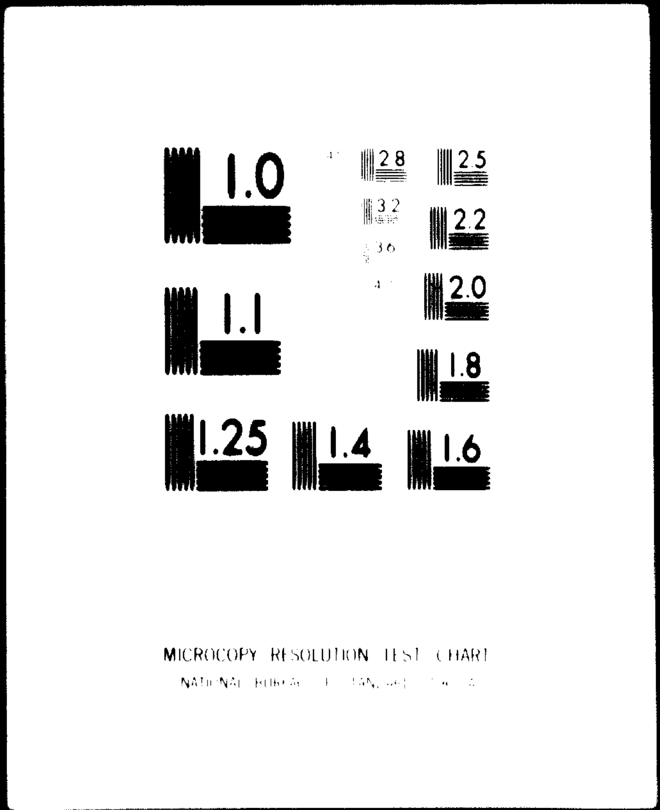
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FINAL

BUILDING REPORT

VOLUME I
LABORATORY IMPLEMENTATION

TO

UNIDO (CONTRACT 72/17)

FOR

SPAIN ELECTRICAL TESTING AND EXPERIMENTATION TESTING

IN

MADRID

SPAIN

Lalonde Girouard Letendre & Associates Ltd.
in Association with IREQ
Montreal, Canada

LALONDE, GIROUARD, LETENDRE & ASSOCIATES LTD.

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Montreal, September 7, 1973

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Lerchenfelderstrasse, 1
Vienna, AUSTRIA.

Att.: Mr. D.C. Newton, Chief, Technical Equipment
Procurement and Contracting Office.

Subject: SPAIN: Electrical Industry Test Experimentation Centre
UNIDO Contract No. 72/17 - Project No. SF SPA-012

Gentlemen:

We are submitting herewith our Final Building Report for the above mentioned project. This Report follows the Draft Building Report which has been submitted on September 29, 1972. It has been modified in accordance with the Contract documents and more particularly with article 2.01 item "V" concerning the suggested design changes by the Government and/or the Project Manager.

Following meetings held in Madrid with the Spanish Technical Committee and various experts a new implementation has been agreed on, whereby the proposed one-building concept is still maintained while a greater distance is kept between the High Voltage Laboratory and the High Power Laboratory.

Mr. D.C. Newton, Chief, Technical Equipment
Procurement and Contracting Office.

This Final Building Report offers sufficient information to allow the local architectural and engineering group to prepare the final design of the buildings. Additional information will be found in the First and Second Equipment Reports.

It was indeed a pleasure to perform this most challenging study on your behalf and we may assure you of our sustained interest in this project.

Yours very truly,

Jean-Paul Lalonde, Engineer.

JPL/cl

Unido - Vienna:	6 copies
Project Manager in Madrid:	2 copies
Spanish Government:	10 copies

SYNOPSIS

This Final Building Report constitutes a complete set of recommendations for the implementation of the High Power Laboratories forming part of the Electrical Testing and Experimentation Centre in Madrid, Spain.

Included also are drawings to be used, in conjunction with Performance Specifications, as a general guidance by the Government's Architectural Contractor in the final design and layout of the Laboratories.

This report relates to the buildings as recommended and also to certain functions of these laboratories. For a complete understanding of the whole, it may become necessary to refer to the First Equipment Report issued October 1972 on long delivery equipment, and to the Second Equipment Report issued September 1973 in two separate volumes:

a) High Voltage Laboratory
b) High Power Laboratory

The Second Equipment Report describes the equipment that can be procured in a short delay whether on the local or on the international markets. In an appendix to the Second Equipment Report for High Power Laboratory is reproduced a list of instrumentation already supplied to UNIDO in Octobre 1972.

For convenience, the Final Building Report has been subdivided in several volumes, as follows:

- Volume I - Laboratories implementation
- Volume II - Civil engineering
  - a) Site considerations
  - b) Structural engineering
- Volume III - Electrical and Mechanical engineering
- Volume IV - Terminal Section and Appendices
- Volume V - Drawings.

In accordance with the Terms of the Contract, the Final Building Report covers only the systems and sub-systems required for the implementation of the Laboratories with sufficient details to allow the local Architect to prepare the final design for construction. It does not cover the various services on the site which are the responsibility of the National Consultants.

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INTRODUCTION

I- INTRODUCTION

In accordance with the Terms of the Contract between our firm and United Nations Industrial Development Organization (UNIDO) on the 13th of March, 1972, we submit a Building Report covering the High Power and High Voltage Laboratories as described in the objectives and under the responsibilities of the Contractor. For easy reference these articles of the Contract document are repeated herein under Chapter II.

The purpose of this Report is to substantiate guidelines for the setting up of an Electrical Centre that will fulfill the following objectives:

a) To carry out testing of electrical equipment and parts;

b) To provide technical advice to the electrical industry through experimentation by groups of scientists;

c) To promote development of applied research in electrical engineering and electronics. This way, the Centre will serve as an academic complement to the Escuela Tecnica Superior de Ingenieros Industriales.

This Final Building Report shows our recommended implementation of the Laboratories and the various supporting areas. We indicate our choice of location for ths construction of the buildings on the selected site and discuss briefly the grounds of our motivation in relation to environment, access and egress, railway and services.

A chapter deals with the recommended structural design and gives sufficient details to allow the local Architect to proceed with the design and construction drawings. In other chapters, we indicate what we recommend for the various supporting systems and sub-systems in the electrical and mechanical fields.

The equipment needed for the operation of these Laboratoriss is described under separate reports: First Equipment Report - for equipment of long delivery - Second Equipment Report - for others.

VARIOUS PHASES:

From the analysis of data collected we were able to prepare the Draft Building Report, which was followed by the First Equipment Report related to testing equipment of expected long delivery. Because of this long delivery some of this equipmsnt is on the critical path in the schedule of construction and operation of the laboratories.

The presentation of our Draft Building Report was followed by meetings in November 1972 where questions were raised by Unido Consultants, Dr. H.Prinz and Dr. Cihelka mainly on the concept of the combined buildings. These questions were answered in detail in our Special Report of December 1972 with substantiating documents. Further meetings were held in Madrid during January of 1973 with other experts familiar with laboratories of the combined concept. At a session of February 1973 the concept as it now appears in our Final Building Report was proposed.

At the beginning of May 1973 we submitted two proposals of the stretched concept of which proposal No. 2 was accepted by the Project Manager's letter of June 27, 1973 and we were requested to proceed with report modifications on this basis. This letter was confirmed by a telex from UNIDO's Chief TEPCO, Mr. D.C.Newton on July 6.

INVITATION TO VISIT

In order to understand better some of the problems encountered in a design of such a nature, we have felt that visits to existing laboratories was indeed very much recommended. We have transmitted invitations to members of the Technical Committee as well as to other Officials, to visit IREQ's Laboratories in Montreal, Province of Quebec, Canada, considered to be one of the most modern actually in existence. Because we considered such visits as highly important we went as far as discussing such matters with the Federal Ministry of Trade and Commerce, so that such invitations could be considered as official by our Government. We still are of the opinion that Officials, Technical Advisers and Designers should visit our installations and others before they freeze their budget, finalize their design and procure the necessary equipment.

PERSONNEL IN TRAINING

Before the laboratories start operations it is, as was manifested in the Terms of Reference for engineering proposes, essential that some of the personnel in each section receive at least a year training in an existing laboratory. IREQ has offered to train four electrical engineers, candidates to the future operation of the laboratories. Two should train for the HVL and two for the HPL. The conditions set forth by IREQ for the training of these candidates have been expressed in various letters, and it was finally agreed that IREQ should work out with the Government all matters pertaining to this training of personnel.

TERMS OF CONTRACT

OBJECTIVES & TERMS OF CONTRACT

To facilitate the reading of this document and offer easy reference, we are repeating here the objectives of this project and certain terms of the contract that are of utmost importance and are referred to in this report.

" 1.00 *AIM OF THE PROJECT*

1.01 The aim of the Project is to assist the Government of Spain in establishing the Electrical Industry Testing and Experimentation Centre near Madrid to carry out testing and advisory services for the electrical industry.

a) This Centre will serve the electrical industry in undertaking the following activities:

i) Provision of technical advice to the electrical engineering industry and to the Government;
ii) Preparation of official reports for the Government;
iii) Provision of technical advice and expertise on legal questions;
iv) Carrying out of electrical and electronic measurements;
v) Preparation of electrical industry standards;
vi) Testing of electrical equipment and parts;
vii) Training of high level specialists in the field;

viii) Development of applied research in electrical engineering and electronics.

b) The Centre will be organized in the following Sections:

i) High Power Laboratory Section, for short circuit tests on prototypes and production models of such items as switchgear, cables, fuses, transformers, distribution boards at medium and high voltages;

ii) High Voltage Laboratory Section, to measure material insulation such as strengths of insulators, bushings, cables, transformers, lightning conductors, and other similar items.

At a later stage:

iii) Network Analysis Section, for the study and design of transmission and distribution networks under continuous and transient conditions. This will include an industrial electronics department for the design and construction of auxiliary test equipment.

iv) Standardization and Measurement Section, for preparing standard specifications, carrying out test and calibration work on measuring instruments, and determining the physical constants of conductive, dielectric and magnetic materials.

v) Quality Control Section, for quality control testing of small electrical appliances.

c) This Contract applies to the first two Sections only, the High Power Laboratory and the High Voltage Laboratory described in paragraphs b) i) and ii) above.

2.00 RESPONSIBILITIES OF THE CONTRACTOR

2.01 Statement of Work

Part A.

The Contractor shall provide the necessary services and facilities to perform the following:

a) General Requirements

i) Design

The Contractor shall design the High Voltage and High Power Laboratories according to the technical parameters set forth in paragraphs 2.01 b) and c) below. The Contractor shall undertake the systems design and be responsible for the functional performance of the sub-systems and the system as a whole.

ii) Building

The Contractor shall prepare a Building Report, including the design of the power supplies to subsystems and the system as a whole, giving a recommended layout of the High Power and High Voltage Laboratories showing estimated overall dimensions and weights, and any special facilities required

ii) *Building* (continued)

for the installation or operation of the major items of equipment. The report shall include floor plans and elevations, together with structural, material handling and utility requirements in sufficient detail for the architectural plans to be prepared by others. The Contractor shall also advise on the final structural design and layout of the laboratories. Structural design of the building will be accomplished by the Government's Architectural Contractor (see paragraph 3.01 below). The Building Report shall be furnished in accordance with paragraph 2.09 b) i) below.

iii) *Equipment Specifications and Analysis of Tenders*

The Contractor shall prepare detailed tender specifications for equipment to be purchased. It is mandatory that these specifications be drawn up in sufficient detail and in such terms to allow international competitive bidding for equipment. The Contractor shall report on expected delivery dates, together with a proposed installation schedule, estimated costs and names of suggested suppliers of equipment. The Contractor shall also analyse the tenders received and make appropriate recommendations on equipment purchase for the Government and for the UNIDO. Agreement as to the equipment to be purchased by the Government and

iii) <u>Equipment Specifications and Analysis of Tenders</u> (continued)

the Unido must be reached with the Contractor before actual procurement. The basic criterion of such agreement shall be the specifications for the equipment as prepared by the Contractor. The equipment specifications shall include general technical conditions, engineering specifications, performance criteria and minimum quality requirements. Tender specifications shall specify that the manufacturer will supply the wiring diagrams, controls and instruction manuals. When this information is received, the Contractor shall finalize the design drawings accordingly in order to assure that there is the proper electrical interconnection of the equipment. The specifications for those items of equipment which involve special building requirements or which must be specially manufactured and will therefore have a long delivery time shall be furnished within five (5) months after commencement of the work in the Project Area. Specifications on all other items of equipment shall be furnished within eleven (11) months after commencement of the work in the Project Area. The Contractor shall furnish in accordance with paragraph 2.09 b) below a Summary Report of all equipment specifications provided.

b) <u>High Power Laboratory</u>

i) The Laboratory equipment shall be specified in

b) *High Power Laboratory*

i) (continued)

order to provide facilities for testing electric power equipment, such as electric motors, generators, transformers, circuit breakers, fuses, conductors, reactors and capacitors. The criteria shall be analysed in depth by the Contractor to prevent early obsolescence of the Laboratory. The concept of the Laboratory has been defined and the buildings and equipment described by a UNIDO expert, Mr. J. Cihelka, during his mission to Madrid in April 1970. His report (Annex A) has received preliminary approval of the Spanish authorities and shall serve as general guidance only for the Contractor in the preparation of equipment specifications and other tasks.

ii) The testing power to be provided shall be as follows: a small short circuit generator approximately 600 MVA rating; one short circuit generator of maximum 3,000 MVA rating, space to be provided for a future 3,000 MVA generator and expansion provided for synthetic testing including circuitry and equipment parameters. The Laboratory shall also include:

a) short circuit test transformers;
b) Circuit breakers and the appropriate auxiliary equipment consisting of reactors, capacitors and resistors connected in banks;
c) control equipment, measuring instruments and associated equipment; and

d) *machinery and tools for a machine shop.*

e) *High Voltage Laboratory*

i) *The same general considerations shall be given to the High Voltage Laboratory as those described above for the High Power Laboratory. The concept and the parameters of the Laboratory have been described by UNIDO expert Professor Hans Prinz, of the Institute of High Voltage Engineering of the Technische Hochschule Munich, FRG. His report (Annex B) has received preliminary approval of the Spanish authorities and shall serve as general guidance only for the Contractor for the preparation of equipment specifications and other tasks.*

ii) *The High Voltage Laboratory already exists at the Escuela Superior de Ingenieros Industriales in Madrid and is equipped with some measuring equipment. This equipment may or may not be transferred by the Government to the new High Voltage Laboratory. The Government shall obtain prices from the original suppliers of this equipment to expand and upgrade it for testing power equipment of 380 kV line voltage with a possible extension up to 750 kV. The Contractor shall obtain pricing information on new equipment in order that the Government may make a decision on whether to upgrade or replace the existing equipment. The testing equipment shall be suitable for a maximum one minute power frequency voltage to earth of 880 kV rms or power frequency test voltages which may be prescribed by the national standards code in Spain. To this shall be added 30% for breakdown voltage test, 10% safety margin and 25% research factor amounting to 1.2 MV which is the nominal voltage of the cascade transformers. Similarly, the maximum*

ii) (continued)
voltage of the impulse generator has been determined as 4 MV. Final decision with respect to the equipment will be taken by the Government based on the recommendations of the Contractor.

iii) At a later stage, a DC generator of 1 MV shall be added and the buildings will be designed accordingly. The major facilities are planned to be: 1.2 MV two-stage cascade generator for 15 minute current of 1.25 A; 1.2 MV voltage divider; 4 MV impulse generator for 1.2 - 50 micro second standard lightning impulse and 250 - 2500 micro second switching impulses; two (2) meters sphere gap; 1.2 MV indoor-outdoor bushing for supplying the AC voltage of the cascade generator to the outdoor test area; an outdoor test tower, an indoor control room with three control desks; a mobile sphere gap two meters in diameter, as well as the necessary instrumentation, data display, indicating instruments and switchgear. The Contractor, however, will submit alternative proposals for decision by the Government.

iv) The planning of the new High Voltage Laboratory shall be based upon the maximum possible reuse of equipment already existing in the High Voltage Laboratory.

3.00 RESPONSIBILITIES OF THE UNIDO

3.01 UNIDO - Facilities and Services

To assist the Contractor and his Project Area personnel in the performance of the work, the UNIDO shall provide, or cause the Government to provide, at no cost to the Contractor, the following facilities and services as UNIDO may determine to

3.01 UNIDO - Facilities and Services (continued)

be necessary for the execution of the project:

a) Office space and essential office furniture and equipment and local transportation for official purposes as may be available to UNIDO and as normally provided to UNIDO experts in the Project Area;

b) A Centre building constructed on a suitable fully served site on the outskirts of Madrid with about 250,000 square meters of covered area and services suitable for the proposed laboratories and work-shops, bearing in mind the requirements of air conditioning and of anti-vibration necessary for some of the equipment to be installed;

c) Transfer of the existing equipment recommended by the Contractor (see paragraph 2.01 c) from the existing High Voltage Laboratory at the Escuela Superior de Ingenieros Industriales in Madrid to the new location in the Centre Buildings;

d) Necessary data as follows:

i) Electrical Industry

Sufficient knowledge of the state of the actual electrical industry as far as manufacturing, local markets, international markets, type of production, number of expected tests, etc. and evaluation of its potential and the electrical industries future development. The origin and destination of material to be tested for proper flow arrangement and proper sizing of areas for mounting as well as equipment needs and sizes.

ii) Electrical Distribution

Transmission and distribution systems which will

ii) Electrical Distribution (continued)

be needed in the Contractor's assessment of research requirements. Knowledge of standards of distribution voltages and currents in order to prepare the specifications of the equipment.

iii) Transportation

Standards for road construction, bridges, railroads so as to foresee some of the limitations which will be imposed on the design.

iv) Site

General area maps, site plans, contours, geology and pedology.

v) Services

Quality of water with supporting analysis for various usage. Disposal of wastes, of waste water, of surface and storm drainage, required treatments, environmental factors. Requirements for area lighting, parking, recreation, fire protection.

vi) Buildings

Different codes or standards, floor occupancy in offices, modules if in existence, accommodation for personnel. Statistics on precipitation, daily temperatures and relative humidity.

vii) Future Phases

Future phases of the overall development as they relate to the initial phase.

e) Inspection and performance tests of the equipment at the manufacturer's plant."

PRELIMINARY SECTION

III- PRELIMINARY SECTION

RESULTS OF FINDINGS

The Building Report is based mainly on data, publications and general information gathered by our staff in Madrid supplemented by visits from our various experts on the site. In June 1972, a delegation from our group had the opportunity to meet with Government Officers, made a visual survey of the proposed site and visited some hydro-electrical installations as well as some electrical equipment manufacturers.

Through the information gathered it was possible to assess the actual development trends and to foresee a considerable increase of the Country's electrical market over the next decade. Electrical consumption has increased threefold between 1960 and 1970 and this tendency should continue for a good number of years knowing the efforts put forward by the Government towards industrialization. The creation of this Centre is a proof of the Government's interest, which in turn will no doubt help greatly the industrial development.

CONCLUSIONS REACHED

With an increase in electrical equipment fabrication the proposed Testing Centre should be larger than required to meet the present needs. We are aware that most Testing Centres throughout the world have reached their objectives in a shorter period than anticipated at the planning stage. They had to consider expansion and addition of services and facilities sooner than expected to meet a fast developing technology.

RECOMMENDATIONS

The recommendations stated hereafter in this Building Report are minimal. Any reduction whether in dimensions of buildings or facilities would result in serious difficulties in the near future for the operation of the Centre in accordance with technological progress.

Throughout these studies carried ou by our group, we have often referred to the reports of UNIDO's experts Professor Dr. Hans Prinz concerning the High Voltage Laboratory and Dr. J.Cihelka for the High Power Laboratory. We may have gone a little beyond the recommendations of these two experts on account of two major factors:

a) the actual trend and the future requirements of the electrical industry;

b) our recent involvement in the implementation of a research laboratory that turned out to be one of the largest in the world.

Our stand may also reflect a difference between the objectivee pursued in each caae. The aima that have been given to ue in the Terme of Reference and eventually in the Terms of the Contract may not have been the same that were expoeed to the two UNIDO experts.

This Final Building Report supersedes the Draft Building Report which was submitted in September of 1972. After many meetinge where numerous consultants offered comments on the Draft, a series of recommendations was issued which led to the preparation of thie Final Building Report.

These discueeions have been mostly oriented towards our concept of a combined building implementation as compared to the more traditional layout of separate buildings maintaining a distance of 150 meters and more between the HV and HP teeting areas.

A compromise was finally arrived at, where a modified approach to the combined system was accepted which kept a distance of metere between the HV laboratory and the HP teeting areas. Thie modified layout maintains the combined concept by introducing the common areas between the two laboratories in an elongated form of implementation.

We have indicated in correspondance and reports that our preference went to our initial recommendation but we had no objection to the compromise solution. We wish to repeat here that technically our initial proposition was sound, in that respect we have given sufficient answers to various objections raised and that no valid demonstration of operating deficiencies in this concept have been made. In the overall analysis, we recognize the existence of other factors of a social and/or environmental quality for which the local Government representatives and the Committee they have set up to study this project are better qualified than us to form judgment. We have tried to be objective and have offered in such discussions our own experience and knowledge.

It is important also to note that in our concept we were concerned with matters of economy in both building volume and subsequent operations. We have mentioned in our Special Report of December 1972 that the final layout represented an increase in foreseen expenses. We had made calculations to substantiate our say and we think it is of interest to indicate here the magnitude of these increases:

Exposed walls,	3,832 m^2
Foundation perimeter,	170.8 m^2
Roof,	434 m^2

These increases will of course have some repercussion on the cost of certain electrical and mechanical services in the building both in capital expenditure and in operation charges.

LABORATORY IMPLEMENTATION

IV- LABORATORY IMPLEMENTATION

GENERAL LAYOUT

Figure I shows the different parts of the building sheltering the High Voltage and High Power Laboratories.

Main divisions

The areas 1 to 7 are mainly devoted to the High Voltage Laboratory for dielectric tests. Areas 8 to 16 make the section of common services to be used by both laboratories.

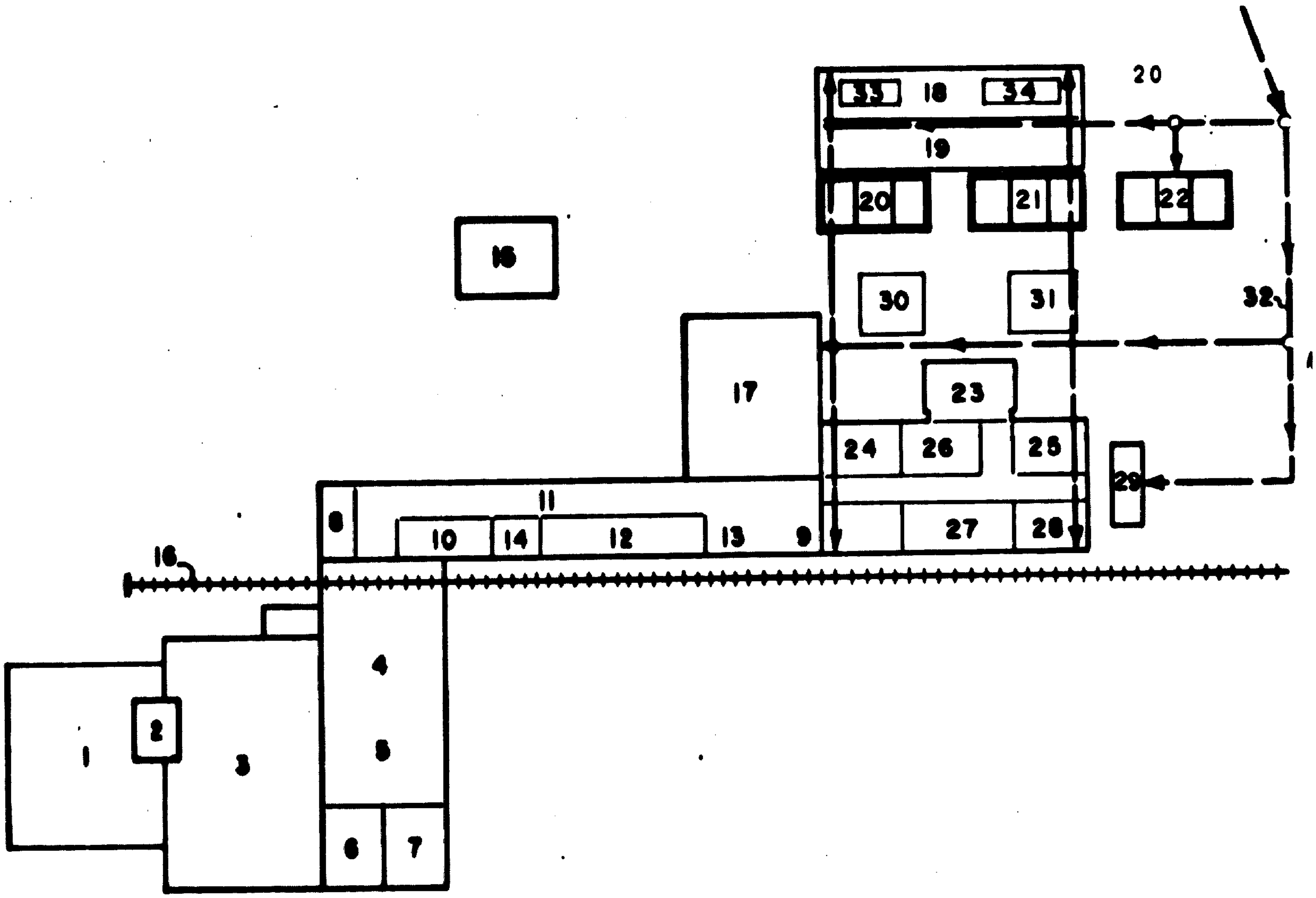
Areas 17 to 34 are the different sections of the High Power Laboratory.

Reasons for this layout

There are many advantages in having the two laboratories close to each other. Some of these are as follows:

- The management and operation personnel will be reduced and a better coordination between the two laboratories can be achieved.

- Services like, receiving, storage, handling of materials and equipment, machine shops, can be shared, with a better efficiency than having two separate sections.



HIGH VOLTAGE

1. External Test Area
2. Control Room of H.V.L.
3. H.V. Main Hall
4. Transformer Test Hall
5. Mounting Hall
6. Corona Hall
7. Pollution Room

COMMON SERVICES

8. Oil Pumping & Treatment
9. Compressed Air Equipment
10. Auxiliary Machines
11. Corridor
12. Workshops
13. Shipping & Receiving
14. Rest Area
15. Offices
16. Railroad Siding

HIGH POWER

17. Synthetic Hall
18. Main Machine Hall of H.P.L.
19. Reactance Hall
20. Transformer Set No.1
21. Transformer Set No.2
22. Transformer Set No.3
23. H.P.L. Control Room
24. Assembly Rooms
25. Assembly Rooms
26. Climatic Room
27. High Current & D.C. Tests
28. 25KV Test Cells
29. 500 MVA Transformer Set
30. Test Yard No.1
31. Test Yard No.2
32. 220KV Incoming Lines
33. Generator No.1
34. Generator No.2

- The short-circuit generator will be used as a power source at the High Voltage Laboratory for tests on large transformers. The actual layout will permit this connection.

- The high capacity of the capacitor bank of the synthetic source (area 17) can eventually be used as compensator during tests on large transformers and reactors.

- Also many equipment will be shared like: oil pumping and treatment, compressed air systems, machine hall, climatic room and assembly rooms 24, 25 and 26.

MAIN CHARACTERISTICS

The laboratories have been designed to do all the tests required by the standards on electrical equipment used on distribution and transmission systems. The present and planned Spanish systems have been taken into consideration including possible ties with other countries.

Since the main purpose of building these laboratories is to help the Spanish electrical industry in producing and developing new equipment, the design offers flexibility and secrecy.

Flexibility means that many tests can be performed at the same time at the High Voltage Laboratory and at the High Power Laboratory. This is possible by dividing the main hall in the High Voltage Laboratory in sections when lower voltages are required, and by having three main sections at the High Power Laboratory. This layout brings this flexibility without increasing the cost in the same proportion.

Secrecy is kept during all the time the customer's equipment is in the laboratory. The assembly rooms, the procedure at the test cell and the handling of the results for the test report (dark room) are criteria which have been taken into great consideration during the study of the layout to ensure a maximum secrecy.

MACHINE SHOP & DEPOT

The purpose of a machine shop equipped with a minimum of tools is to be able to build some special adapters for apparatus under test or do some changes on the equipment itself if required. For example a leak proof container with a bushing could be built in a short delay.

The shop services should offer the following:

- a machine shop
- sheet-iron equipment
- a material storage
- welding equipment
- a woodwork shop.

Appropriate tools are of the general type and do not require a very high level of precision.

FEEDING LINES AND STATION

Incoming lines

A study has shown that it will be more convenient to supply the power needed for the laboratories by the double circuit line at 220 kV located one kilometer from the site. The electrical diagram No. 201 shows the different feeders.

Two main circuits are defined. One as a normal energy supply and a second one for test purposes at the High Voltage and High Power Laboratories. The power estimated for the normal circuit is as follows:

University Center	5000 kVA	
High Power Laboratory	2500 kVA	
High Voltage Laboratory	2500 kVA	+ 4000 (2ϕ)
General purposes	2000 kVA	
	12000 kVA	

Because of asymetrical load due to the regulators (400 kVA) at the High Voltage Laboratory connections y/z (yz 5) are proposed.

The power required for the test circuit is 12000 kVA. Taking into account the nature of the load and future extensions, a capacity of 16000 kVA is foreseen.

The voltage drop on the 220 kV circuit during a test in the 500 MVA section will be 2,5%, negligible when starting the motor-generator at the High Power Laboratory.

MAIN SUBSTATION

For reasons that we have indicated previously we do not favor the position of the main substation as shown on drawings. This position was recommended to us and is in agreement with the contractual documents article 2.01 item V. We have therefore prepared our drawings in accordance with this positioning. We must at this point express the opinion that this position should be further studied in the final design stage, when more data are available on the total development of the land. In our view and in relation to the laboratories only this recommended position does not comply with our criteria of aesthetics and economy.

GROUNDING NETWORK

Special attention should be taken for the grounding network. Short-circuit currents circulating in the ground conductors produce different ground voltages between equipment and are dangerous if no special protection is foreseen.

Telephone equipment should be isolated by transformers. Underground pipes should be made with insulating materials for a specific section. Railroads should also be protected against voltage rises by resistors. An analytical study would specify the values of voltage rises and the corrections required.

Regarding grounding and shielding reference should be made to the Special Report of December 1972 where covering articles have been included.

PERSONNEL

Personnel required to start the operation of the laboratories could be as follows:

Manager and staff	6
Senior Engineers	2
Test Engineers	6
Technicians	16
Labor	10
TOTAL	40

After some years depending on the demand this number will be adjusted.

TRAINING

Senior Engineers in their respective field should have at least five years experience. Test engineers should have a training of nine months to one year in a High Voltage and in a High Power Laboratory respectively. Some laboratories will accept to train young engineers inside a specific contract. This training is very important because an error could bring a big loss of equipment and also reduce the goodwill of the laboratory.

HIGH POWER LABORATORY

GENERAL

The High Power Laboratory will be used to test electrical equipment used in distribution and transmission systems mainly under short-circuit current conditions. The principal equipment tested will be:

- Circuit breakers
- Disconnect switches
- Fuses
- Lightning arresters
- Load break switches
- Transformers; power and instrument
- Reactors, capacitors
- Bus bars, line equipment and cables.

Besides short-circuit tests,other tests will be performed as:

- Load breaking tests with different power factors
- Short-time tests
- Heat run tests.

HIGH POWER LABORATORY

FOUR PHASE PLANNING

CONSTRUCTION PROGRAM	MAIN TEST FACILITIES	VOLTAGE & POWER AVAILABLE
Phase I	Section 1 2100 MVA test circuit 3 transformers 2 outdoor test yards	19,5 to 220 kV 2100 MVA 3ø, 1200 MVA 1ø
	Section 2 500 MVA test circuit 3 transformers supplied at 220 kV 2 test cells	3.6 to 26 kV 500 MVA 3ø, and 1ø
	Section 3 a High-current test circuit. 3 transformers supplied at 22 kV - 16,6 MVA - 1ø One large test area, shared with D.C. tests	100 V - 290 kA 3ø tests 692 V - 42 kA 100 V - 500 kA 1ø tests 1200V - 42 kA
	Section 3 b Direct-current test circuit 27MW S.C. cap. Transformer & Rectifier supplied at 22 kV. - 3ø primary - 6-3ø secondary windings.	600 V - 45 kA 3600V - 7,5 kA
Phase II (not later than 1 one year after Phase I)	1) Synthetic test circuit capacitor bank 2 - 2,5 MJ	765 kV equivalent 3 ø 6000 - 9600 MVA 1ø 14 000 - 22 000 MVA 3ø Equiv.
	2) Climatic chamber	Temperature - 25°C to +65°C, Ice, 100% humidity.
Phase III (when required)	1) 2nd, 2100 MVA test set, same as above. 1 additional test cell 14 kV	Two sets in parallel 14 kV: 19,5 - 220 kV, 4200 MVA 3ø 2400 MVA 1ø
	2) Extension of the synthetic circuit	765 kV 3ø equivalent 12 000 - 19 200 MVA 1ø 28 000 - 44 000 MVA 3ø Equiv.
Phase IV (future)	5000 MVA transformer set supplied from the 200 kV network	Two generator sets & transformer set in parallel 7400 MVA 1 -> 5000 MVA 3ø

Table I

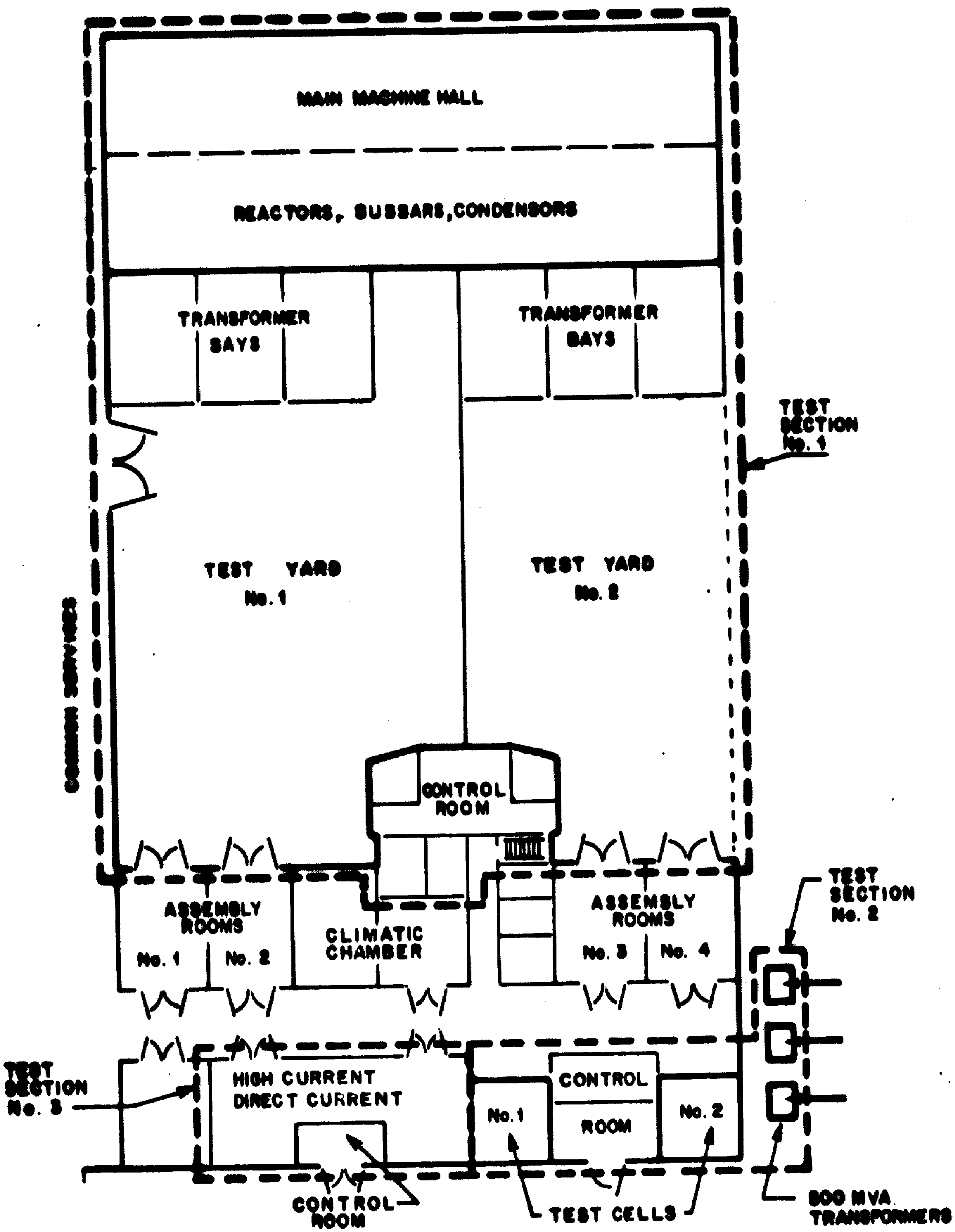


Fig. 3 HIGH-POWER LABORATORY LAY OUT

1. THE LAYOUT OF THE HIGH POWER LABORATORY

This layout is shown in Fig.3. Three test sections specified in Table I and in circuit diagram Fig.2 and the climatic chamber are shown.

Section No.1 contains the main machine hall, reactor hall and transformer bays, two outdoor test yards, separated by a wall and a control room serving both yards. In the control room, on each side, there is an observation room for the representative of the client and on the second floor there is a larger observation room to accomodate a larger number of witnesses or to film a test with special cameras.

The equipment to be tested will normally be assembled in one of the four assembly rooms, which may also be used as testing stations. There is a direct access from the assembly rooms into the test yards, so that even a big circuit breaker or other piece under test can be easily shifted into the test area using air bearings or other means of transportation. (See photos No.1 and No.2)

Within the test yards some protection against explosions during the tests are foreseen. All doors leading into this space are blast proof and will be electrically blocked when the equipment is alive. The test transformers are protected by a wall, made up of sections, or modules, which may be disassembled for a revision or repair of the transformer. A similar wall separates the two test yards. It is easy to disassemble this wall using a small crane, so that a larger test area is made available if necessary.

On ths right, (fig.3) the test yard No.2 is opened, but protectsd by a fence at a safe distance. This is the direction for extension and a third test yard may be located to ths right of ths test yard No.2 in ths future, if desirable.

The observation from ths control room on the ground floor and from the observation room on ths second floor is through safety (bullet-proof) windows.

Section No.2

This section is the 500 MVA test section supplied from a group of transformers, located outdoor and connected to ths 200 KV line. This section is a typical doubls modula, having two indoor test cells and a common control room between. Ths cells, including the access door are blast proof, ths observation from the control room and client's observation room is through safety windows. The equipment of this section, shown in the circuit diagram Fig. 2 is located in the basement of the same part of the building.

Section No.3

This section is located next to section No.2 on the same side of the central corridor of the building. It is supplied by cable from the 22KV substation and alternatively, by cable as well, from the neighbouring section No.2. The common equipment of the two subsections as shown on the circuit diagram is located in ths basement, the high current transformer and the transformer-rectifier group is located inside the test hall. This is necessary in order to reduce impedances on the low voltage side of the transformers.

Climatic chamber

Apart from the three test sections, there is the climatic chamber located in center, between the two sets of assembly rooms, as shown in Fig.3. This section consists of the test chamber itself with a small control room and access space, the purpose of which is to limit the heat exchange when entering the chamber at low temperature. The adjacent module will be used to accomodate the equipment serving to prepare the required climatic conditions.

The four assembly rooms may be used for assembly of the equipment to be tested in any of three test sections and climatic chamber in principle. It is understood, however, that in specific cases the assembly may be made within the test space, if preferable.

A more complete description of the climatic chamber will be found in the Second Equipment Report, Item HP-15.

We have been requested during some meetings in Madrid to move the climatic chamber closer to the High Voltage Laboratory. We have given our reasons for keeping this chamber in the HP area in our Special Report of December 1972, p.12-13-14. We have repeated in a letter dated

May 24, 1973 to your Project Manager that we fail to see why such a change should be made and gave the reasons why the climatic chamber should remain in the HP area. We went further by saying that we would not change our recommendations in that respect in the Final Building Report. We now of course leave that question to the local designers since we cannot offer additional comments and furthermore as we have said in the previously mentioned letter we see no practical reason for the move.

Safety

The whole region of the high power laboratory will be provided with a system of safety lights and a system to block the doors, so that access to the dangerous areas, including main machine hall, reactor hall, test yards of section 1, basements of sections II and III and test cells of section II will be impossible.

Safety regulations are to be designed and enforced for the employees of the laboratory as well as for clients and visitors.

2. TYPES OF TESTS

Three different types of tests could be devined as follows:

a) Official acceptance tests (certification tests).
b) Development tests on prototypes.
c) Tests for research purposes.

To illustrate the possibilities of the laboratory the following examples are listed, having in mind that this list may not be exhaustive.

1. Current carrying short-circuit tests on all types of low voltage and high voltage equipment having low impedance. Typical examples: circuit breakers in closed position, isolators, current transformers, bus bars, distribution switches, etc..

2. Current carrying short-circuit tests on high impedance equipment such as power transformers and current limiting reactors.

3. Short-circuit making and breaking tests on circuit breakers ranging from low voltage up to highest voltage existing.
   Typical tests:
   a) Terminal short-circuit interruption tests.
   b) Short-circuit interruption tests.
   c) Hi-speed reclosing tests on short-circuits.
   d) Evolving fault interruption tests.
   e) Short-circuit interruption tests under out-of-phase conditions.

4. Switching tests other than short-circuit at high voltages (H.V.)
   a) Load current switching tests on load switches.
   b) Switching tests of capacitive currents of capacitor banks, long unloaded lines, unloaded cables.
   c) Switching tests of small inductive currents of transformers at no-load, shunt reactances, H.V. induction motors, reactance loaded transformers.

5. Interrupting tests on L.V. and H.V. fuses from small overloads up to high short-circuit currents.

6. Direct current switching tests on high-speed circuit breakers, fuses and other switchgear from load currents up to short-circuit currents.

7. Temperature rise tests at very high permanent currents, A.C. and D.C. on: bus-ducts, bus bars, circuit-breakers, insulators, etc..

8. Tests with high power arcs, such as behaviour of insulators and their protection rings during a flashover, behaviour of H.V. cubicles under arcing short-circuit inside.

9. Different kinds of tests for research and developments in the field of high current and high power arcs.

10. Tests of electrical switchgear under different climatic conditions, such as high temperature and humidity or very low temperatures and under ice coating. Life tests on insulation using the cycling method of temperature.

3. TEST FACILITIES AND PARAMETERS

Main test sections

The main test facilities and their respective parameters are listed in Table I as a function of the construction schedule. Three main test sections are being proposed as outlined hereafter:

Section No.1

This main section will cover direct testing facilities for equipment rated at 14KV up to 220KV and synthetic testing facilities for higher voltage equipment up to 765KV. It will be built gradually in four phases.

At the beginning (Phase I) one generator-transformer set will be provided, rated at 2100 MVA. Immediately following, the synthetic circuit will be added (Phase 2) raising the single phase test capacity 5 to 8 times.

Later on, after some 4 to 5 years of operation a second generator-transformer set will be added, together with an extension of the synthetic circuit (Phase 3). Still later on, possibly 10 years later a further extension of test capacity is planned by the addition of a transformer bank rated at about 5000 MVA supplied from the 220KV network.

Section No.2

This section will be mainly devoted to distribution equipment. Testing facilities for equipment voltages from 3,6KV up to 25KV and capacities up to 500 MVA will be completely built up in the first construction phase.

Section No.3

This low voltage section includes two subsections, high current and direct current test circuits.

These two circuits have a common feeder at 22KV. According to table I both subsections are included in the construction phase No.1. However it is possible to delay subsection 3b, into Phase II, if reasons should exist to do so.

Test facilities in time

After completion of Phases I and II, all the types of tests as described above will be possible. It is estimated that the facilities will meet 90% of the tests requirements. The remaining 10% will include the following cases:

1. Heavy generator-circuit-greakers rated at 15 to 25KV and 3500 to 5000 MVA.
2. Tests on complete poles of E.H.V. circuit breakers. Only individual interruptors or pairs of interruptors could be tested using synthetic method.
3. Short-circuit tests of power transformers whose three phase continuous ratings exceed some 50 MVA and of current limiting reactors whose short circuit ratings exceed some 500 MVA.

By the addition of phase III the capacities given in the three above mentioned cases will be doubled. Besides, the two 2100 MVA s.c. generator-transformer sets will be able to operate independently, increasing the number of tests in a period.

Choice of the main parameters of Section No.1

Two major principlea have been taken into account:

a) Parameters required for teats

b) Availability of reliable and economical designs of equipment.

As to the test requirements, two distinct groups may be specified.

- Distribution switchgear ranging up to 45KV with 2000 MVA, is made normally as three phase equipment and a three phase test circuit must be uaed.

- Switchgear for 100 KV and higher is mostly designed as aingle phase units, and then, tests are made single-phase. Due to short-circuit power of networka now 5000 MVA and above it is out of queation to try to reach this power by direct teats.

  Single phase synthetic testing shall be used instead.

- Concerning the availability of test equipment, there is no doubt that all elements of the main test circuit can be manufactured by several manufacturers, with one exception: the main short-circuit generator. In fact this machine is the key point of the circuit and the associated equipment must be compatible with it.

- Several large companies have developed and built auch generators, but with very little exceptions, for their own laboratories only, and in many cases just one machine was built. It is evident that in these cases the aspects of economy are very uncertain, compared with machines made for a larger market. It is even possible to think that some companies were probably willing to pay a generator more if made in their own workshops than to buy a machine from the competitor, because of prestige and publicity.

Some of these generators are very heavy low-speed machines, having 4 to 8 poles. Most likely, the cost of those machines would be much higher than that of high-speed generators. The transportation problem would also be quite significant.

It is being confirmed by the opinion of several machine designers that the most economical solution of a short-circuit generator is a high-speed (2 poles) machine.

Very few companies built more then two identical machines.To our knowledge, only three such companies and generator types exist in the world.

1. Generator designed by ACEC Belgium, in about 1938. Five machines have been built, so far, by ACEC and under its licence. Its voltage is 12KV, speed 3000 rpm,capacity 2500 MVA at the terminals (accidental) and about 1200 to 1500 MVA in the test cell. This machine is relatively old and small and cannot meet the requirements for a modern laboratory.

2. Generator designed and built by Electrosila in Leningrad, Russia. Six machines of the same type have been built, but no positive information is available concerning its reliability and operation experience. Its voltage is 12KV speed 3000 rpm short-circuit capacity approx. 1500-1800 MVA. The pruchasing of this generator hardly comes into consideration.

3. The Company Oerlikon (now part of Brown-Boveri group) has an exceptional position in this field. The number of short-circuit generators built is 14, last 6 of the same generation. It is the most modern generator for H.P.L., rated at 14KV, 2100 MVA at 50 Hz and 3000 r.p.m. and is made for operation at 60 Hz with a bit higher voltage and capacity.

Without eliminating other possible makers, it is most probable that this is the best choice from technical and economical view-points. This is why the parameters of this machine have been used as reference for the present specifications.

In conclusion, it is felt that a test capacity of approximately 2000 MVA is a most convenient choice for the short-circuit generator, meeting both above mentioned viewpoints namely that of covering distribution switchgear area on one hand and that of availability of a modern generator of similar rating on the other hand.

Section No.2

The electrical parameters of this section are in fact described in Section No.1. The justification for this section is based on statistica from testing stations, showing that some 60% to 70% of the number of tests is made using capacities not exceeding 400 MVA. Actually the percentage might be lower, say around 50% in this specific case, and will still fall down gradually in the future, it is clear thatit is possible to roughly double the number of tests for an additional expenditure of some 12 to 15% of the main circuit by providing a second-medium power test circuit rated at 500 MVA. Comparing now two possible alternatives, namely:

a) 500 MVA generator-transformer set;

b) 500 MVA transformer set supplied from the 220 network, the second alternative is clearly superior for economical reasons. It is estimated that in case a), the cost would be:

Generator:	$800,000.00
Transformers:	$300,000.00
Total:	$1,100,000.00

In case b) in spite of the fact that the cost of the transformer set would be higher due to the 220 KV primary and to a more complicated secondary, and that some additional costs must be added because of a greater number of reactors, the total estimated cost would only be $400,000., giving a saving of about $700,000.

On the other hand, to obtain a short-circuit of 500 MVA capacity there is no problem whatsoever from the 220KV system. The short-circuit power is, around 12000 MVA for the time being and will increase in the future. In fact, 500 MVA equals approximatively the normal load and the voltage drop will be less than 3%.

Section No.3

High current and direct current test circuits.

These two circuits will be supplied from the 22KV bar of the laboratory substation, so that its operation will be independent of the 2100 MVA and 500 MVA circuits.

The two subsections will have a common feeder, including the back-up circuit breaker, the set of reactances and the closing switch.

It will be possible to supply this section from the 220KV network via the 500 MVA transformer set. This has been made for the following reason: for high current dynamic or short-time tests, which will be the most usual cases, the section will be supplied from 22 KV bars, and the value of current will be controlled by current limiting reactors on the 22 KV side. The voltage regulation on the secondary side is not of much importance and a few large voltage steps, say 100, 200, 300 and 400 V is fully satisfactory. When testing L.V. circuit breakers both A.C. and D.C. for interrupting ability, however, both current and recovery voltage must be adjusted to prescribed values and in this case, a better voltage regulation is needed. This is obtained by supplying the high-current or rectifier transformer from the 500MVA transformer set, using the good voltage regulation available on the secondary side of this transformer set.

In addition, this alternative supply serves either as spare voltage in case of some accidental fault in the 22 KV substation or when voltage variations due to short-circuit tests could perturb some sensitive tests in other parts of the laboratory.

Climatic chamber

The dimensions of the available test space within this chamber are proposed to be 4,75m x 6,6m x 8mH. This volume will permit the tests of a complete apparatus up to:

1. Isolator 72KV - 3ϕ
2. Isolator 230KV - 1ϕ
3. Breaker 230KV - 1ϕ

The temperature range considered is:

a) -25°C + 65°C, raising and lowering of the temperature between these limits in 20 to 120 minutes.

b) +25°C - 25°C, 3 hours cycle at least.

Humidity will be controlled between the natural humitidy of the environment (very low in Spain) up to 100% at 65°C (saturation). The tests to be made in this chamber are the following:

1. Test under ice condition
2. Accelerated ageing tests
3. Tests at low temperature
4. Tests at high temperature (dry)
5. Quick temperature changes
6. Condensation tests.

The position of the chamber is shown on figure 1.

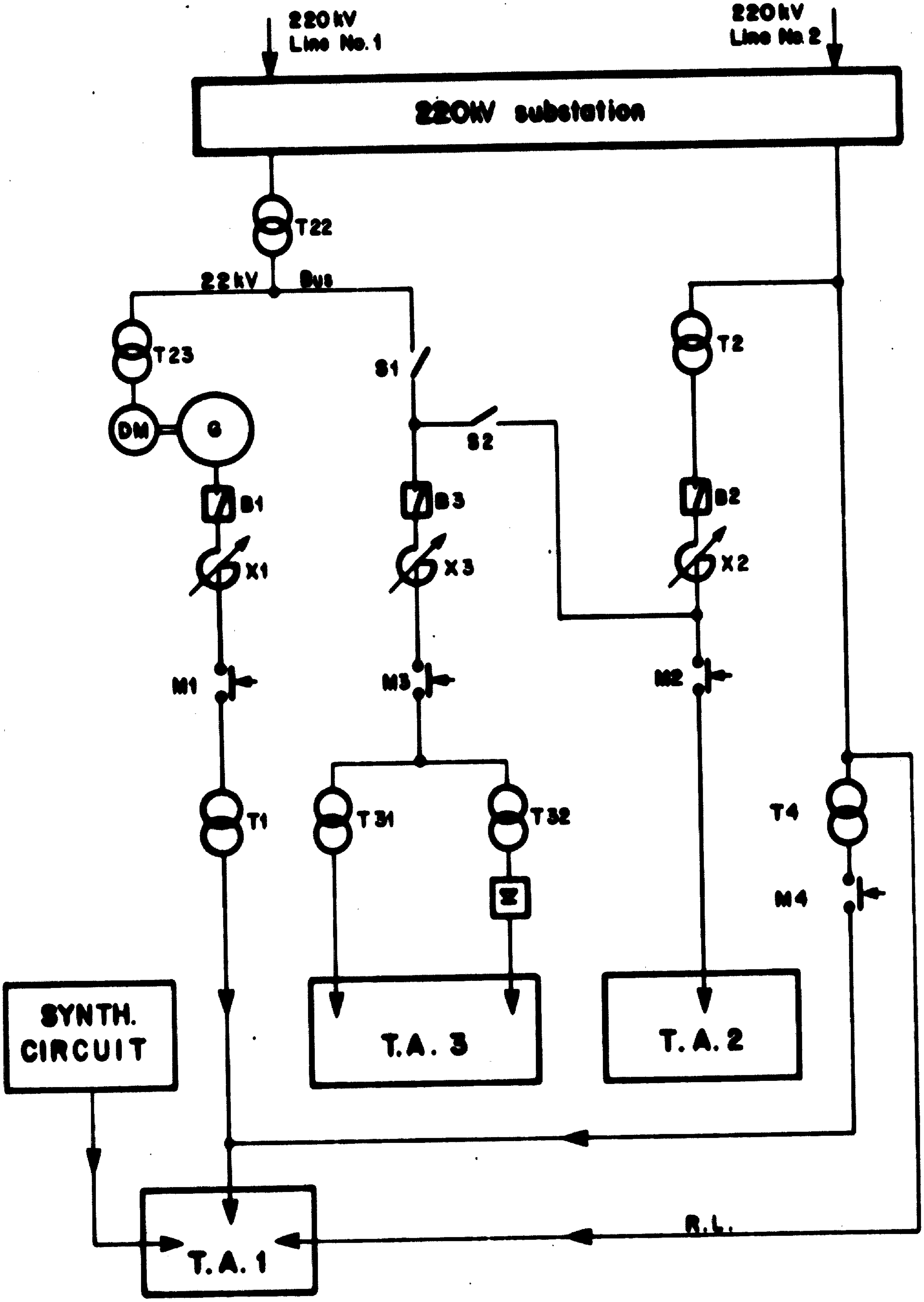


Fig. 2 Basic electrical diagram.

4. BASIC ELECTRIC DIAGRAM

This diagram is shown on Fig.2. It shows three main test circuits and test areas, corresponding to Table No.1. Only the most essential elements are shown.

4.1 2100 MVA test circuit:

- Transformer T_{23} connected to 22KV bar;
- Driving motor DM;
- Main short-circuit generator G_1;
- Back-up circuit breaker B_1;
- Reactor set X_1;
- Making switch M_1;
- Set of 3 short-circuit transformers T_1;
- Test area TA, No.1

4.2 500 MVA test circuit:

- Set of 3 short-circuit transformers T_2;
- Back-up circuit breaker B_2;
- Reactor set X_2;
- Making switch M_2;
- Test area TA, No.2

4.3 High current & direct current test circuits:

- Back-up circuit breaker B_3;
- Reactor set X_3;
- Making switch M_3;
- High current transformer T_{31};
- Rectifier transformer T_{32};
- Rectifier RF;
- Test area No.3.

According to Table No.1, the capacity of this section I will be raised by the addition of the synthetic test circuit during Phase II of construction program, then in Phase III by a second generator-transformer set (not shown on Fig.1) and finally in Phase IV, by a 5000 MVA transformer T_4.
No extensions are foreseen for the test sections No.2 and No.3.

4.4 The main ideas incorporated into this diagram are the following:

a) The three test circuits, specified above are completely independent and may be operated simultaneously, giving the station a remarkable flexibility and effectiveness. Compared with the basic diagram shown in the terms of reference, it can be seen that in the latter, the two generators are connected to a common bus, only one reactor set and one making switch is provided, and different transformers and test cells are connected to the same secondary bus as well. In this way, the advantage of having two separate sources, two transformer sets and several test cells is completely lost because they cannot be used independently and simultaneously due to the common elements of the test circuit.

The cost of a few additional elements required such as X_2, M_2, B_3, X_3, M_3 and even the direct current facility T_{32} and RF, will be over compensated by the substantial savings obtained in replacing the 500 MVA short-circuit generator as per the reference proposal by the transformer set T_2.

We recommend the diagram of Fig.2 which gives a much higher flexibility and effectiveness than the diagram proposed in the Terms of Reference since our diagram permits making direct current tests for the same cost.

b) The test circuit No.3 can be supplied either from 22 KV bus or from secondary T_2 via B_2 and X_2.

The supply from 22 KV bus will be used mainly for dynamic tests and short-time thermal tests, via high current transformer T_{31}. In this case, the value of the test current will be adjusted by the corresponding reactor X_3.

On the other hand, for interruption tests of L.V. and D.C. breakers, both current and recovery voltage must meet the required values. In this case, supply from T_2 will be used, as the secondary of T_2 has a large choice of voltage values. This connection makes it possible to use just a few big voltage steps on secondaries of T_{31} and D.C. test circuits.

c) The return line RL, combined with the incoming line No.2 offers additional test facilities which were not available in the terms of reference. Using this line, it is possible to connect on the load side of the tested breaker located in the TA. No.1, either an unloaded long line or a short-circuited short-line for line dropping tests. It is also possible to connect transformer T_2 and reactor X_2 on the load side of the same breaker and make an artificial circuit for simulation of different switching operations, such as switching of shunt reactors or reactor loaded transformers, etc..

See Appendix No.2 for possible test circuits.

HIGH VOLTAGE LABORATORY

GENERAL

The High Voltage Laboratory will be used for dielectric tests at very high voltages on such items as the following:

- Insulators
- Capacitors
- Bushings
- Instrument transformers
- Circuit breakers
- Disconnect switches
- Lighting arresters
- Power Transformers
- Reactors... etc..

for system voltages up to and including 765KV RMS.

The dielectric tests will include:

- Lightning impulse tests
- Switching impulse tests (wet and dry)
- Power frequency tests (wet and dry)
- Measurements of partial discharges
- Measurements of radio interference voltages
- Measurements of capacitance and Tan

In addition to the above, one section of the High Voltage Laboratory will be devoted to acceptance testing of power transformers (area 4 on fig.1). Such tests will include:

- Heat run tests

Induced voltage teets
Open circuit tests
Ratio measuremente
Impedance measurements
Impulse tests

LABORATORY DESCRIPTION

The layout philosophy for the High Voltage Laboratory is based on the use of mobile test equipment. Since it is unlikely that the impulse generator and cascade transformer will be used at maximum voltage simultaneously, the building dimensions and costs will be reduced if the equipment is mobile. Air cushions will be used for transportation.

The High Voltage Laboratory will be divided into three principal test areas:

a) <u>High Voltage Hall</u>

This area (area 3 on fig.1) will be devoted mainly to all lig tning impulse, switching impulse, and power frequency tests up to 765KV RMS.

The High Voltage Hall clear dimensions are 44m x 28m x 25m H. The hall will be subdivided (by means of a fence) into two smaller test areas. It will be possible to perform simultaneous tests in these two areas at lower voltages or on small tests objects. When tests are required at maximum voltage on large test objects such as disconnect switches or circuit breakers, the full volume of the High Voltage Hall will be required.

A control room near the centre of one wall will serve to control the two test areas or the complete hall as required. The control room will be located on the ground floor and an observation room will be situated immediately above.

The walls of the High Voltage Hall will form an electromagnetic screen and will be electrically bonded to a copper earth mat which will be buried approximately 5cm. below the surface of the floor.

A 5T. monorail crane will be provided along the axis of the hall for the suspension of the voltage divider. Two 10T bridge cranes will be installed on each side of the monorail. These are required for the suspension of insulators, erection of test objects, installation of bushings, etc..

b) Transformer Test Areas

This test area (area 4 on fig.1) is located adjacent to the High Voltage Hall.

This area will be used for performing tests as mentioned above mainly on power transformers up to 200 MVA single phase. It should be noted that this is not the top limit for transformers which may be tested. Larger transformers may be tested by using the 2100 MVA generator in the High Power Laboratory as the power source.

Transportation and handling:

Heavy transformers will enter the receiving area on special cars or floats either from the railway or the highway. Small loads will mostly be delivered by trucks, into the reception area. A 150T. crane will be installed initially for the purpose of unloading these heavy loads but the building structure will be designed to carry a second 150T. crane at some future date, when traffic warrants.

Test equipment such as regulators, auxiliary transformers, compensating capacitors and reactors for transformer tests will be located outside. The neceeeary power for the tests will then be fed into the building by means of 3 wall bushings.

c) Corona Room

A corona room 11.5m x 20m H. area 6 will be adjacent to the Mounting Hall. This room ia required for partial discharge measurements on capacitors, buehings, distribution transformers etc.. The corona room will be screened and will form a Faraday Cage to prevent interferences produced by external aources.

d) Pollution chamber

A description of functiona of the pollution chamber appears at the end of this section.

e) Outdoor Test Area

The Outdoor Test Area (area 1) will be used for dielectric tests on extremely large test objects such as phase to phase switching impulse tests on high voltage disconnect switches. It will also be used on long duration test projects and it will also help to relieve testing loads on the High Voltage Hall. The control room for this Test Areas will be located adjacent to the control room for the High Voltage Hall.

A 10m x 14m H. door next to the control room will permit the transportation of test objects and test equipment between the indoor and outdoor test areas.

MAJOR ITEMS OF TEST EQUIPMENT

The following items cover the major pieces of test apparatus required by the High Voltage Laboratory. Apparatus required for dielectric testing and also for acceptance tests of power transformers is described.

1- Impulse generator 4 MV, 200 kJ

This impulse generator is required for producing lightning impulses and switching impulses suitable for testing equipment for transmission systems up to 765 kV RMS. The energy rating of 200 kJ will also make the impulse generator suitable for performing impulse tests on large power transformers.

2- <u>Impulse generator 2 MV, 24 kJ</u>

This impulse generator is a lightweight apparatus compared to that described above. It will be used for tests at relatively low voltages on such things as insulators, small distribution transformers etc. It will help to relieve the load on the larger impulse generator and it will also be required for phase to phase impulse tests. This impulse generator rating is similar to that of the impulse generator already existing in LCOE, Madrid. This existing impulse generator could be easily modified to comply with the requirements for the High Voltage Laboratory.

3- <u>Cascade Transformer 1, 2 MV RMS, 1A</u>

This transformer is required for dielectric tests at 50 Hz and 60 Hz on equipment for transmission systems up to 765 kV RMS. The transformer will consist of 3-450 kV units which can be used singly or with 2 and/or 3 units in cascade. This gives a very flexible arrangement since many tests will be made at voltages which require only one or two units.

The transformers will be energized by means of:

a) 1 350 kVA 0-5 kV 1 voltage regulator.
See (N) on drawing 201.

b) 1 300 kVA 0-5 kV 1 Hz, 60 Hz generator.
See (Q) on drawing 201.

The voltage regulator will be used for all tests at 50 Hz.

The generator (driven by a synchronous motor) will normally be used for 50 Hz tests. However, by changing the gear ratio betwsen the motor and the generator, tests may also be performed at 60 Hz.

By having two independent supplies, different cascads transformer arrangements can be used simultaneously in different test areas.

4- Voltage divider 3,5 MV impulses, 1, 2 MV RMS 50 Hz

This apparatus is required for the output voltages of the impulse generators and cascade transformers.

The divider consists of resistors and capacitors connected in series and it can be used for the measurement of waveforms varying from 1/50 μs to 50 Hz. This divider will be suspended upside down from the monorail crane in the High Voltage Hall. This technique will save much valuable floor space.

5- Wavefront Capacitors 10 of 20 000 pF, 500 kV and 6 of 4 000 pF, 500 kV

These capacitors are used in conjunction with the impulse generators. They are normally connected in parallel with the test object and are used for controlling the wavefront duration of the generated surges.

6- Discharge Free Capacitor 600 kV RMS, 1 000 pF

This capacitor is used for measuring partial discharges and radio interference voltages (RIV) during AC testing with the cascade transformers.

7- Compressed Gas Standard Capacitor 800 kV RMS, 50 pF

This capacitor utilises compressed gas as the dielectric. The low voltage measuring electrode is almost completely surrounded by the High Voltage electrode. This design provides a very stable and loss-free capacitance. It is used for precision voltage measurements, calibration of potential transformers, voltage dividers and for the measurement of capacitance and Tan δ of capacitors, bushings etc. This capacitor will be suitable for tests on equipment for transmission systems up to 750 kV RMS.

8- Wet Test Apparatus 1,25 - 5 mm/min.

This apparatus is required for the production of artificial rain during switching impulse tests and also during AC tests.

It will be suitable for testing objects as large as disconnect switches for 750 kV systems. (See Photo No. 20).

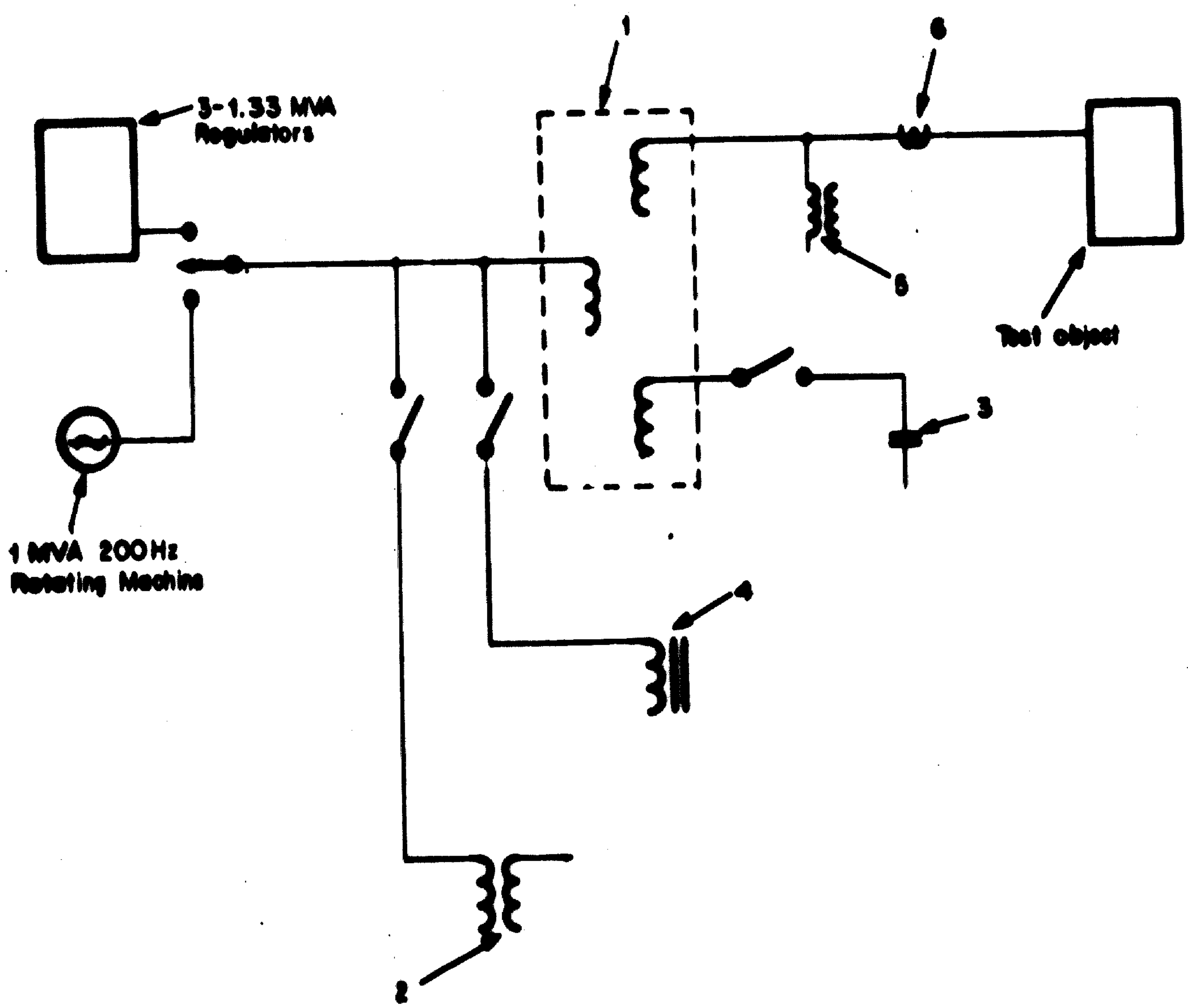
Demineralised water will be mixed automatically with the local supply water to give a range of resistivities for the mixture varying from approximately 50 Ωm. to 250 Ωm.

TESTS ON POWER TRANSFORMERS

A group of 3-1, 33 MVA, 1ϕ voltage regulators will be used as the power source for tests on large power transformers. These are required for all tests at 50 Hz. If occasional (once a year) tests are required at 60 Hz, the power can be supplied from the generator in the High Power Laboratory.

The following diagram indicates the basic test arrangement for tests on power transformers. The various pieces of test equipment are described with reference to this diagram.

ARRANGEMENT OF MAJOR EQUIPMENT FOR THE TRANSFORMER TESTING AREA



NOTE: All requirements are based on equipment needed to tests a 200 MVA 1 ϕ transformer with HV winding for 765 kV with a BIL of 2,1 MV.

1.- THREE PHASE COUPLING TRANSFORMER

Primary winding: - 5 kV delta connected

- 8 MVA at 50 and 200 Hz.

Secondary winding:- 20 to 100 kV delta or Y connected

- 78 MVA at 50 Hz

- not less than 8 MVA at 200 Hz.

This winding has a off-load tap changer which permits:

Delta conn.		Y conn.	
19 steps of 1 986 kV	20 kV ... 100/ 3 kV	20 3 kV ... 100 kV	19 steps of 3,44 kV

Tertiary winding:- 11,6 kV delta connected

- 20 kV Y connected

- 70 MVA at 50 Hz

- no specific rating at 200 Hz.

This winding will normally be used Y connected. When it becomes necessary to have maximum regulation from 5 to 12 kV, then the tertiary winding delta connected can be used as output winding by a temporary connection to the entrance bushings.

With full 70 MVA of compensating capacitors on the tertiary winding, this transformer could perform a heat run on a 600 MVA 3φ transformer for the 765 kV system providing that the impedance of this transformer is not above 13%.

2- SINGLE PHASE COUPLING TRANSFORMER

This transformer is used during induced voltage test when it is necessary, in order to minimize inter-turn stresses, to fix the neutral of a Y connected winding at a voltage not exceeding its low frequency insulation level.

It will also be used as a single phase source from one of the regulators.

Primary winding: - 5 kV
- 1,33 MVA, 50 and 200 Hz

This winding will have a three position selector switch which will give an adjustable HV to LV ratio.

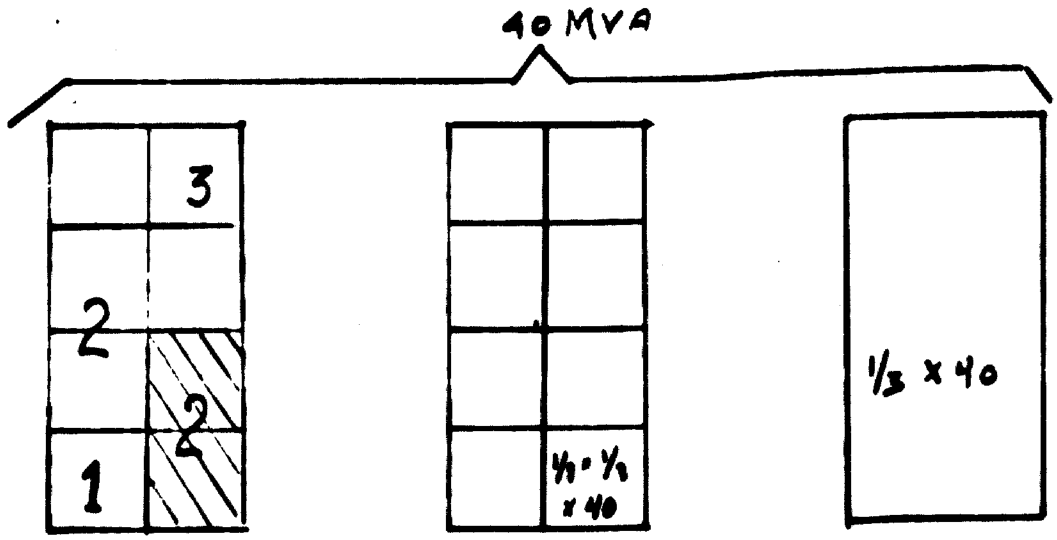
Secondary winding: - 16,6 - 20 - 25 - 33,3 - 40 - 50 - 60 - 75, 80 and 100 kV
- 1,33 MVA at all nominal voltages except at 60 and 75 where it will be 1,0 MVA.

This winding consists of 4 windings that can be connected series or parallel with exterior links. It will be mobile on air cushion.

3.- COMPENSATION CAPACITORS

40 MVAR

Connected Δ or 1 ϕ all in parallel 20 kV when connected Δ or parallel 1 ϕ will consist of 8 steps of 5 MVAR 3 ϕ.



1 → 1/3 x 40 x 1/8

2 → 1/3 x 40 x 2/8

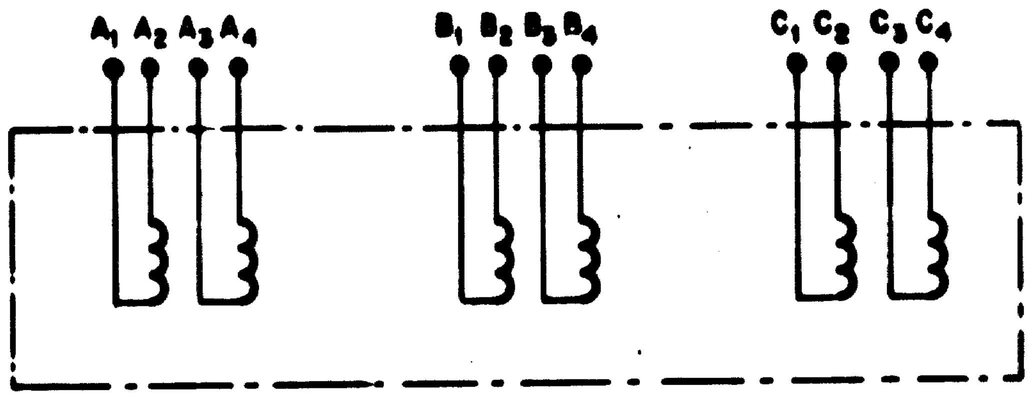
3 → 1/3 x 40 x 3/8

As can be seen, by choosing the groups of capacities, 0 to 40 MVAR in steps of 5 MVAR can be obtained with 3 ϕ arrangement. Also when operating 1 ϕ, 0 to 40 MVAR can be obtained in steps of 1/3 x 5 MVAR.

4.- COMPENSATION REACTANCE

3 single phase units in same tank for a total capacity of

3 MVAR - 200 Hz.



Each winding is rated 2,5 kV 0,5 MVAR. This arrangement will

give these possibilities.

	1 ϕ	2,5 kV	1 MVA	2 MVA	3 MVA
	1 ϕ	5 kV	1 MVA	2 MVA	3 MVA
Y	3 ϕ	2,5 x 3 kV	2,5 MVA	3 MVA	
Y	3 ϕ	5 x 3 kV (5 kV)	3 MVA (1 MVA)		
Δ	3 ϕ	2,5 kV	1,5 MVA	3 MVA	
Δ	3 ϕ	5 kV	3 MVA		

5.- **POTENTIAL TRANSFORMERS**

- 2 sets of three single phase units
- precision ± 0,1%
- phase error ± 1 minute

a) Ratios: 1500, 800, 400

ex: $165/\sqrt{3}$ kV to $110/\sqrt{3}$ Volts

b) Ratios: 200, 100, 50

ex: $22/\sqrt{3}$ kV to $110/\sqrt{3}$ Volts

6.- **CURRENT TRANSFORMERS**

- 2 sets of three single phase units
- precision ± 0,1%
- phase error ± 1 minute

a) Ratios: 400, 200, 50, 20

ex: 2000/5 A

b) Ratios: 10, 5, 2, 1, 0.5

ex: 50/5 A

POLLUTION CHAMBER

In this test area insulators will be subjected to high voltage tests while exposed to a salt fog atmosphere.

By reducing the salinity of the aqueous solution used for the fog, the maximum value at which the insulator will not flash over is obtained. This salinity is taken as the criterion of performance, and comparison with the results obtained by natural-pollution testing shows that it can be taken as a valid guide to the performance of the insulator in service conditions.

The artificial-pollution method has been used as a research tool for comparative tests of insulators and is proposed for use as a standard test.

DESCRIPTION OF THE ARTIFICIAL-POLLUTION TEST METHOD

The insulator is installed in its normal working position in the test chamber after having been thoroughly washed, dried and slightly heated in closely reproducible conditions. It is energized at its maximum normal working voltage, and the chamber is then filled with fog from jets fed with salt water and compressed air. The salt-water droplets are similar in size to those in a natural fog. If, under these conditions, the insulator flashed over within an hour, the test is repeated using a solution of a lower salinity. The maximum salinity at which the insulator will not flash over within the hour is taken as the criterion of performance:

the higher the value the better the insulator. Because the results show some statistical variation, three withstand tests out of four at any salinity are taken as establishing a withstand value.

SALT SOLUTION

The salt solution shall be made up to the required concentration using mains water and pure dried vacuum salt. The temperature of the solution shall be kept constant at 18-20°C. It is convenient to measure the concentration of salt by measuring the conductivity and temperature of the solution.

It is recommended that the salt-solution concentration used should be one of the values 0.25, 0.5, 1, 2, 4, 8 and 16%. Other intermediate values may be used where necessary to distinguish between insulators which would otherwise have the same withstand salinities.

Salt-solution concentration or salinity

The percentage salinity is the weight of salt in solution divided by the weight of the solution and multiplied by 100.

Withstand salinity

The withstand salinity is the maximum salinity of the liquid making up a fog which the insulator will endure without flashover for at least three out of four tests.

Pollution tests are usually performed at normal working voltage, however it was decided to apply a factor of 1.25 for research purposes. Consequently, the following Table shows the maximum test voltage for three system voltages.

System voltage	Phase voltage	Max. test voltage
138 kV	80 kV	100 kV
220 kV	127 kV	159 kV
380 kV	219 kV	274 kV

A current of 1 A is considered to be an acceptable value for the nominal load current at 220 kV to ground. The transformer rating will therefore be:

: (220 x 1.25) x (1 x 1.25) kVA
: 343.7 kVA

This was rounded off to 350 kVA - 1∅

This transformer will be fed by a voltage regulator 22 kV-350 kVA - 1 phase.(See A1 on drawing 201 and Second Equipment Report, HV25.)

By specifying two primary windings which can be connected either in series or in parallel it will be possible to obtain the full output of 350 kVA at either full output voltage or half output voltage and therefore the versatility of the transformer will be increased.

During pollution testing, surge currents may exceed 1A peak without necessarily developing into flashovers. It is therefore important that the regulation of the transformer and regulator should not be so great that flashover is inhibited by a drop in the voltage or a distortion of the voltage waveshape.

The minimum short circuit current normally acceptable for pollution tests is 8 - 10 A. Therefore, a short-circuit current of 12.5 A has been specified for the transformer plus supply regulator.

The test transformer will be situated inside the pollution chamber and will be a steel tank design with a conventional porcelain clad bushing. The surface of the bushing must be covered with grease in order to prevent flashovers. The grease will have to be cleaned off and replaced approximately once per month.

The fog atmosphere is produced by forcing a saline solution and compressed air simultaneously through a special nozzle arrangement.

The pollution chamber 11 m x 12.5 m 12 m approx. would be suitable for tests on insulators for system voltage up to 380 kV. For aesthetic reasons the height of the room can be maintained to the same elevation as the adjacent Corona Room.

The required air pressure is approximately 685 kPa (7 kg/cm^2). The total flow of liquid is approximately 0,5 l/sec. The total liquid content of air is approximately 5.3 g/m^3.

Due to the corrosive nature of the salt fog, special precautions will be necessary for the protection of the walls, ceiling, floor metallic fittings, etc.

A 2T. monorail crane will be required inside the pollution chamber for the erection of test objects or for the suspension of insulators under test.

FINAL

BUILDING REPORT

VOLUME II
CIVIL ENGINEERING

TO

UNIDO (CONTRACT 72/17)

FOR

SPAIN ELECTRICAL TESTING AND EXPERIMENTATION TESTING

IN

MADRID

SPAIN

Lalonde Girouard Letendre & Associates Ltd.
in Association with IREQ
Montreal, Canada

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CIVIL ENGINEERING

V- CIVIL ENGINEERING

1. LOCATION ON SITE

1.1 Definition

A general implementation of the future buildings has been reached in accordance with the contract objectives and is described under Section IV. It now becomes necessary to decide where such a complex should be built or if a site has already been chosen indicate where it should be situated on this site. Therefore, this activity is defined as the location of the buildings on the site together with related services.

1.2 Scope

This search for the best layout considering both present and future total development has to weigh the various alternatives in relation to the function of each part as well as of the whole, of the environment and of all the services related. It requires a knowledge of the land, the movement of people and goods, the social impact on the community, the personnel that will be affected, the industrial and educational implications.

1.3 Selection Criteria

In the selection of the site we are governed by the following main criteria:

1.3.1 Economy

Access and egress by road
Railway requirements
Earthworks (geology & Pedology)
Construction foundations
Other services.

1.3.2 Operation

Operational and testing requirements
Topography of site and relation to overall development
Future needs and land use
Environment

1.3.3 Aesthetics

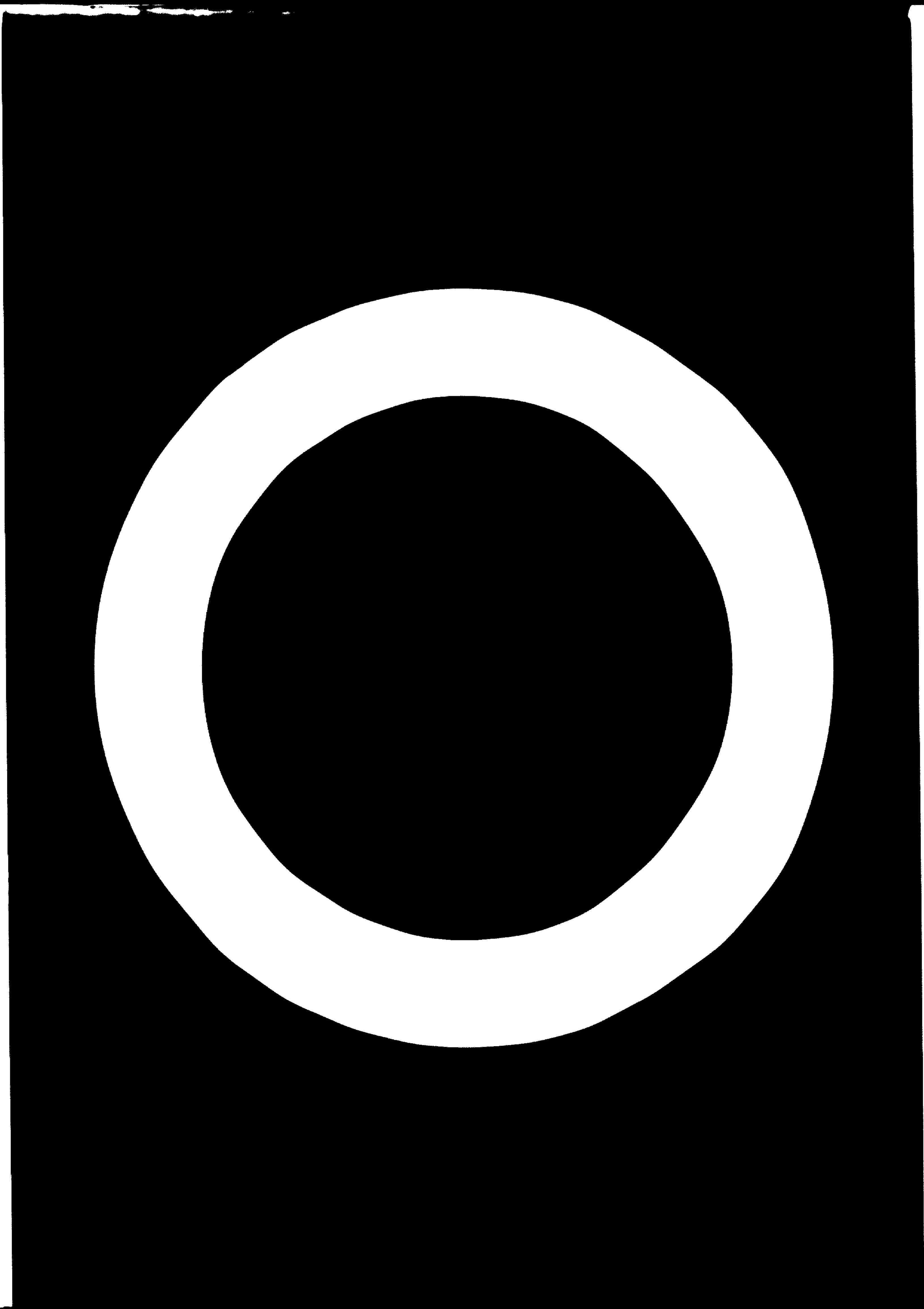
Architectural considerations for the total development
Environment
Social aspects
Availability of materials.

Since these Laboratories are to be built on a university campus, we have been aware early in the study that the building layout must be considered under two aspects: educational and industrial. It is believed that the Architectural Contractor will be in a better position while developing the total land use plan to determine which aspect will predominate.

The Laboratories do not require the architectural treatment that might be envisaged for the institutional complex, on the other hand the potential role of the industrial development and the contribution of electricity in such matters should be expressed eloquently. A prestige venture such as the actual Laboratories now in their development process should be located and treated so that they would be referred to advantageously as an attractive landmark for the region.

Because of a proposed expressway adjacent to the site we believe that this objective can be achieved, provided the Laboratories are built high enough on the land so they can be seen from any angle. However, we are not recommending that they be located in an area where they may become a distraction for the expressway users and an eventual source of accidents.

In this undulating land, there will be deep cuts and high fills. We have looked for a solution where in their final location large portion of the buildings would not have huge embankments as background. Our recommended location is in the less undulating portion of the land and as seen from the expressway the inevitable embankments will be less conspicuous.



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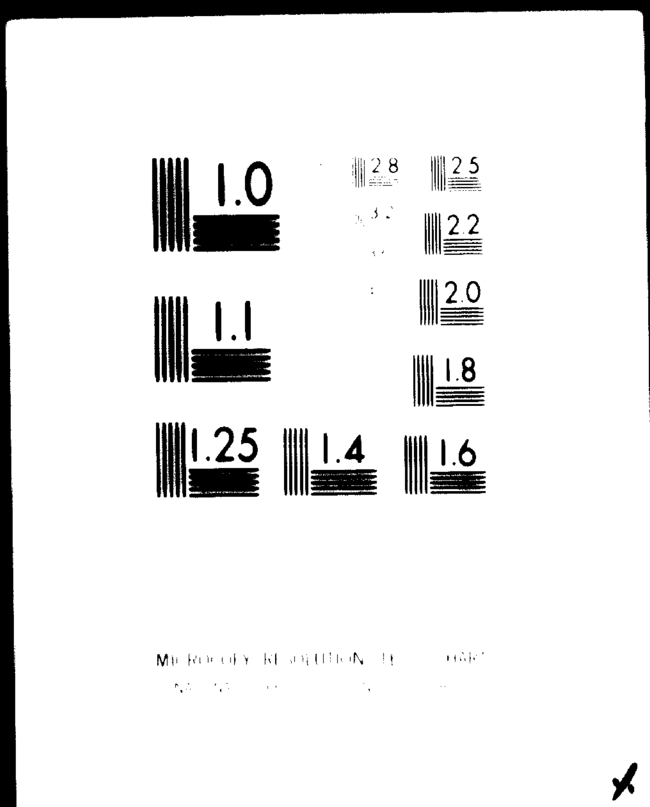

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1.3.4 Construction

Budget
Cost of materials
Services during construction
Construction period

1.4 General Layout Plan

The general layout plan bearing our number 412-001 which is included with this report does not necessarily meet all conditions set forth in the selection criteria. We would have preferred a more prestigious location where it is believed the main administration buildings of the Escula Superior will be built. It is not our intention to discuss this point of view in this Building Report, and we accept such choice to be wise. Moreover, less damage will result in the total development of the land since with the Laboratories on the summit the railroad would split the property. This is very important, considering there is a 40 metre variation in the contours, and the resulting longitudinal profile requirements that have to be dealt with for the railroad. Unavoidable deep cuts and high fills would have definitely divided the land in two. It would have been necessary to foresee some underpass or overpass to permit free movements from one side of the railroad to the other.

Our recommended choice will not cause such segregation. The selected location offers sufficient area for future expansion and caters well to the immediate needs. It will be disadvantaged by the embankments in the northeast area hiding therefore a portion of the High Voltage Laboratory. Another disadvantage is the necessity of diverting an existing creek. It will be of easy access for both road and rail.

After careful examination of the site topography three locations appeared possible for the Laboratories. These are shown on drawing 412-002 and are numbered 1, 2, 3.

Site No.1

The land on this site is elevating rather steeply. With different elevations of main floor we have tested this site and came out with an excessive excavation between 300 000 and 450 000 cubic metres. At the best building elevation, the railroad would have been faced with heavy fills, the access road starting from the future expressway would have been much longer. The construction of the buildings proper would have necessitated high foundation walls as it is not recommendable to build on disturbed soil of fills.

Site No.2

Is the best location on the whole property especially in relation to the selection criteria that we have already set forth. It is a prestige site, so much after discussion it was decided to abandon it in favor of some more prestigious building that will no doubt be built on these premises. The volume of earthwork remains acceptable, the access route is short and the railroad has to be a little longer than on other sites. Because of the elevation at which the main floor should be built the railroad fills in the lower portions of the land will be rather high.

Site No.3

Though this location will not be as advantageous on a prestige basis and on the aesthetic criteria formerly defined, we came to the conclusion after study that it was the best solution because it offered the large area required with the minimum earthwork, good access and egress, and meeting the railway requirements. It will necessitate the diversion of the existing creek. Should budget permit, this diversion could be piped and thus offer the usage of another tract of land 20 metres wide. This in turn would allow the buildings to be moved another 20 metres in a south-westerly direction. This move should substantially reduce earthwork in the northeast direction of this location but may complicate the railway location.

1.4.1 Roads:

Our layout is showing the roads that are needed around the Laboratories only as a guide. This layout can be modified to suit the requirements of the overall area development.

The road system is to be designed by the National Consultants, it should be of a design sufficient to withstand the heaviest loads that will be delivered to the site from any surrounding expressway, highways, roads, etc. This maximum load is in most cases subject to bridge capacity. The only place where loads up to the design capacity adopted within the Laboratories themselves will be met outside, is at the Outside Testing Area where a direct connection for transfer of heavy loads on air bearings will be built between the Mounting Hall of H.V.L. and this Outside Testing Area.

1.4.2 Watertable

Being closer to the creek the water table may be at a higher level a very important factor in the grounding of the various Laboratories, depending on the soil resistivity and the water table grounding may affect a very large volume of earth or rock. Results of boring are given in Appendix No.1.

1.4.2 Future expansion:

Sufficient space had to be allowed from certain buildings or areas for future expansion as well as for other needs, this is why at places we have chosen to remain at a distance from the property line. The distances we have kept are minimal and we would not recommend that they be diminished.

Furthermore it was resolved at a meeting in Madrid that sufficient space should be foreseen for the eventual construction of a High Voltage Laboratory of 1200 KV testing and research capacity.

1.4.4 Land acquisition:

It may be expected that when the expressway is built some land residue after expropriation may become part of the project's property, specially if this expressway is to be of limited access.

1.4.5 Creek diversion:

In order to minimize the volume of earthwork and take advantage of the flatter land, we have recommended a deviation of the existing creek to a point as close as possible to the property line. We recommend, where the building foundations will fall in the site of the abandoned creek, that they be laid on undisturbed soil. Because of the heavy loads imposed on the foundations there will be a great danger of settlement if they are laid on a fill. The diversion should have the same dimensions as those of the existing facilities.

Special precautions are recommended in the backfill of the abandoned creek. Material selected for closure shall be of a quality that will prevent any seepage. There will always be a danger of infiltration into the old bed whenever a head is created in the canal. Under buildings it will be necessary to include drains and sump pumps deep enough to take care of this possible infiltration.

2. TRANSPORTATION

In accordance with article 3.01 par. d) iii) the Government is to inform the Contractor of the standards of road construction, bridges, railroads so that he can foresee some of the limitations which will be imposed on the design.

In the course of our performance and to understand fully the problems involved we had to go beyond the stipulations of the contract. Just foreseeing some of the limitations imposed on design are not enough, we had to consider all aspects of transportation related to the laboratories, because their operation is essentially based on transportation. Two main modes of transportation had to be considered: a) railroad, b) roads. The maximum load to be transported on highway is approximately 100 tons: on the railway this maximum becomes 300 tons. It appears therefore that all heaviest loads destined to the Laboratories will be delivered by the railway system.

2.1 Railroad

We are recommending that the main railway line enters the Mounting Hall where the shipment will be unloaded by the 150-25 ton overhead crane. It is not acceptable in our concept to proceed to testing and to any internal movement of equipment under test without removing such equipment from its delivery car or float. This crane should have for the beginning of the operation a capacity of

150 tons with a 25 ton auxiliary. Another crane of the same capacity can be added later when conditions dictate, giving you the 300 tons capacity of the railway and of the heaviest load of expected delivery. The building and crane runways are to be designed accordingly. When ordering the second crane, it will be necessary to include a lifting beam of 300 tons capacity.

Since heavy transformers are usually travelling on special design cars of the multiple axle type, which are pulled rather than pushed, it is recommended that a siding be built as close as possible to the point of delivery, so that the locomotive may be capable of either pushing the load to enter the Mounting Hall or change its position for the long trip. It is also practical to have some loads unloaded at the siding, to that effect it may become necessary to install an unloading platform. Locomotive movements have to be studied and turning possibilities provided.

The oil for transformers and the oil system can also be delivered by rail. We have shown the rail extending for approximately 65 metres on the opposite side of the entrance. At this point, a door is needed anyhow so it is only a matter of installing the rails on a concrete pad to assure a better foundation and extending the line in common with the road. This extension may be very useful in many circumstances.

On both side of the building as well as inside, the railway should be kept on a horizontal profile that is 0.0%; in the siding a grade 0,15 to 0,25% may be maintained. Where the rails are built inside as well as outside on a concrete pad special drainage precautions have to be incorporated. These details will appear on the structural drawings as well as on the drainage drawings. Some special care will also be required for grounding details which are shown on drawings prepared by the electrical division. Where pavements abute to the rails, we recommend a special rail arrangement so that the pavement can be well shouldered and properly tamped on edges.

2.2 Roads

The proposed expressway to Madrid adjacent to the property is of paramount value in the selection of this site. It is expected that the bulk of the activities of the Electrical Testing and Experimentation Centre will be road-based. Though we have no confirmation on the matter we were made to understand that the maximum weight of any object delivered by road will be around 100 tons.

Because of the activities of this Centre, we recommend that a special access and egress from the expréssway be built with direct connection to the Laboratories and Administrative Building. This system can be connected to the campus network if so desired. In that case, extra precautions and special signing will be required because of the potential danger of the numerous high voltage installations. All areas where danger exists should be properly fenced in.

The road layout we have indicated is functional but submitted only as a guide and can be modified to suit other requirements. At the date this report was prepared, we did not have on hand the geometric design, the profile and other elements of the proposed expressway, which are needed to complete a more thorough study. It seems edivent that longitudinal profiles have to show grades as low as possible. Due to the topography of the land, it appears that the maximum grade may reach around 4%. This maximum is not recommendable because of the heavy loads anticipated and of the expected low speed on the premises.

From the main entrance, we have shown an access to the outside Testing Area, an access to the Mounting Hall where the roadway joins the railway, an access to Synthetic Testing, an access to the High Power Testing Area and to receiving, an access to the Administrative Building and the adjoining parking lot, as well as other service roads. The parking lot should accommodate approximately 50 cars. A parking space for 5 vehicles should be included in front of the Administrative Building for special visitors.

Because of the heavy loads anticipated, we recommend that roads have a concrete foundation topped by tibuminous concrete. They should have curbs (concrete or stone) and drained through gullies connected to the storm sewerage system. It is also recommended that a good lighting and signing system be installed. Some very special effect can be obtained through the lighting of the buildings in combination with the road system, parking, etc..

2.3 Handling

2.3.1 Foreword

From what has been said previously, it is clear that as soon as a heavy load has been unloaded from its carrier, some form of transportation has to take over, in order that this equipment can be moved around for the various tests it is intended to undergo. For such movements we recommend the usage of air bearings. After careful studies supported by a series of tests on platform built specially to that effect it was decided that this system be adopted in all of IREQ's Laboratories. This decision was indeed a good and sound one. Since the laboratories have been in operation many heavy loads have been moved around on these platforms and it is considered unanimously as the system of excellence working even better than expected. Moving heavy loads and positioning them for any purpose is a very simple operation. Moreover, all equipment has been ordered and supplied on the same type of platform with air bearings.

For this system two things are very important:

a) The floor finish has to be very smooth;

b) compressors and an air distribution system have to be incorporated in the buildings. Outlets are provided at regular intervals everywhere we want to travel and a air hose mounted on a reel assures the flexibility of connection between the load and the outlet of the system.

The movements of testing equipment together with equipment under test are of the greatest interest in such Laboratories mainly because of the dimensions and the weight of the loads involved. At the outset it is rather difficult to forecast the number of trips, their volume and weight, the path that will be followed and the intensity. Nevertheless, relying on past experience as well as on the objectives of these Laboratories, this is not like an industrial process or a repititive function, it is known that the system must be as flexible as possible while provisions must be made to handle the heaviest loads expected from the Laboratories design parameters.

Such decisions, as may well be understood, are of the greatest importance when considering foundations and structural elements of the buildings as well as those of supporting systems and the cost factor.

The transportation or handling system is faced with two main components: a) Horizontal movements b) Vertical movements. These in turn will affect the size, dimensions and capacity of the Mounting Hall, the Storage and Depot Areas and finally, the various inherent services in all other areas.

2.3.2 Horizontal movements

The Building Report is based entirely on the usage of air bearings for the movement of all heavy loads and rubber-tired wheels for small equipment. It is expected that the majority of equipment to be tested will reach the site by road for loads up to 100 tons. The heavier pieces will be delivered and returned by rail to a maximum of 300 tons. Because of the lapse of time required to complete the test or a series of tests on any equipment to be tested, it is understandable, as we have mentioned previously, that any special float or railway car cannot be immobilized during such long periods as demurrage charges would increase the cost terribly, without mentioning the encumbrance of these special units. Moreover, in many cases, such as transformers, they may be delivered without oil, insulators or other components because of weight or clearance limitations. It is therefore necessary to consider that every shipment has to be unloaded from its carrier.

We will see in the vertical handling section that we recommend the usage of overhead cranes for unloading and reloading. There are of course, depending on the carrier, other methods of unloading which we leave to the future operators. Whatever this unloading method may be, the system of air bearings recommended for horizontal movements is adaptable to any piece of equipment and offers the versatility that we have considered a major criterion in the selection of horizontal handling method.

Modular platforms

It requires prefabricated platforms with air bearings, incorporated surge tanks, distribution piping, valves and controls. The size of the platform has to be determined from a small size to an eventual combination of such units to form a larger platform capable of handling the largest delivery. The design must include the possibility of bolting small sections together. In this case, connection for air between sections must be through a main pipe and flexible hose couplings. A typical arrangement is shown on drawing No. 412-302. The platforms should be equipped with recess jacking points so that an air bearing may be removed under load, should there be a puncture. It must also be possible to remove a platform from under a transformer and vice versa.

<u>Air bearings</u>

We recommend the usage of air bearings as designed by Aero-Go Inc., Seattle, Washington, U.S.A. This company offers a caster made of neoprene and nylon very resistant, a self pressure regulating system, a centre landing pad (see pages 89, 90, 91 and 92. It can be ordered mounted on an aluminum plate approximately 3mm thick. This plate is secured to the platform by bolted flat bars (see Photo No. 2). Some retractable wheels may be added to the structure for steering or moving around when not in use. This is not a necessity and it adds up to the cost. For pulling a standard shop mule is all that is needed with a capacity of around 2000 kilos of drawbar pull. The connection between mover and platform should be rigid. When moving large objects it is recommended to use another machine as a holder. This is an extra precaution because if anything should go wrong with the puller, by closing the air valve, the whole load will immediately come to a complete stop.

Air supply

From the central air compressor station a system of piping and valve is incorporated in the building as described under mechanical division. The outlets are placed at strategic points in every area where air bearings may be used. A reel with a sufficient length of air hose is utilized to connect from outlet to platform and allow a certain travel before a connection change must be made.

Floor finish

The floor finish is to be very smooth as specified under structural division. Special precautions have to be taken at joints or other similar break in the floor from which air may escape and deflate the bearing. In general, as an example, a piece of heavy polyethylene taped all around on the floor will be sufficient to go over a catch basin. When going over rails a piece of masonite solidly taped on the floor will also do the trick. This system is very flexible as it allows any movement in any direction and requires the minimum of energy. The old rail system is very inconvenient as it limits the workable area, requires more energy for movement, requires more complicated platform, pinpoints the loading with the ensuing structural and foundations requirements plus the grounding and shielding extra precautions. The slope in the floor should not exceed 0,50%.

Maintenance

Maintenance is very simple since it amounts to keeping the floors clean at all time and a revision of the casters every now and then, depending on usage, to remove any solids that may have adhered as well as oil and grease. The pressure regulators should be checked every six months, especially as water and oil are often found in compressed air which may affect their operation.

Outside areas

The same system will apply for movements to the exterior of the buildings. This means that the outside Test Areas have to offer the same finish as the interior floors and be provided with the same services as compressed air, etc. Special passage and doors have been included in the design to meet these conditions.

2.3.3 Vertical movements

When speaking of vertical movements, we are faced with two main objectives:

1) Loading and unloading of goods received as well as mountings for testing and experimentation;

2) Supporting parts of equipment or components during test.

In the High Voltage Laboratory nearly all mountings will be made in the Mounting Hall adjacent to the Main Testing Hall. In the High Power Laboratory, we have suggested several smaller mounting areas. In this last case most of the mountings are smaller than for the High Voltage Laboratory..

Overhead Cranes

For proper handling, we have equipped all these mounting halls with overhead travelling cranes. A list of these cranes is included giving their capacity and the various speeds for proper operation. In some cases, these speeds are dictated by the precision required in the operation. We would not recommend increasing such speeds. The overhead travelling cranes will, in most cases, be operated by a pendent push button station, except for the 150-ton crane which should be cab operated and the two 10-ton cranes in the Main Hall of the High Voltage Laboratory which should be radio-operated for better efficiency and also because of the height involved.

In the Building Report we have not included any specifications for overhead cranes as these are considered as forming part of the fixed building equipment, which is to be specified by the Architectural Contractor and his group. However, if so desired we will put at your disposal a model of the specifications that were prepared for IREQ for public tendering on similar cranes.

Besides overhead travelling cranes, we have monorails, jib cranes and fixed points. The recommended monorail in the Main Hall of the High Voltage Laboratory is a very worthy innovation. This monorail is designed to hold permanently the voltage divider. In other laboratories, this was done by an ordinary hoist as a fixed point. It was found that in many instances the possibility of moving this equipment along the central axis of the Main Hall offered sufficient advantages to warrant the expenditure of installing a travelling hoist of the monorail type. The monorail recommended in the Rotating Machine Hall is only for service on small parts. We have estimated that it would be too expensive to install an overhead crane of sufficient capacity to remove the rotor for periodical inspection as compared to sliding the rotor on rollers for this purpose. A removable panel has been foreseen in the wall for sliding the rotor out and from where a mobile crane can lift all the rotating machine components for expedition to the revision point.

Fixed points

The fixed points are composed of ordinary rope hoist or chain blocks of light capacity but long reach, installed in the roof of various areas for the purpose of supporting portion of a mounting during test.

Besides these fixed points, it will be necessary to stock nylon cords of various sizes for mounting purposes. Though, these mountings may vary considerably, it is recommended to leave holes of 10 x 10 cm in the ceiling decking at very 8 m& in both directions. For this purpose, the permissible load is not to exceed 50 kg.

Elevator

Because the ceiling of the Main Testing Hall of the High Voltage Laboratory is designed to allow access by operators for a number of good reason, a small elevator is included for such easy access as shown on drawings adjacent to the transformer testing area. To meet security principles a stair is also indicated. These areas have to be closed with doors, which should not open when a test is in progress, especially in the Main Hall. This is indicated in the Electrical Section.

Mobile Equipment

To complete the handling system, some portable tubular platforms will be required, they form part of the small equipment, easily available and which should be procured as the needs are met by the various activities of the Laboratories. It will also be necessary to equip the Laboratories with a self-propelled telescoping platform which is very practical for access to all kinds of mountings and equipment, specially in the highest areas. Examples of this type of equipment are given herewith. (See Figure No. 1 and No. 2).

For the outside Testing Areas, it may be necessary to utilize a crane to complete a mounting or for any other reason. We have found that self-propelled cranes with telescoping boom are the answer to this need. On the other hand, they are very expensive and we have not recommended the procurement of such machines, but rather resort to rental which should prove much more economical specially when you consider the number of hours of effective utilization.

OVERHEAD CRANES & HOISTS

1- **Erection & Transformer Test Area** (Areas Nos C-101 & C-103)

Nominal capacity:	
Main hoist	: 150 tons
Auxiliary hoist	: 25 tons
Approximate speeds:	
Main hoist	: 1,2 m/min 5 speeds
Auxiliary hoist	: 8 m/min 5 speeds
Trolley	: 12 m/min 3 speeds
Bridge	: 25 m/min 3 speeds

2- **Corona Room** (Area No. C-104)

Nominal capacity	: 2 tons
Speeds:	
Hoist	: 2 & 6,5 m/min
Trolley	: 9m/min
Bridge	: 9m/min

Type: underrun
Operation: pendant push button station.

3- **Pollution Room** (Area C-102)

Nominal capacity	: 2 tons
Speeds:	
Hoist	: 2 & 6.5 m/min
Trolley	: 9m/min
Type: monorail	:

Operation: pendant push button station
Special: corrosive atmosphere - totally enclosed motor - gearbox, etc.- Stainless steel track.

4- <u>High Voltage Test Areas</u> (Areas Nos. A-104 & A-105)

2 cranes - Nominal capacity : 10 tons

Speeds
Hoist : 1,3 & 10m/min
Trolley : 10m/min
Bridge : 30m/min
Type: underrun
Operation: remote radio control
Grounding very important.

For certain mountings often a basket is hooked to these cranes from which an operator can work. In such cases, extra precautions are recommended for the security of the worker. It may even be necessary to hook these cranes on the emergency power generator. So that in case of power failure an operator may not be left suspended in the air for an indefinite period until power is restored.

5- High Voltage Test Area (Areas Nos A-104 & A-105)
<u>Synthetic Test Hall</u> (Area No. B-101)

2 units - Monorail
Nominal capacity : 5 tons
Speeds:
Hoist : 3m/min
Trolley : 10m/min
Type: monorail - low headroom
Operation: one wall mounted push button station at each end.

6- <u>Shipping and Receiving Area</u> (Area No. D-108)

1 crane - Nominal capacity : 10 tons
Speeds:
Hoist : 7 m/min
Trolley : 8m/min
Bridge : 8 & 25m/min 2 speeds
Type: overrunning
Operation: pendant push button station.

7- <u>Assembly Rooms</u> (Areas Nos. F-106, F-107, F-108 & F-109)

4 units (one in each room)
Nominal capacity : 5 tons
Speeds:
Hoist : 1m/min & 10m/min 2 speeds
Trolley : 8m/min
Bridge : 8m/min
Type: underrunning
Operation: pendant push button station.

8- <u>Test Cells</u>(Areas Nos. F-114 & F-115)

2 units jib cranes - nominal capacity : 2 tons
Speeds:
Hoist : 6m/min
Trolley : 6m/min
Rotation: manual
Operation: pendant push button station.

9- <u>Main Machine Hall</u> (Area No. E-101)

1 unit overhead overrunning
Nominal capacity : 5 tons
Speeds:
Hoist : 3m/min
Trolley : 8m/min
Bridge : 8m/min
Operation: pendant push button station
This crane to be used only for small parts.

10- <u>Suspension Points</u>

6 permanent fixed suspension points in the High Voltage Test Area (Areas Nos. A-104 & A-105). These points should have a capacity of 1 ton, be operated electrically from a fixed station mounted on the wall. They can be either standard chain blocks or still better a nylon chainer cord hoist. Because of the height, precautions have to be taken to prevent rope or chain from twisting.

Power supply will be 380 volts, 3 phases, 50Hz.

6 permanent fixed suspension points of 1-ton capacity each in the synthetic Test Hall (B-101). These are only attachments to the structure that shall be used occasionnally to attach hand - operated chain blocks or hoist.

11- One lifting beam of 20-ton capacity shall be provided to be used on 2-10 ton adjacent cranes in the High Voltage Laboratory (areas Nos. A-104 & A-105).

SERVICING PLATFORMS

BASIC HYDRAULICS and INDUSTRIAL EQUIPMENT LTD.
Highway 58, P.O. Box 488, Welland, Ontario

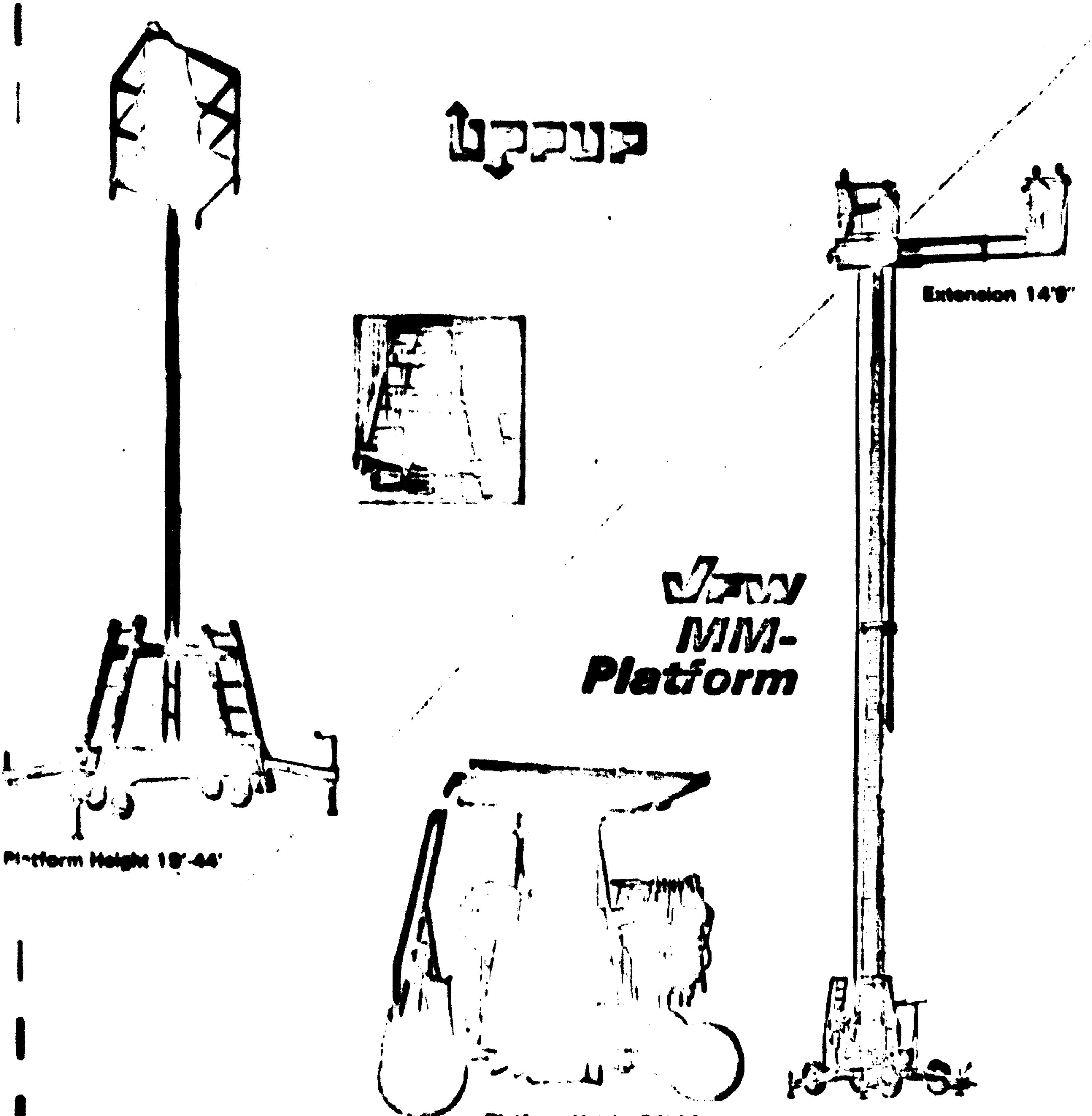


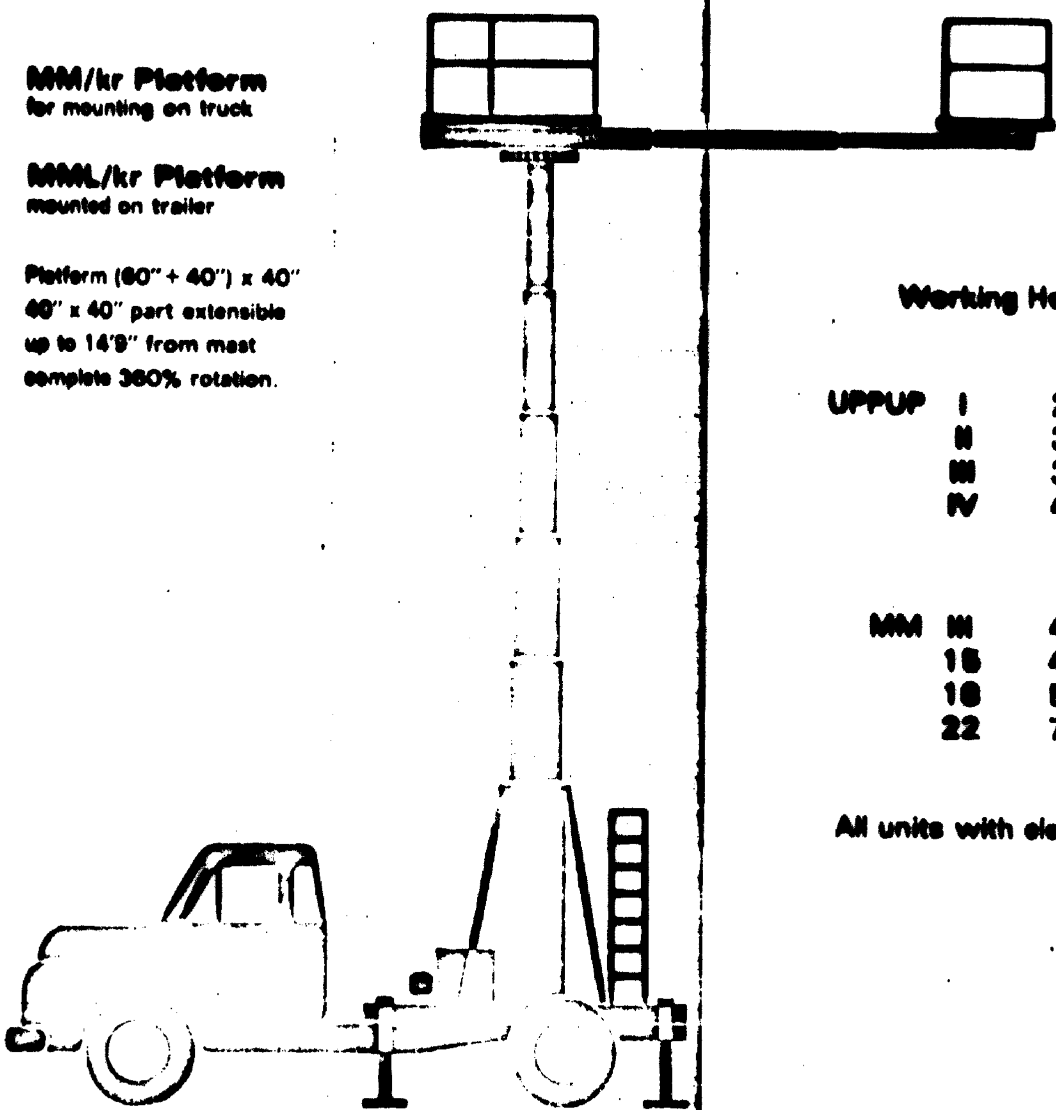
Figure No. 1

Upup .....Places a Work Platform At The Overhead Job Site With New Levels Of Safety.....Convenience.....Efficiency.

MM/kr Platform
for mounting on truck

MML/kr Platform
mounted on trailer

Platform (60" + 40") x 40"
40" x 40" part extensible
up to 14'9" from mast
complete 360% rotation.



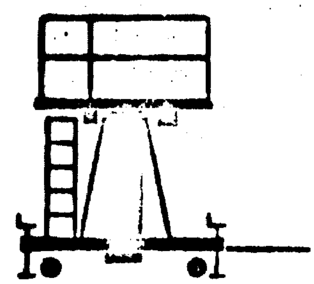
	Working Height		Capacity
UPPUP	I	25'	750 lbs.
	II	30'	
	III	35'	
	IV	40'	
MM	III	40'	650 lbs.
	15	48'	
	18	58'	
	22	72'	

All units with electric drive 12/24 Volt D.C.

Type	Min. Height inch	Platform Dimension inch	Transport Dimension inch	Lifting Time sec.	Weight lbs.
MM III	100	79 x 32	49 x 104	100	3700
IIIs	104	118 x 32	49 x 104	"	3850
IIIL/s	104	118 x 32	63 x 149	"	4500
IIIkr	107	(60 + 40) x 40	54 x 115	"	5720
IIIL/kr	107	(60 + 40) x 40	73 x 158	"	6310
M 15	112	79 x 32	54 x 112	110	4350
15s	116	118 x 32	54 x 112	"	4500
15L/s	118	(60 + 40) x 40	73 x 158	"	5300
15L/kr	120	(60 + 40) x 40	73 x 158	"	6800
MM 18L/kr	134	(60 + 40) x 40	73 x 158	150	8100
M 22L/kr	140	(60 + 40) x 40	73 x 168	180	12800

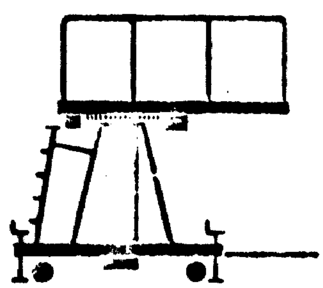
MM Platform

with tow bar,
with solid rubber rollers,
central fixed platform



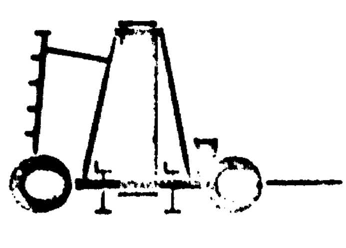
MM s Platform

with tow bar,
with solid rubber rollers,
central fixed mast,
displaced platform,
rotatable by 360



MM I Platform

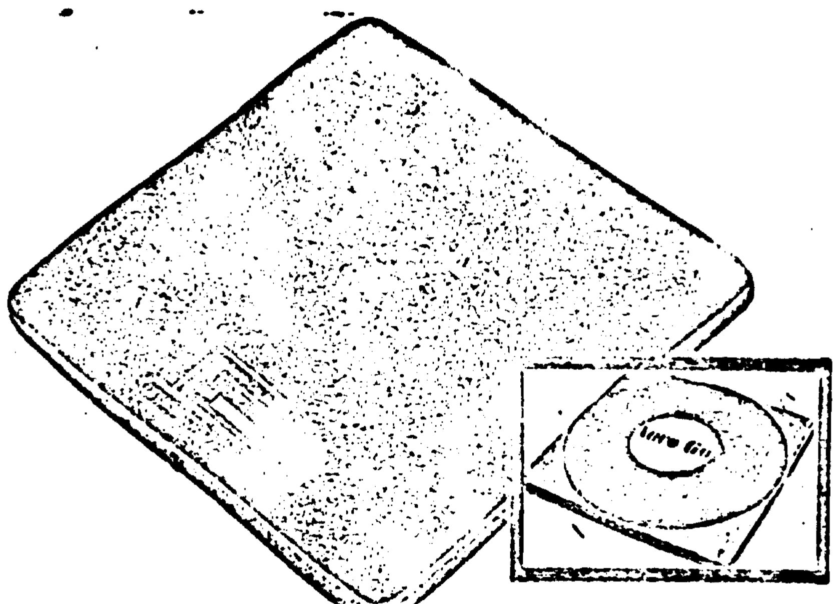
pneumatic tyres wheels
with tow bar,
brake over-run



MM Platform made by VFW
Plant Hoykenkamp · W. Germany

Figure No. 2

Aero Go, Inc.
5800 Cor[illegible] Avenue South
Se[illegible]ttle, Washington 98108
(206) RO 3-9380

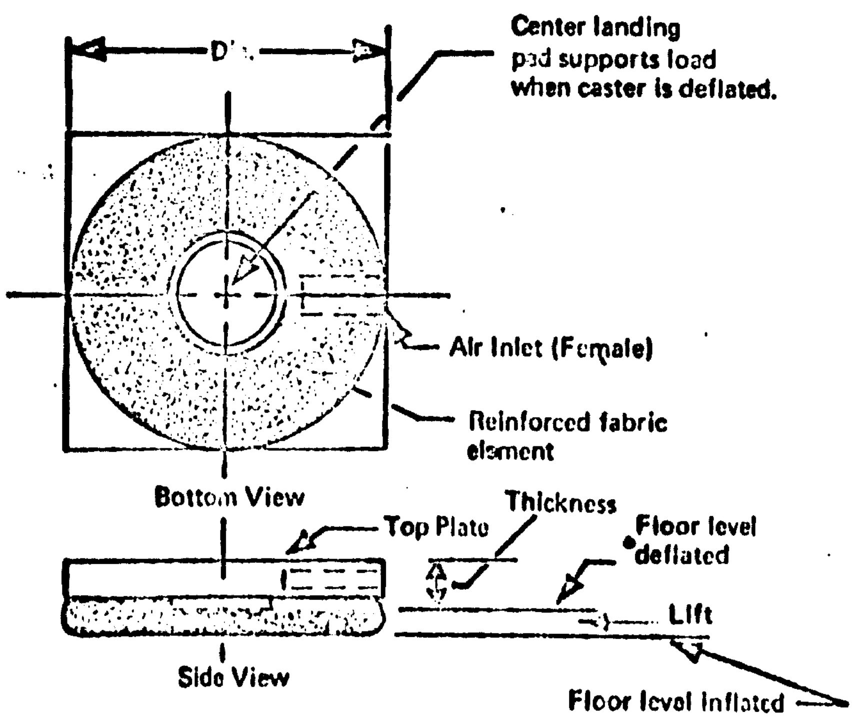


Aero-Casters are modular transfer platforms used for moving loads effortlessly.

Aero-Casters are available to match any load requirement. When used in combinations of 3 or more they provide a stable base for easy, omnidirectional movement of virtually limitless loads on a low pressure film of air. Systems from 500 pounds to hundreds of tons are now in successful operation.

AERO-CASTER LOAD MODULE PERFORMANCE AND SPECIFICATIONS

MODEL	RATED LOAD (LBS)	PRESS AT CASTER (PSIG)	AIR FLOW (CFM)	WT. (LB.)	DIA. IN.	THICK. IN.	LIFT IN.	AIR INLET
K12	2,000	25	5-15	5	12	1	3/4	¼NPT
K16	3,500	25	5-20	8	16	1	7/8	¼NPT
K21	7,000	25	5-30	18	21	2	1	½NPT
K27	12,000	25	5-40	40	27	2	1¼	½NPT
K36	20,000	25	8-50	80	36	2¼	2	½NPT
K48	40,000	25	10-60	140	48	2¼	3	½NPT



MATERIALS:

Top Plates — Aluminum

Aero-Casters — Nylon Reinforced Neoprene

Use Aero-Casters to move your massive loads with great savings of time, effort, manpower, and expense. Costly crane or other lift equipment is not necessary when Aero-Casters allow one man to move many tons with slight effort.

PLACEMENT OF CASTERS...

For best performance the Aero-Caster assemblies should be mounted under loads in a way that divides the total weight approximately equally. For stability, three or more casters arranged in a triangle, or square pattern, is recommended. Center of gravity of load should be as close as possible to geometric center of the caster pattern. If an eccentric load is unavoidable, more air pressure may be applied through a simple regulator to the heavy side to compensate.

FLOOR SURFACE...

The volume of air required to float Aero-Casters is determined by the floor surface. A very smooth floor, vinyl tile, sealed concrete, metal decking, etc., requires least air. Air flow and friction force will increase in proportion to increase in surface roughness. Cracks and steps in floor surface should be bridged with common plastic tape. Plastic sheet or light gage sheet metal overlays can be used to cover rough or dirty surfaces. The substantial benefits and savings afforded by Aero-Casters will warrant the upgrading of a poor floor surface by resurfacing with fillers or terrazzo grinding. For unusual environments, please contact us.

OPERATION...

The load carrying capacity of the Aero-Caster is directly related to the air pressure available at the caster. In effect, the Model K21 Caster is an open ended piston with a lift area of 280 square inches. At 1 psig, 280 pounds can be lifted, at 10 psig, the same caster will lift 2,800 pounds. As the main valve is opened, compressed air is introduced into the caster through the air inlet fitting. Air is evenly distributed within the assembly and allowed to escape in a continuous flow through orifices in the flexible Aero-Caster. The Aero-Caster inflates, raising the assembly. A thin film of air flows between the periphery of the Aero-Caster and the floor surface to "float" the load. To avoid dragging the Aero-Caster and possible damage, be certain load is at full stop before cutting air supply.

MOVING FORCE...

Typical coefficient of friction between inflated Aero-Caster and a smooth, level surface is 0.001 or less. For example, a 2,000 pound load can be moved with a push of under 2 pounds. On inclined or undulating surfaces, free floating casters will drift to the lower level.

AIR SUPPLY...

Aero-Casters are designed to operate from clean compressed air. Air should be supplied to casters through piping or hoses of nearly equal length and diameter to assure uniform operation. 3/4" ID hose or larger (available from Aero-Go) is normally required. Smaller hose may be used under certain conditions.

ACCESSORIES...

Air supply source, control, and distributing devices are available separately from Aero-Go. Sources of air supply can be plant air, portable piston type compressor accumulator, low pressure centrigugal blower or air bottle, depending on load and floor surface conditions. Aero-Casters are self pressure regulating systems that may be operated without separate line regulators. A slow opening flow control valve is recommended to avoid sudden pressure surge and to meter volume of air for most economical performance. In some applications, a quick opening relief valve may be desired to provide rapid lowering of load. Screw jacks, clamps or other devices to attach load are available mounted upon Aero-Caster module. Aero-Go, Inc., will recommend and provide complete accessories for specific applications upon request.

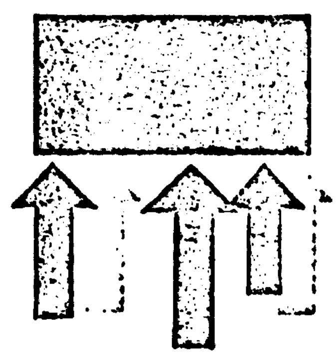
NOTE:

Aero-Go produces complete systems to resolve critical material handling problems or can supply you with custom designs to incorporate into your product for lifelong mobility.

As progress in air film technology is dynamic, products and specifications may be changed without notice.

HOW TO ORDER

Other Aero-Caster sizes, standard transport pallets to fit under your entire load, and units with self-contained air source are available. Call your Aero-Go representative.



SOLD BY:

3- SERVICES

Though the sanitary engineering services on the property are the responsibility of the Government and their agents, we think it is appropriate to bring a few special considerations to your attention.

3.1 Drainage

Drainage implies two different systems:

3.1.1 Storm drains

3.1.2 Sanitary or Domestic sewers.

3.1.1 Storm drains

With the presence of creeks or ditches on the site, there does not seem to be any special problem for surface drainage. Except that around the whole area to be developed, the run-off from paved areas, roofs, landscaped areas, should be collected in catch basins connected to an underground piped system terminating in the main creek. All floor drains should be connected to this system also, but protected with oil catchers (see mechanical section). Some systems like air conditioning and humidifying should have their run-off connected to the storm drain.

3.1.2 Sanitary sewers

With the total development of the property there will no doubt be some form of sewage treatment. The Laboratories are not adding anything special to a standard form of treatment. There are no toxic or hazardous wastes entering this system. The only potential danger is an oil spill and since this would reach the floor drainage sub-system which we have recommended to connect to the storm drain, there is no danger of affecting the sewage treatment plant. May we add that because of the difficulties often met in treatment plants by an excessive dilution we recommend fixtures consuming the least water possible, when such fixtures are available on the local market. Because of grounding problems, it is also recommended to use a non-conductive material for underground piping and provide some insulation in the manholes. If a pumping station should be required, all connections should also be insulated for the same reason.

3.2 Water

The Government will provide a water of an acceptable quality for general requirements as well as for testing. The governing factor in the amount required is generally the fire protection, which may require the construction of a reservoir for such an area. The water should be of the following quality:

(Expressed in p.p.m. unless otherwise specified)

pH	7 units
Hardness	20 to 125 as $CaCO_3$
Iron	0,1 above natural
Chlorides	20
Turbidity	less than 5 units
Color	less than 3 units
Odor	3 (Thr odor No.)
Resistivity 25°C	Not less than 170 ohms/m

The distribution system should loop the entire complex and provide, if possible, a dual feed. If your distribution main is to be of cast iron, a certain length will have to be of a non-conductive material for grounding reasons. We will inform you in such a case of the protection required.

The water requirements and distribution within the buildings form part of the specifications included under the Mechanical Section. Though sizing and detail may not be incorporated in these specifications sufficient information is given to allow the National Consultants to prepare their final design.

4- **PROTECTION**

The security of the personnel working within the Laboratories is covered under Section VII - Electrical and under Sections describing the functions of the Laboratories. In these sections are described certain minimum requirements for the protection of operators during tests and also cover the protection for the instrumentation and the testing itself.

Under this title we intend to draw the attention to the potential danger of the whole electrical distribution and equipment on the premises. It is customary to have the sub-stations totally enclosed by a high enough fence to protect the public against any hazard. The outside testing areas adjacent to the High Voltage and adjacent to the High Power Laboratories will be as dangerous to the public as a sub-station. It is, therefore, a sound recommendation to fence the whole area and establish a unique point of entry on the premises. At this point, should be a guard house where a control would be kept on the movement of people and goods.

The fence closing the area on the whole perimeter should be signalized so that occurence of any break or intruder would immediately be brought to the attention of the attendant at the guard house. Such installations have not always been implemented in similar laboratories because of a lack of fund. We feel this is a poor excuse and strongly recommend that some precautions be taken to guard the public against the risk of accident inherent to this type of electrical installation, the high power and also the testing proper. Explosions resulting from testing have sent parts under test flying good distances. Though such explosions should only occur within specially designed testing cells, there is always a danger that they may happen in outdoor areas.

Along the recommended fence sufficient signs should indicate the electrical danger.

Other precautions for the protection of operators against excessive noises or falling objects will have to be taken but these form part of the operation and the training that future operators will receive prior to start-up.

STRUCTURAL ENGINEERING

VI- STRUCTURAL

1- GENERALITIES

1.1 Scope

The purpose of this report is to enumerate the structural requirements for the various buildings forming the Experimentation Centre. In addition, the criteria for design upon which the structural concept has been evolved is defined. Sufficient information is contained within this report and on the accompanying drawings to allow the Government's Architectural Contractor to proceed with the design and specifications.

Each building block within the complex is discussed separately. In addition, special topics concerning the complex as a whole are defined.

The structural scheme proposed is presented in detail on the following drawings:

101- Architectural, ground floor, general layout
102- Architectural, basement, general layout
103- Architectural, first floor, general layout
104- Structural, "A" and "C" ground floor
105- Structural,"A" and "C" roof plan
106- Structural, section A-A,"A" and "C"
107- Structural, elevation B-B, "A"
108- Structural, elevation C-C, "A" and "C"

109- Structural, section D-D and elevation E-E, "A" and "C"
110- Structural "B" and "F" ground floor and observation deck
111- Structural, "B" and "F" roof plan
112- Structural, "D" ground, first and roof plan
113- Structural, "E" ground and first floor
114- Structural, "E" roof plan
115- Structural, details, all blocks
116- Structural, exterior test yard

The primary objective of this study is to devise a structural scheme which meets the functional requirements of the complex at a minimum cost. The two most widely used construction materials, namely structural steel and reinforced concrete, are used in combination to achieve that result. The structural dimensions given herein may be varied for the final design in order to obtain an optimum result.

1.2 Position of the Building

The position of the building on the site is such that there is approximately 10m (665 to 675) difference in ground elevation from one end of the building complex to the other.

After a study of the recommended site, the finished ground floor elevation has been set at elevation 669. (See Section V- Civil Engineering Art.1 - Location on site).

1.3 General Description

The complex is divided into seven separate areas referred to as blocks. Blocks "A" and "C" are reinforced concrete buildings to the ground floor level with structural steel frames above enclosing the walls and roof. Blocks "B", "D", "E" and "F" are reinforced concrete buildings throughout. The design of Block "G", the office building, is left to the description of the Architectural Contractor.

It is desirable to have a uniform module throughout the building complex. However, due to functional requirements in certain section areas, it was necessary to deviate from the 5 metre module chosen for the project.

Major mechanical and electrical equipment rooms are located in the basement level. In addition, direct access is required to certain areas beneath testing facilities. Therefore, except for Block "B", the ground floor structural system is accessible from beneath, providing a basement level. To keep the basement level uniform and provide just sufficient headroom, some areas may have to be filled.

1.4 Borings

Four preliminary bore holes have been completed at the site. The results of these borings are given in Appendix 1.

The preliminary results indicate that there are various layers of sandy clay and clayey sand mixed with gravel at some levels at the site. The data is insufficient to prepare a final foundation design. The soils consultant suggests that end bearing piles may be required in some areas. Therefore, the preliminary information should be complemented with additional bore holes as required by the Architectural Contractor to design the structural foundations of the building.

1.6 Foundations

Assuming that an adequate soil bearing capacity will be available, the design of the foundations shall meet the following requirements:

1. Continuous wall footings and individual column footings shall be used.

2. All footings should be designed for equal pressures to minimize differential settlements.

3. If possible, all footings should be located in similar undisturbed soil strata. No foundations shall be on fill.

4. The results of the preliminary Boring Schedule No.1 should be complemented with additional tests where necessary.

5. The recommendations of the soil specialist shall be followed.

6. The sub-base for slabs on grade shall be prepared

and compacted in accordance with the live load requirements and the recommendations of the soils specialist.

In the event that the additional borings confirm that end bearing piles are required, it is adviseable to provide such foundations for at least all the blocks that are connected together. Differential settlements that may occur as a result of having some blocks on piles and others on spread footing could seriously affect the use of air cushion bearings to transport heavy loads.

1.6 Floor Finish

The floor topping which covers the structural slab throughout the complex shall have the following special characteristics:

1. Resistant to wear
2. Resistant to oil
3. Free of cracks
4. Minimum quantity of construction joints
5. Smooth, non absorbant, non dusting surface
6. Perfect adhesion with the structural slab
7. Good appearance and minimum maintenance.

In other similar installations it had been found that when air cushions are used to transport heavy loads, the topping may lift off where there is poor adherence and air is forced into cracks in the floor finish.

Additional problems were to be expected where the grounding expanded copper mesh is required between the structural slab and the topping. We undertook to study the problem with special emphasis on shrinkage of the concrete and the adherence of the topping to the structural slab which are interdependent and the most difficult to control. The results of this study are given in the following recommendations.

1.6.1 Recommendations

These recommendations shall be followed when constructing the floor topping:

1. The top surface of the structural slab shall be rough and solid. It shall be finished with a wire brush.

2. All areas shall be sand-blasted to remove surface laitance. Those areas which have been stained or dirtied with grease, oil, mortar or other materials shall be sand-blasted and washed with muriatic acid solution.

3. The structural slab shall be kept humid for a period of at least 72 hours before pouring the topping.

4. The construction joints in the topping shall be made directly above the construction joints in the structural slab. The number of

construction joints shall be kept to a minimum. The first pour at each joint shall be made with the aid of steel angles anchored into the structural slab and oiled to prevent adhesion of the topping to the angles.

5. Where required, the grounding copper mesh forming part of the Faraday Cage shall be completely installed within the construction joints before starting the concrete pour. The grillage should be smooth and flat.

6. The entire area shall be given a thorough cleaning with air blowers to remove all debris and surface water.

7. Just prior to pouring the topping, the structural slab shall be coated with a cement grout brushed onto the surface. The grout should have 1 litre of water per 1 kg of cement. It may be necessary to use cement powder in lieu of grout in those areas having copper mesh and interconnecting flat bars. (See Section VII - Electrical for design of grounding system).

8. The concrete topping should contain special aggregates in order to keep the amount of shrinkage to a minimum. The concrete strength should be 250 kg per square centimetre minimum at 28 days. Air entraining agents and plastifiers

may be used to reduce the water cement ratio and obtain a workable mix having a slump of approximately 5 cm. Admixtures containing calcium chloride or other chlorides shall not be used. The thickness of the topping should be in the order of 3.5 to 4 cm.

9. A surface hardener composed of silica sand or emery should be applied to obtain a hard, non-dusting, perfectly smooth surface. The hardener may be colored if desired.

10. After levelling the topping, the application of the hardener and the topping has sufficiently set, the surface shall be polished. At leaat, two mechanical trowellings and one manual trowelling shall be made with steel trowels in order to obtain a smooth dense surface.

11. The topping should be cured under water for a period of 15 days in order to obtain sufficient strength of the concrete before the evaporation of the free water.

12. All construction joints shall be sawn and filled with an appropriate joint filler.

13. A final epoxy finish, though not essential, provides more efficient use of the air bearings, when applied to the floor topping.

1.7 Doors

There are many special doors required within the complex. The minimum clear opening and door type is indicated on the drawings. Although some latitude can be admitted in the selection of various door types, each type recommended best suits the functional requirements of the Laboratory. The specific requirements of each door type is given below.

1.7.1 Sliding doors

1. These doors are laterally supported by the structure at the top and they move on rails embedded in the ground floor slab. The doors shall be constructed of sheet steel.

2. The doors shall be electrically operated with controls on both sides.

3. A personnel pass door approximately 1m x 2m shall be provided through the doors.

4. The shielding of the doors when required shall be built of the same materials as used for the inside cladding.

5. The doors shall have adequate sound absorption characteristics as defined in other parts of this report.

6. The exterior doors shall have adequate

nuclear reactors, bomb shelters, rocket complexes and other places where the protection of human life is an important factor. The doors shall provide a constant seal against the passage of flames and gases into the protected area. Minimum deflection shall be assured during and after the blast, permitting full operation of the doors at all times. The hinges shall be designed to carry the weight of the doors only and shall not be subjected to blast loading. In addition to the blast load forces previously defined, the following requirements shall be included in the design, fabrication and installation.

1. The doors shall be constructed of steel.

2. The doors shall be single or double leafed as shown on the drawings and capable of opening 180°.

3. The doors shall be manually operated.

4. Personnel pass doors shall be provided in all the large double leafed doors.

5. The exterior doors shall have adequate insulation characteristics as defined in other parts of this report.

6. The doors shall have a failsafe interlocking mechanism combined with the main control desk

insulation characteristics as defined in other parts of this report.

7. The doors shall have adequate safety and locking devices.

8. The door to the climatic chamber shall meet the special insulation requirements as defined. (See the "Second Equipment Report" Section HP 15)

1.7.2 Vertical lift doors

1. These doors are laterally supported by the structure. The blades are held in a guide assembly resting on the ground floor slab. The doors shall be constructed on sheet steel.

2. The doors shall be electrically operated with controls on both sides.

3. Personnel pass doors should be provided beside the vertical lift doors.

4. The exterior doors shall have adequate insulation characteristics as defined in other parts of this report.

5. The doors shall have adequate safety and locking devices.

1.7.3 Blast resistant doors (See Photos Nos. 23 to 26)

These doors are similar in type to those used in for each testing area. The control desk cannot be activated unless all doors are properly locked.

1.7.4 Large hinged doors

1. These doors are 3m high or more. They shall be braced and attached to the structural frame. They shall be constructed of sheet steel.
2. The doors shall be double leafed capable of opening 180°.
3. The exterior doors shall have adequate insulation characteristics as defined in other parts of this report.
4. The doors shall have good locking devices.
5. A personnel pass door approximately 1m x 2m shall be provided through the doors.

1.7.5 Other doors

1. The small equipment and personnel doors may be anchored to the interior partitions.
2. The doors shall be constructed of sheet steel.
3. The exterior doors shall have adequate insulation characteristics as defined in other parts of this report.

4. The doors shall have good locking devices.

1.8 Cladding and Partitions

The cladding and partitions described herein and shown on the drawings are suggestions only and may be changed by the Government's Architectural Contractor as long as the functional requirements are met. The following materials are suggested:

1.8.1 Exterior cladding

1. Blocks "A" and "C" - Insulated metal panels with a baked enamel finish attached to a light-weight steel frame composed of columns, girts and diaphragms.

2. Blocks "B","D", "E" and "F" - Brick or precast concrete on the outside, block on the inside with insulation, vapour barrier and air space between. The workmanship and materials shall conform to the local code requirements. Where required by the design, the walls exposed to explosions occurring in the Test Yard shall be built with cast in place concrete walls or specially designed pre-cast concrete panels properly anchored to the structure. Additionally for block "E", the 10 meter width in front of the Main Machine Hall at each end of the building shall have removable insulated metal panels, for the full height of the building.

3. Block "G" - Left to the discretion of the Government's Architectural Contractor.

1.8.2 <u>Interior partitions</u>

1. Block "A" - Shielding and sound absorption shall be made with perforated and insulated metal panels attached to a lightweight steel frame composed of columns, girts and diaphragms.

2. Block "B" - No interior partitions.

3. Block "C" - Sound absorbing double concrete block walls and single concrete block walls as shown on the drawings. The workmanship and materials shall conform to the local code requirements.

The Pollution Laboratory requires special precautions with regards to finishing and partitioning due to the salt water environment and its corrosive nature. The concrete floor finish should be protected with an epoxy coating or other suitable material. The floor should be adequately sloped to provide the proper drainage as described in Section VIII. The partitions should all rest on concrete curbs suitably waterproofed and protected with epoxy. The inside face of the partitions should be waterproofed with an asphalt base paint in addition to a vapour barrier on the exterior. The doors leading to the Pollution Laboratory should be properly sealed and protected from the corrosive atmosphere. The ceiling and lighting fixtures should be completely sealed and waterproofed. The ceiling support structure should be independant of the main structural frame. All steel elements within the Pollution Room should be sandblasted to bare metal and painted with a metallic paint. All structural elements adjacent to the Pollution Laboratory should have an extra coat of paint. The 2-ton crane, support beams and rails should also have additional protection. Control Room No. 10 should be shielded as described in Section VII.

The Corona Room shall have concrete block wall partitions. Due to their height, the partitions shall be attached to and braced by steel frames. The Laboratory and Control Room No.9 should be shielded as described in Section VII.

4. Blocks "D", "E" and "F" - Single concrete block walls as shown on the drawings. The workmanship and materials shall conform to the local code requirements.

5. Block "G" - Left to the discretion of the Government's Architectural Contractor.

2- BLOCK "A"

2.1 Principal Functions

1. High Voltage Test Areas Nos. 1 and 2.

2. Control Rooms Nos. 6 and 7

3. Control Room for Outdoor Test Area.

2.2 Design Criteria

The structural concept for this block shall be based on the following requirements:

1. Live load equivalent to 7500 kg per square meter, except for Control Rooms - 500 kg per square meter.

2. Unobstructed floor space of 30 m x 50 m.

3. Clear height from ground floor to overhead crane hook equal to 25 m.

4. Two 10-ton overhead travelling cranes and one 5-ton monorail to be suspended from the roof structure (underrun type cranes). Six fixed anchorage points of 1-ton capacity at the roof.

5. The entire block including walls, floors, and ceiling shall form a Faraday Cage.

6. The walls and ceiling of the main halls shall be covered with a sound absorbing material with at least 75 cm of free air space to the outer partition.

(See acoustical requirements in Section VIII).

7. Access to all points within the double wall system as well as the ceiling space shall be possible. Maintenance of mechanical equipment is required and short circuiting to the Faraday Cage during tests may occur, therefore all welds shall be accessible. A stairway and elevator is recommended. Ladders shall be provided within the double wall system for additional security.

8. Large door openings are required to transport equipment from the unloading area in Block "C" to the High Voltage Test Areas and to the Outside Test Areas. Provide bracing for these doors.

9. A control room with observation deck servicing both the indoor and outdoor test areas.

10. Various grounding boxes and measuring boxes should be accommodated within the structural system of the ground floor.

11. The finished floor should be smooth and level to permit the transportation of heavy loads on air cushions bearings. (See Section VIII - Mechanical for drainage requirements).

12. Local building Code.

2.3 <u>Ground Floor</u> (see drawing 104)

In consideration of the very heavy floor loads, the large floor areas, the random distribution of electrical and measuring boxes and the unobstructed ceiling space that results, a reinforced concrete flat slab with drop panels is recommended.

From the many possible combinations, the slab thickness shown is 30 cm, the total drop thickness is 45 cm and the columns are 90 cm square. These dimensions allow for a reasonable amount of reinforcing steel and provide the required shear capacity.

The exterior foundation walls are a combination of pilasters and nominally reinforced horizontal elements. The pilasters provide a reduction in the span to the first interior columns as well as aid in the framing of various openings which are required along the exterior walls.

2.4 <u>Walls and Roof</u> (see drawings 105,106,107,108,109)

The structural system recommended herein best suits the functional aspects of the High Voltage Test Hall. The basic design criteria such as span, height, Faraday Cage and crane loads are met. Considering the building dimensions, a steel structure is the easiest and fastest to erect. The total dead load of the structural system is kept to a minimum.

The structure consists in a series of one directional rigid frames tied together, for stability purposes, with lateral bracings and diaphragms at the roof, cross-bracings and trusses at the walls. The frames are anchored at the ground floor level to large concrete columns and are spaced at 10m, 15m, 15m and 10m to accomodate door openings and the Control Rooms.

At the roof, spanning between the rigid frames, there are joists carrying the roofing, wide flange beams carrying the ceiling and additional structural elements carrying the underrunning cranes and monorail.

The diaphragms have a depth equal to that of the main frame since they also support the roof decking, interior acoustical decking and the fixed anchorage points. Since the ceiling space is to be fully accessible, the acoustical decking should have adequate strength to carry a nominal live load (200 kg per square metre).

A secondary structure consisting in horizontal trusses (i.e. the plane of the truss being horizontal), spans between the legs of the rigid frames and is hung from box trusses at the roof level and intermediate level. This secondary structure has the triple junction of: firstly, carrying the exterior cladding on the outside chord of the horizontal trusses, the interior cladding (Faraday cage) on the inside chord; secondly, the horizontal trusses being 1m deep are sufficiently rigid to transmit wind loads to the legs of the rigid frames;

and thirdly, walkways within the claddings and all around the building are carried by some of the horizontal trusses.

The elements of the main rigid frames consist of trusses for the horizontal beams and built-up sections for the legs. The legs are built-up using rolled wide flange sections. The flanges are tied together with a web system consisting of either, a solid plate with access holes, or latticed bars, or batten plates.

The proposed structural system was chosen on the basis of simplicity of construction, for both fabrication and erection using standard methods and materials; economy in using the right details for shop and field connections, and flexibility in the accommodation of doors, Control Rooms and other openings without affecting the main rigid frames.

3- BLOCK "B"

3.1 Principal Functions

1. Synthetic Test Hall.

3.2 Design Criteria

The structural concept for this block shall be based on the following requirements.

1. Live load equivalent to 1500 kg per square metre.

2. Unobstructed floor space of approximately 30 m x 25 m.

3. Clear height from ground floor to ceiling through the equal to 23 m.

4. One 1-ton monorail and six fixed anchorage points of 1-ton capacity each to be suspended from the roof structure.

5. The finished floor should be smooth and level (see Section VIII - Mechanical for drainage requirements) to permit the transportation of moderately heavy loads on air cushion bearings.

6. Provide bracing for large vertical lift door.

7. Local building Code.

3.3 <u>Ground Floor</u> (see drawing 110)

No access is required from the basement level to the Synthetic Test Hall. A slab on fill having a structural thickness of 15 cm shall be used. The slab shall be reinforced with wire mesh. To prevent shrinkage cracks, the slab shall be saw cut to a depth of approximately 5 cm at intervals not exceeding 10 m in both directions. The floor finish shall be completed as described in Article 1.6.

The foundation walls up to the ground floor level shall fully enclose the area of the Synthetic Test Hall.

3.4 <u>Walls and Roof</u> (see drawings 111)

The structural system for the exterior walls is a simple arrangement of beams and columns. However, due to the proximity of the Exterior Test Yard the structure must resist the lateral load effects of explosion pressures as well as those due to wind.

The wall along axis 20 is shown to be cast in place concrete. However, precast concrete panels would be acceptable if properly designed and anchored to the structure. If required, additional lateral stability may be obtained by building shear walls along axes J and O between axes 18 and 19. Two levels of beams should be provided at approximately 8m and 16m above the ground floor level to laterally support the columns in addition to supporting the precast concrete panels.

The roof structure is comprised of sixteen (16) single span prestressed concrete tee beams. The beams are 2m wide by 1m high. The beams are seated on supports comprised of neoprene bearings at one end and steel bearing plates at the other. The beams shall have a steel plate cast into one end which shall be welded to the steel bearing plate at the support. Adjacent beams shall have alternately neoprene and steel bearings. The beams shall be welded together at their flanges through steel inserts cast into the flanges at 3m intervals.

In addition to the local code defined loads, the roof structure shall support a 1-ton monorail to be suspended along the length of the Hall. Several fixed anchorage points shall be supported from the roof tee beams.

The weight of the wall bushings (to be determined at the time of their purchase) as well as the tension force applied to them shall be carried by the cast in place concrete wall or the precast concrete panels on axis 20.

4- BLOCK "C"

4.1 Principal Functions

1. Transformer Test Area

2. Mounting Hall

3. Corona Room

4. Pollution Room

5. Main Railway Line for Loading and Unloading.

4.2 Design Criteria

The structural concept for this block shall be based on the following requirements:

1. Live load equivalent to 7500 kg per square metre.

2. Unobstructed floor space of approximately 25m x 35m.

3. Clear height from ground floor to bottom of crane hook equal to 15m.

4. Two 150-ton overhead travelling cranes with 25-ton auxiliary cranes to be accommodated. One to be installed immediately and the second, to be installed at a later date. One 2-ton crane is required for the Corona Room. One 2-ton crane is required for the Pollution Room.

5. Block "C" should be separated from Block "A" with a high quality sound barrier (see Section VIII - Mechanical for acoustical requirements).

6. Heavy transformers and other equipment will be delivered by a railway spur into the building.

7. Two large vertical lift door openings are required to permit the entry and exit of loaded railway cars. Provide bracing for these doors.

8. Large volumes of air are required through the floor in the Transformer Test Area.

9. The finished floor should be smooth and level (see Section VIII - Mechanical for drainage requirements) to permit the transportation of heavy loads on air cushion bearings.

10. Local building Code.

4.3 <u>Ground Floor</u> (see drawing 104)

The structural system for this block is integrated with that of block "A". Several modifications are necessary to accommodate some special requirements.

The Transformer Test Area requires large volumes of air. This air is brought in through the exterior cladding, down into the basement beneath, which serves a plenum and up through the ground floor slab on both sides of the Test Area. (Refer to Section VIII - Mechanical for the technical requirements). The design shown on the drawings is schematic and may be modified in accordance with the requirements of the equipment to be tested.

The intake area is closed off with a block wall. However, the floor exhausts must be covered over with steel gratings capable of carrying the heavy floor loads of 7500 kg per square metre. Since the method of transportation is on air cushion bearings, removable steel plates are required to cover the floor gratings. The steel plates, when in place, should be flush with the finished floor.

To accommodate the railway spur which crosses through the building, the floor slab must be thickened to make up the loss in depth due to the rails that shall be set level with the finished floor. Filler blocks shall be placed in the rail slots when transporting equipment on air cushion bearings over the rails.

The exterior foundation walls are a combination of pilasters and wall sections.

4.4 __Walls and Roof__ (see drawings 105,106,108)

The roof and walls of Block "C" are framed with built-up columns and roof trusses. The columns on axis 4 are common to Blocks "A" and "C".

Since access is required within the wall system along axis 4, holes must be cut at various levels in the web plate joining the column flanges. Columns along axis 9 may be left solid.

The built-up columns support two 150-ton cranes with 25-ton auxiliary cranes running between axes B and F. The cranes are supported on heavy plate girders spanning from column to column. Except for the frame on axis A, all columns should be designed to carry the full capacity of both cranes working together.

A secondary structure is required to support the masonry block around the Corona Room and the Pollution Room. The 2-ton over-running cranes may be supported from the secondary structure.

The main frames are braced with a system of diaphragms, girts, trusses and hangers which transmit the horizontal forces and support the exterior cladding and roof system. The weight of the wall bushings, as well as the tension force applied to them, is carried by the secondary wall system and transmitted to the main rigid frames.

5- BLOCK "D"

5.1 Principal Functions

1. Oil Treatment Room.
2. Auxiliary Machinery.
3. Receiving and Storage.
4. Rest Area.
5. Repair Shop.
6. Store.
7. Sheet Metal and Welding Shop.
8. Woodwork Shop.
9. Pipe Shop.
10. Mechanical Workshop.
11. Distribution Area.
12. High Pressure Compressed Air Room.
13. Telephone and Interphone.
14. Emergency Generator and Battery Room.

5.2 Design Criteria

The structural concept of this block shall be based on the following requirements:

1. Live load equivalent to 1500 kg per square metre throughout.

2. Clear height from ground floor to underside of roof structure of 10 m in passage ways.

3. One 10-ton overhead travelling crane to service the receiving and storage area.

4. Ground floor and first floor, shall be unobstructed by equipment.

5. Basement level shall accommodate large pieces of equipment.

6. The finished floor should be smooth and level (see Section VIII - Mechanical for drainage requirements) to permit the transportation of heavy loads on air cushion bearings.

7. Local building Code.

5.3 <u>Ground Floor</u> (see drawing 112)

To achieve maximum flexibility and headroom a flat slab structural system is recommended. The functional requirements of this block are such that two variations in the flat slab column spacings are required. The slab, drop and column dimensions shall provide adequate shear capacity without additional reinforcement.

To accommodate the First Floor Workshops and Corridor between axes H and I, the regular 7,5m x 5m module has been modified to provide a 6 m corridor width.

One expansion joint in the Block is located between axes 12 and 13.

5.4 First Floor (see drawing 112)

The second level is required to provide space for additional workshops. The structural system shown on the drawings is a beam and slab arrangement. Materials can be lifted to or lowered from the first floor using chain blocks suspended from the roof.

In lieu of providing a first floor for the workshops, they could be located at the basement level. However, an opening in the ground floor slab would be required through which materials can be moved.

The mezzanine in the Auxiliary Machinery Room is a beam and slab system which is suspended from the roof beams with ties at 5 m intervals.

The exterior foundation walls span vertically from the foundation level to the ground floor slab.

5.5 Roof (see drawing 112)

The roof structure supports the suspended mezzanine in Auxiliary Machine Room, the chain block loads for the workshop areas and the electrical distribution lines coming from the substation in addition to the local code requirements. A simple beam and slab arrangement is recommended.

In the shipping and receiving area a 10-ton over-running travelling crane is supported on brackets projecting from the columns. A steel beam spans from column to column to support the crane rail.

6- BLOCK "E"

6.1 Principal Functions

1. Equipment rooms for reactors resistances and condensers.

2. Main Machine Hall for Rotating Machines.

6.2 Design Criteria

The structural concept of this block shall be based on the following requirements:

1. Live load equivalent to 1500 kg per square metre except the Main Machine Hall. Foundation levels and structural arrangement to be in accordance with the Rotating Machine manufacturer's requirements.

2. The equipment rooms on two levels are located within the 10 m clear height from ground floor to the underside of the roof structure.

3. The Main Machine Hall requires an unobstructed floor

space of approximately 10m x 50m.

4. The clear height requirement of the Rotating Machines are to be accomodated within the distance from the foundation to the crane hook.

5. Electrical currents which could be induced in the structure by electro-magnetic effects shall be prevented.

6. Provision shall be made for the support and suspension of various equipment from the underside of beams and from columns.

7. Provide supports for 5-ton overhead travelling crane in Main Machine Hall.

8. Local building Code.

6.3 <u>Ground Floor</u> (see drawing 113)

A beam and slab arrangement with a clear span of 10 m is recommended for the portion between axes R and S. The basement area under the reactors has sufficient height and width for additional electrical equipment. Equipment access to the basement is through an opening in the floor as shown on the drawing.

In the Main Machine Hall, a fill-in slab is required between the two Rotating Machines. The shape and load capacity of this slab will depend on the requirements of the manufacturer of the Rotating Machines. The

Rotating Machines themselves, occupy the full height in the Main Machine Hall from the basement level to the roof. The foundations and other structural elements in this area are to be defined by the manufacturer of the Rotating Machines.

The foundation wall along axis R spans vertically from the foundations to the ground floor. The foundation wall along axis T shall be designed in accordance with the openings in the ground floor slab required for the Rotating Machines.

6.4 <u>First Floor</u> (see drawing 113)

A second equipment level is required between axes R and S. A beam and slab arrangement is recommended with a clear span of 10m. Several openings will be necessary in the slab to accommodate the circuiting of the electrical equipment. The size and location of these openings will be defined by the equipment manufacturers.

6.5 <u>Roof</u> (see drawing 114)

In addition to acting as a shelter, the roof over the reactors and auxiliary switchgear will carry suspended equipment. The additional load, in the order of 750 kg per square metre, should be verified with the equipment manufacturer.

The roof over the Main Machine Hall may have several large openings to accommodate the ventilation system.

Brackets projecting from the columns support a 5-ton overhead crane which travels the entire length of the Machine Hall.

6.6 Equipment Supports

To aid the installation of the suspended electrical equipment at the ground floor and first floor levels, we recommend that continuous slotted inserts be installed in the underside of all beams and on the faces of all columns. These inserts should have a capacity in the order of 3000 kg per metre.

6.7 Insulation of Reinforcing Steel

To prevent the induction of electrical currents in the reinforcing steel, the bars must be insulated from one another in all slabs and beams at the ground floor, first floor and roof level in the area of the reactors and auxiliary machinery (between axes R and S). This is accomplished by breaking the contact between intersecting bars. In slabs, plastic chairs which clip onto the bars work effectively. For beams, the contact points between bars and stirrups should be broken with electrical tape wound around the stirrups. This method works effectively also where slab reinforcing crosses the beam reinforcing. The number of reinforcing bars should be kept to a minimum. Therefore, larger diameter bars should be used wherever possible.

7- BLOCK "F"

7.1 Principal Functions

1. Assembly Rooms.
2. Climatic Chamber.
3. High Current and Direct Current Laboratory and Control Room.
4. Test Cells No. 1 and No.2 and Control Room.
5. Storage.
6. Control Room No.1 and Observation Rooms for Exterior Test Yard.
7. Mechanical and Electrical Equipment Rooms.
8. Conference Room.

7.2 Design Criteria

The structural concept of this block shall be based on the following requirements:

1. Live load equivalent to 1500 kg per square metre except:

   a) Control Rooms - 500 kg per square metre.

   b) Electrical Equipment Rooms - 1250 kg per square metre.

2. Structural columns to conform to use of floor space and accommodation of a central Corridor.

3. Clear height from ground floor to underside of roof structure equal to 10 m.

4. Test cells shall resist the explosive effects of equipment equivalent to 3 kg of TNT.

5. Control Rooms require an underfloor distribution system for wiring similar to computer installations.

6. Electrical currents which could be induced in the structure by electro-magnetic effects shall be prevented.

7. 5-ton overhead travelling cranes to be provided in Assembly Rooms and 2-ton jib cranes to be provided in Test Cells (under-run type cranes).

8. The finished floor should be smooth and level (see Section VIII - Mechanical for drainage requirements) to permit the transportation of moderately heavy loads on air cushion bearings.

9. Local building Code.

7.3 Ground Floor (see drawing 110)

To support the moderately heavy live load, a flat slab system provides an economical, efficient and simple construction arrangement. To conform the use of the space at the ground floor, the module has been adjusted to accommodate a 6m central corridor. The slab, drop and column dimensions are such that no additional shear reinforcement is required.

The structure under the control rooms is framed with beams and slabs to accomodate an underfloor electrical distribution system. The required space may be determined in accordance with equipment chosen.

The reinforcing steel in the slab in the High Current and Direct Current Laboratory shall be insulated as described in Article 6.7 of this Section.

The foundation walls span vertically from the foundation level to the ground floor.

7.4 First Floor (see drawing 110)

A second level shall be provided in two areas. Above Control Room No.1, an observation area is required for the Test Yard. This area shall be framed with beams and slabs.

Above Control Room No.2 an equipment area is required. This area shall be framed with beams and slabs. A door on the Corridor shall be provided for access of equipment.

7.5 Roof (see drawing 111)

The roof shall be an arrangement of beams and slabs. The system shall be capable of supporting the 5-ton cranes running between the roof beams in the Assembly Rooms. The other live loads shall be in accordance with the local building code.

Various openings in the slabs shall be provided as required for ventilation.

7.6 <u>Test Cells No.1 and No.2</u>

These cells shall be designed for the following additional requirements:

1. The entire Test Cell shall be capable of resisting, within the elastic stress limits of the materials, the effects of explosions equivalent to 3kg of TNT.

2. The design of the Test Cell shall be made in accordance with the recommendations given in Technical Manual No.5-1300 "Structures to Resist the Effects of Accidents Explosions", Superintendant of Document, U.S. Government Printing Office, Wahsington, D.C. 20402. The wall thicknesses given on the drawings may be revised as required.

3. Two large exhaust vents shall be provided in each cell and shall be closed with blow-out panels.

4. The floor slab of the cells shall be cast on well graded crushed stone compacted to 95% Proctor. Anchoring points shall be provided as required for

the Test Equipment. The reinforcing steel in the floor slab shall be insulated as described in Article 6.7 of this Section.

8. The design of the main doors to the Test Cell shall be made in accordance with Technical Manual No.5-1300. The doors shall have a personnel pass door. The door frame shall be anchored into the concrete at the sides, bottom and top. The frames shall be designed for 100% rebound. The door materials shall not be stressed over the elastic limit. The door locking mechanism shall be located on the corridor side and designed so that the door cannot be locked with a key unless the locking pins are fully driven. The door bearings shall be designed so that the leaves may be opened manually. (See Article 1.7.3 Blast Resistant Doors).

7.7 Control Room No.1

This Control Room shall be designed for the following additional requirements.

1. The exterior walls shall be capable of resisting the effects of explosions in the Test Yard equivalent to 10 kg of TNT within the elastic limits of the materials.

2. The design of the walls shall be made in accordance with the recommendations given in Technical Manual No. 5-1300, "Structures to Resist the Effects of

Accidental Explosions", Superintendant of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The dimensions given on the drawings may be revised as required.

3. The walls shall be reinforced with pilasters if the floor and roof slabs are not adequate.

4. The design of the doors to the control room from the Test Yard, shall be made in accordance with Technical Manual No. 5-1300. The door frame shall be anchored into the concrete all around. The frames shall be designed for 100% rebound. The door materials shall not be stressed over the elastic limit. The door locking mechanism shall be located inside the Control Room and designed so that the door cannot be locked with a kew unless the locking pins are fully driven (See Article 1.7.3 - Blast Resistant Doors).

5. The observation windows shall be made of bullet resistant glass set in steel frames anchored in the walls and capable of resisting the forces of the explosion.

8- <u>BLOCK "G"</u>

8.1 <u>Principal Functions</u>

1. Main Office Building.

2. Offices for Researchers.

8.2 <u>Design Criteria</u>

The structural concept of this Block shall be based on the following requirements:

1. Live load due to occupancy equivalent to 250 kg per square metre.

2. Structural arrangement to be functional to accommodate offices, corridors and service areas.

3. Total floor area to be determined from the number of personnel.

4. The size and shape of the building shall be determined by the Architectural Contractor.

5. Local building Code.

6. There shall be no windows facing the Exterior Test Yard.

9- <u>TEST YARD (HIGH POWER)</u>

9.1 <u>Principal Functions</u>

1. Two Test Areas.

2. Access from Assembly Rooms.

3. Transformers.

9.2 Design Criteria

The structural elements in this area shall meet the following requirements:

1. The two exterior Test Areas shall have a live load capacity of 1500 kg per square metre. All passageways leading from the Assembly Rooms shall have a similar capacity.

2. A passageway in front of the transformers shall have a live load capacity of 7500 kg per square metre.

3. Anchorage points shall be provided in the slab in the testing areas.

4. All exposed surfaces encompassing the Test Yard shall be capable of resisting the effects of explosions equivalent to 10 kg of TNT without any damage. The design of all structural elements shall be made in accordance with Technical Manual No.5-1300. The area within which these explosions may occur is shown on drawing 116.

5. Brick and block walls shall be reinforced with steel plates or replaced with concrete walls as required to resist the explosion forces and to prevent projectiles from passing through the exterior walls into the complex.

6. The two Test Areas shall be separated by an explosion resistant wall consisting of steel columns and

precast concrete or wood elements capable of resisting the explosion forces. These structural elements shall be designed in accordance with the requirements of Technical Manual No.5-1300. The wall shall be at least 7 m high and shall be built of interchangeable elements.

7. The transformers in the Test Yard adjacent to Block "E" shall be similarly protected by an explosion resistant wall as described above. A fire wall shall be built between adjacent transformers.

8. All doors leading from the complex out onto the Test Yard shall be capable of resisting the effects of the several explosions described above. The door frames shall be anchored into concrete elements and shall be designed for 100% rebound. The materials shall not be stressed beyond the elastic limit. All door mechanisms shall be on the inside of the complex and shall be designed so that the doors cannot be locked with a key unless the locking pins are fully driven.

9. The finished slab shall be smooth and level (see Section VIII - Mechanical for drainage requirements) to permit the transportation of heavy loads on air cushion bearings.

10. Electrical currents which could be induced in the Test Area slab by electro-magnetic effects shall be

prevented. (See Article 6.7 in this Section).

9.3 Test Damages

There are certain dangers associated with the testing performed in the Test Yard. It is extremely important that access to the area be carefully controlled. All points of entry must be monitored by the Control Room.

There is also the risk of projectiles being thrown to adjacent areas, damaging roof membranes, cutting electrical supply lines and piercing thin metal cladding. However, experience has shown that the risk of serious damage is remote and the cost of repairing minor damage as it occurs is much less than the cost of providing fully enclosed blast resistant test cells.

10- OUTDOOR TEST AREA

10.1 Principal Functions

1. Test Area.

2. Access from High Voltage Laboratory.

10.2 Design Criteria

The structural elements in this area shall meet the following requirements:

1. The Test Area shall have a live load capacity of 7500 kg per square metre. The passageway leading

from the High Voltage Laboratory shall have a similar capacity.

2. Anchorage points and a measuring box shall be provided in the slab in the Testing Area.

3. The finished slab shall be smooth and level (see Section VIII - Mechanical for drainage requirements) to permit the transportationof heavy loads on air cushion bearings.

FINAL

BUILDING REPORT

VOLUME III

ELECTRICAL & MECHANICAL ENGINEERING

TO

UNIDO (CONTRACT 72/17)

FOR

SPAIN ELECTRICAL TESTING AND EXPERIMENTATION TESTING

IN

MADRID

SPAIN

Lalonde Girouard Letendre & Associates Ltd.
In Association with IREQ
Montreal, Canada

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ELECTRICAL ENGINEERING

VII - ELECTRICAL

1- INTRODUCTION

This electrical performance specification and the annexed drawings are to be used by the Architectural Contractor as a general guide for the design of electrical systems and sub-systems within the Electrical Experimentation Centre for the testing of equipment manufactured by the Spanish Electrical Industry. Special attention should be taken to the fact that this Chapter treats only of the recommended systems and sub-systems related to the Building Concept itself and that any electrical considerations on equipment needed for the operation of the Laboratory is described in separate reports.

2- POWER SOURCES AND DISTRIBUTION SYSTEM

2.1 220 KV Primary Incoming Lines

Two incoming 220 KV aerial lines shall feed the Main Substation of the Testing and Experimentation Centre. One of these lines shall feed the Medium Power-Medium Voltage Test Area through a set of three single phase transformers (500 MVA, short circuit capacity), the Test Yards No. 1 and No. 2, the Synthetic Test Hall and in the future, a set of three single phase short circuit transformers. The other line shall feed the 220 KV/22 KV Substation.

2.2 Substations

2.2.1 220 KV/22 KV Substation

The 220 KV aerial line mentioned in 2.1 shall feed two 10 MVA., three phase transformers, 22 KV secondary. The first transformer shall supply the normal line (no voltage disturbances) while the other shall supply the test line (permissible voltage disturbances). All disconnect switches, breakers and accessories are shown on drawing No. 201. A local control room shall be built in the Substation.

2.2.2 Main 22 KV Outdoor Substation

The Main 22 KV Outdoor Substation shall be of the weatherproof metal enclosed type. The normal line of Substation shall supply the set of three outdoor 1,33 MVA single phase regulators, the two 310 KVA, single phase regulators, two 1,5 MVA three phase transformers, 220 V/380 V. secondary, and one 500 KVA three phase transformer, 220/380 V. secondary. These three transformers shall feed a cubicle which will feed the lighting, power outlets and receptacles, heating, air conditioning and ventilation. The first two shall also feed the secondary testing points and the impulse generator. Provision shall be made to feed the future University Centre at 22 KV. The test line shall feed the two 2100 MVA short circuit capacity rotating machines, the 1 MVA three phase rotating machine and the 300 KVA single phase rotating machine through 5 MVA three phase transformers, and the High Current-Direct Current Test Area (50 MVA short circuit capacity).

A tie gang operated load break switch shall be provided between the normal line and the test line in order to supply the normal line from the test line in case of transformer or auxiliary equipment failure. It shall also be possible to feed the set of three outdoor 1,33 MVA single phase regulators from the test line during parallel single phase operation of these regulators. All disconnects, load break switches, breakers and accessories are shown on drawing No. 201.

2.3 Underground Lines

From the 220 KV/22 KV Substation, two 22 KV underground lines (normal line and test line) shall feed the Main 22 KV Outdoor Substation located as indicated on drawing No. 200. For the duct bank, rigid P.V.C. conduits or high temperature type fibre conduits embedded in concrete, shall be used. Concrete manholes shall be provided for the pulling of cables. Galvanized cable racks shall be installed in these manholes, refer to drawing No. 200. Underground 25 KV insulated, shielded cables of adequate capacity shall be installed in the duct bank for normal and test lines.

2.4 Distribution

2.4.1 Distribution Centres

Distribution Centres of the self standing cabinet type shall be provided for power distribution as indicated on drawings. Distribution centre for the set of three outdoor 1,33 MVA single phase regulators, distribution centre for auxiliary testing transformer and disconnect switch cubicle for the 5 MVA transformers feeding the two 2100 MVA rotating machines shall be of the weatherproof metal enclosed type. All other distribution centres shall be of the standard indoor metal enclosed type.

9.4.2 <u>Test Voltages Distribution</u>

The test voltages supplied by one of the two 250 KVA single phase regulators, the 1 MVA three phase rotating machine and the 300 KVA single phase rotating machine shall be brought to six primary testing points located as indicated on drawings No. 201 and No. 202. The test voltages supplied by the set of three Outdoor 1,33 MVA single phase regulators, the 1 MVA three phase rotating machine and the 2 100 MVA short circuit capacity rotating machines shall be brought to an outdoor cubicle which will feed the auxiliary testing transformer, the 1,33 MVA single phase test transformer and the primary Testing Points. In addition, the two 2100 MVA short circuit capacity rotating machines shall feed the Test Yards No. 1 and No. 2. The other 250 KVA, single phase regulator shall feed the high voltage pollution test transformer.

2.4.3 Bus Duct

Outdoor weatherproof and indoor standard bus ducts and accessories shall be used where capacities larger than 800 amps., at 208 volts are needed. Low impedance aluminum or copper bars, ventilated bus ducts shall be used.

2.4.4 Cable Trays

Aluminum cable trays and accessories shall be provided in the basement for all the distribution power cables and the control cables. Barriers shall separate conductors of different system voltages. (See photo No. 4).

2.4.5 Conduits

2.4.5.1 General

Rigid galvanized threaded steel conduits shall be used inside the building everywhere in poured concrete slabs, walls, girders, in the concrete floor topping and in areas requiring explosion proof, weatherproof, vaporproof and waterproof installation. All other non-threaded conduits shall be galvanized steel. For the connection to motors and other vibrating equipment, liquid tight flexible conduits and accessories shall be used. Rigid P.V.C. (polyvinyl chloride) conduits shall be used in non-touching armature zones. These zones are room Nos. E-103, E-201, F-002, F-111, F-114, F-115, Outdoor Test Yards No. 1 and No.2.

2.4.5.2 Conduits for Measuring Cables

Conduits in High Voltage Test Areas No.1 and No.2, in High Voltage Outdoor Test Areas and in Synthetic Test Hall used for coaxial measuring cables shall be of copper. Elsewhere, they shall be rigid galvanized steel. Extreme care should be taken in order to prevent galvanic corrosion between the copper conduits and the measurement boxes. In no case, the galvanized rigid steel conduits passing through the Outdoor Test Yards No.1 and No.2 shall be in contact with the non-touching armature in that zone. All conduits used for passing coaxial measuring cables shall have all their coupling welded at a minimum of three points on each side to assure a perfect grounding continuity.

2.4.6 Wires and Cables

Wires and cables shall be as required by the loads characteristics. All 5 KV and higher voltage cables shall be shielded and grounded at both extremities.

2.4.7 Power Outlets and Receptacles

220 volt "Normal" (public utility power source) outlet receptacles shall be provided throughout the building to give the possibility of connecting electrical and mechanical equipment. 220 volt "Normal-Emergency" (public utility power source or emergency generator power source) outlet receptacles shall also be supplied at different locations as indicated on drawing No. 212.

Except in Control Room No. 5, outlet receptacles shall be provided in large quantities in all Control Rooms; a minimum of twelve "Normal" outlet receptacles and a minimum of twelve special 220 volt isolated and regulated output outlet receptacles shall be installed on a wiring trough. (see photo No. 15).

Outlet receptacles with 220 volts "normal" and 220 volts isolated and regulated output (supplied by 220 V. regulators) shall also be provided in measuring boxes installed in the High Voltage Test Areas No. 1 and No. 2 and in High Voltage Outdoor Test Area.

Power outlets for the connection of 380 volts electric equipment shall be provided near work benches in shops, in basement, store, test areas, outdoor in the vicinity of auxiliary transformers, each side of High Voltage Outdoor Control Room and in all other location as indicated on drawing No. 212.

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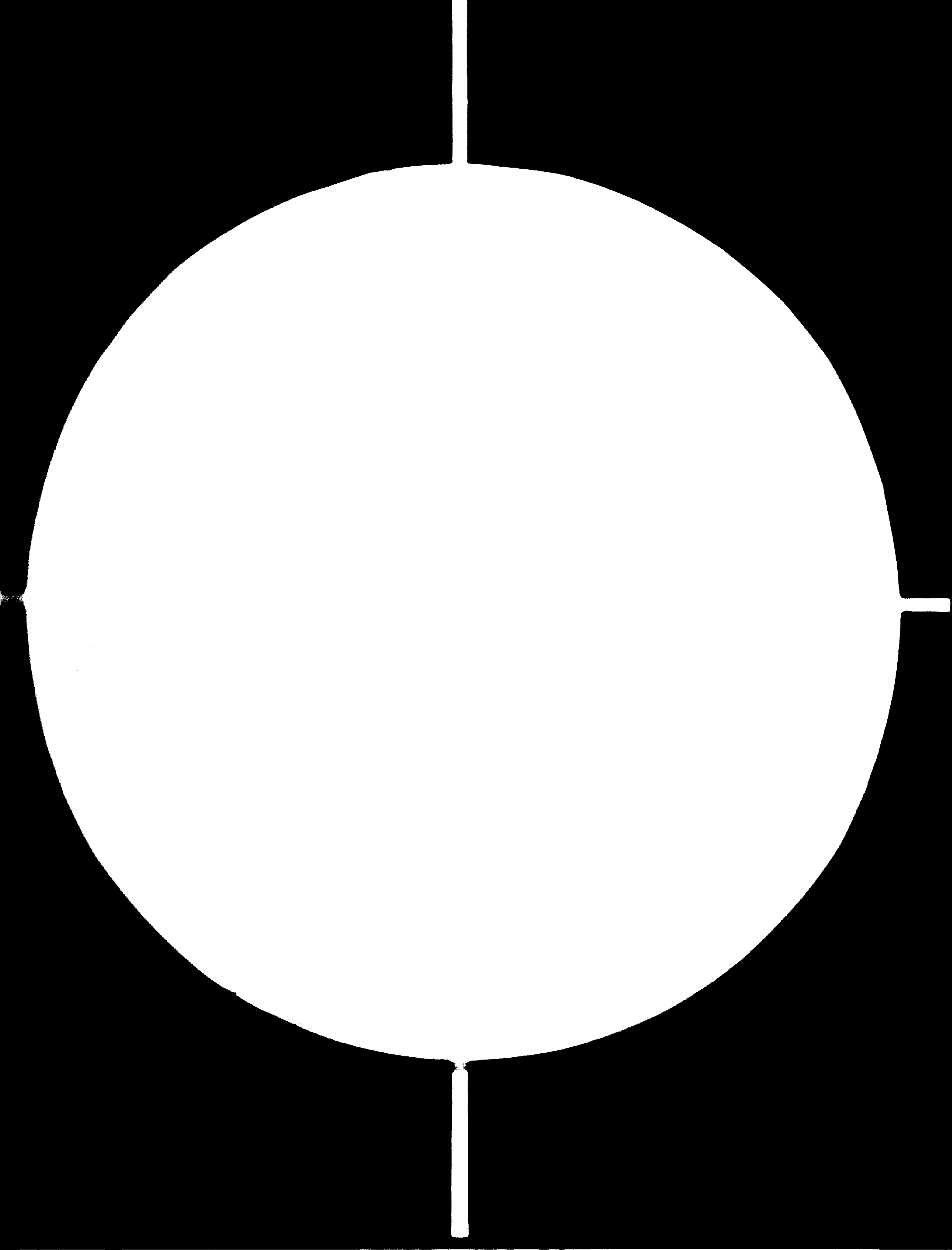

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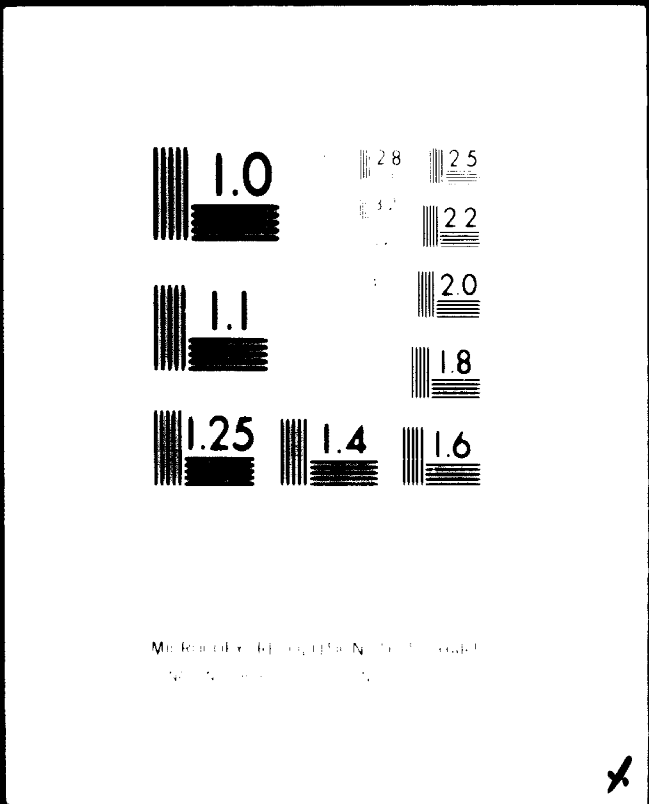

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2.4.8 Special Power Outlets

Special power outlets and sources shall be provided for motors, doors, cranes, elevators, pumps, air conditioning systems, ventilating systems, heating systems, etc...

2.4.9 Concrete Bases

Reinforced concrete bases shall be built to support all metal enclosed cubicles, transformers and outdoor electrical equipment.

2.5 Direct Current Power Supply

Direct current power supply shall be provided for the operation of circuit breakers and control systems. This D.C. power shall be supplied by 92 ventilated accumulators, high performance and low resistance type. The nominal voltage of each cell shall be between 1,2 volts and 1,3 volts. The float voltage shall be between 1,4 volts and 1,5 volts. All the accumulators shall be mounted on racks separated from the charger. The charger shall be of the constant voltage automatic type. The output voltage of the charger shall be regulated for load and input voltage variations. Two-rate charger shall be provided.

2.6 220 Volts Regulated Voltage

220 volts isolated and regulated output voltage shall be provided at different locations as indicated on drawing No. 212. This regulated voltage shall be supplied by regulators having an output nominal voltage of 220 volts,

adjustable from 210 volts to 230 volts. The output voltage shall be constant in a range of 100 millivolts R.M.S. for any input voltage or any lagging power factor of 1,0 to 0. The time required for voltage recovery of 60% of maximum deviation shall be 30 milliseconds. These regulators shall be fed by isolation transformer.

2.7 Emergency Generator

A diesel driven standby electric generator set shall be used to provide adequate emergency lighting in rooms, corridors and other locations and other loads as shown on drawing No. 212.

Upon power failure, pilot devices shall start the emergency generating set after a time delay of 3 seconds. When the generator reaches-up 90% of its nominal voltage, an automatic transfer switch shall transfer all "normal-emergency" loads on the "emergency" power side. After a time delay of 20 minutes when normal power is back, the automatic transfer switch shall transfer all "normal-emergency" loads back on the "normal" power side. The electric generating set shall continue to operate for 10 minutes minimum, to permit engine cool-off. A test push button shall be provided to permit weekly testing of 20 minutes duration with loads. Besides feeding "normal-emergency" loads, the emergency generator shall also feed "emergency" loads.

2.8 Testing Points

2.8.1 <u>Primary Testing Points, Control Cubicles and Control Desks</u>

These primary testing points shall consist of metal enclosed cubicles with front hinged doors and rear bolted panels. (See photo No. 8). All the testing points are connected in parallel to the regulator and auxiliary machines with special "T" connections. The copper bus bars shall be non-insulated with silver plated connections. The grounding bus bar shall be of sufficient capacity to sustain the short circuit current. It shall be continuous in all sections.

Each section shall consist of a disconnect switch (with a front observation window) and a connection cable section (with two punctual contacts on each pole) where the copper hook will be inserted. A fibre rod shall be provided to hold the hook and a wood bar to prevent the disengagement of the hook if the cables are pulled out. (See photo No. 9).

Three access doors shall be provided: one for the access to the disconnect switch, one for the connection cable section and one small rocking door which will be superposed on the preceding door for cable entry.

An emergency push button shall be provided to open the secondary breakers of the regulator and auxiliary machines feeding these primary testing points.

Control cubicles shall be provided, adjacent to the primary testing points, for the control and measuring equipment, pilot lamps and relays, instruments, etc.., for the remote control metering and relaying of regulators and auxiliary machines. (See photo No. 8). These control cubicles are connected to the control desks. Details of these indoor primary testing points and control cubicles are shown on drawing No. 211. The outdoor primary testing points shall be of the weatherproof type.

Control Desks shall be provided at locations shown on drawing No. 203. These control desks shall be used for the remote control of the rotating machines, the regulators, the impulse generator, the coupling transformer, etc.., as well as for instrumentation relative to tests. Details of the control desks are shown on drawing No. 1004.

2.8.2 Secondary Testing Points

Details of these indoor secondary testing points are shown on drawing No. 211. The outdoor testing points shall be of the weatherproof type. They shall be used for the connection of impulse generator and other equipment needed for tests. They shall consist of safety switches of different voltage and capacity, mounted on a painted steel plate bolted on wall. These switches shall be provided with special lugs for the connection of equipment cables. (See photo No. 10.).

2.9 Interlocking Systems

2.9.1 Substations

Electrical, mechanical and key interlocks shall be installed in main substation 220 KV/ 22 KV and in outdoor secondary substation 22 KV in order to provide safe working conditions and prevent damage to equipment.

2.9.2 Primary Testing Points and Distribution Centres

2.9.2.1 Mechanical Interlock

A mechanical interlock between the disconnect switch and the cable connection section shall be installed in order to prevent the opening of this section door, when the disconnect switch is in closed position.

2.9.2.2 Key Interlocks

a. A key interlock shall be provided for the interlocking between the regulator and auxiliary machines feeding the primary testing points and the primary testing points,as well as the interlocking of primary testing points between them. It shall be impossible to use a same source of power (regulator or auxiliary machines from more than one testing point at a time and it shall assure the user of the total control of the source of power.

b. In distribution centre (cubicle Y) there shall be a key interlock between breaker and load break switch, in order to give the possibility of feeding the Primary Testing Points from either the 350 KVA regulator "N" or one of the three 1,33 MVA outdoor regulator "E".

c. In distribution centre (cubicle R) there shall be a key interlock between disconnect switches, in order to bring the power of the 1 MVA Rotating Machine "P" to Primary Testing Points inside building or to outdoor distribution centre (cubicle F).

d. In distribution centre (cubicle F) there shall be four key interlocking systems.

   1. Key interlocks system between each secondary breaker of 1,33 MVA outdoor regulator and the disconnect switch or switches on the load side of these breakers in order to prevent opening or closing of these disconnect

switches under load.

2. Key interlocks between the two disconnect switches on the load side of the same secondary breaker of 1,33 MVA outdoor regulators in order that the only possible arrangement be: single phase parallel operation of the three regulators or three phase operation.

3. Key interlocks between disconnect switches in order that the Auxiliary Testing Transformer "G" or the distribution centre "V" for the 5KV special transformer be fed by either one of the three following power sources: 1,33 MVA outdoor regulators, 1 MVA rotating machine, 2 100 MVA rotating machine. These three disconnect switches shall be closed only one at a time.

4. Key interlocks between the disconnect switches in order that the 1,33 MVA outdoor regulators shall feed the indoor Primary Testing Points alone or the Auxiliary Testing Transformer "G" and the distribution centre "V" alone.

3- LIGHTING

3.1 Indoor Lighting

3.1.1 General Lighting

3.1.1.1 Maintained Level of Illumination

Illumination levels given on drawing No. 212 are based on many years of experience of the "Illuminating Engineering Society" and on our own experience in the new Research Institute of Quebec Hydro.

The values given are not to be construed as initial "lux" provided by a new installation; they are recommended as minimum lux at anytime. This means that the installation must be so designed that dirt and depreciation in light output will not at anytime give an illumination level lower than the one indicated on drawing No.212.

3.1.1.2 Type of Source

Incandescent and Quartz lamps are recommended in rooms requiring dimming intensity of light or in rooms requiring instantaneous illumination. Quartz is recommended over incandescent in rooms where longer life is needed because of the large number of hours of operation.

Fluorescent lamps are recommended in rooms where high level of illumination, longer life of lamps are required and low level ceiling is encountered. High power output fluorescent lamps shall be used in rooms where cranes or special construction are encountered.
Metal halide high intensity discharge lamps are recommended in areas where high level of illumination are required and where the mounting height of the fixture and level of illumination would impose a much larger number of other types of source. These lamps are also recommended in rooms requiring a good color rendition for color photography and color telecast because of their apperent color temperature of 4 500°K. (See photos Nos. 5, 6 and 7).

3.1.1.3 Illumination and Controls

a. General

Three types of illumination are required:

1. Fixed intensity in rooms having no special requirements.

2. Variable intensity by step in test

areas where, the type of light source does not permit the economical use of dimmers but variable levels of illumination are needed, for testing purposes.

3. Variable intensity by dimmers in test areas and in control rooms, to reduce gradually the light intensity for photographic needs and for the observation of discharge phenomena.

b. Variable Intensity by Step

This variable intensity of light system shall provide three fixed levels of illumination by lighting-up groups of lamps, each group of lamps being uniformly distributed over each test area as indicated on drawing No. 212.

c. Variable Intensity by Dimmers

In addition of gradually reducing the light intensity it shall be possible to switch-on or switch-off instantaneously the light at the level selected on the dimmer. It shall also be possible to switch-on instantaneously the light at full intensity at anytime whichever level shall be selected on the dimmer. These dimming systems are required in rooms indicated on drawing No. 212. It shall be pointed out that in Rest Area a conventional dimming system is recommended.

d. Interlocking

1. Special interlocking between the controls of lighting systems shall be provided for the High Voltage Test Areas, Control and Observation Rooms and Attic of this area. This interlocking system shall be as follows:

-From Control Room No. 6, it shall be possible to control the intensity of light in High Voltage Test Area No.1 or in High Voltage Test Areas No. 1 and No. 2. It shall also be possible to control the intensity of light in the Control Room No. 6 simultaneously with the Observation Room above or control the intensity of light in the Control Rooms No. 6 and No. 7 as well as Observation Rooms above.

-From Control Room No. 7, it shall only be possible to control the intensity of light in High Voltage Test Area No. 2. It shall be possible to control the intensity of light only in Control Room No. 7 simultaneously with the Observation Room above. It shall be pointed out that Control Room No. 6 has priority over Control Room No. 7.

-Control Rooms No. 6, No. 7, No. 9 and No. 10 shall have the possibility to switch-off the lights in the Attic. It shall be impossible, when the lights of the Attic have been switched-off from Control Rooms to switch them on locally. Control Room No. 6 shall have priority over Control Room No. 7.

2. Special interlocking between the controls of the lighting systems shall be provided for the Control Rooms and Observation Rooms of Test Yards No.1 and No. 2. From the Control Room it shall be possible to control the intensity of light of the Control Room itself and of the Observation Rooms aside and above.

3. In addition to controlling its own intensity of light, the Control Room No. 2 shall have the possibility to control the intensity of light of

the client Observation Room of either Test Cell No. 1 or Test Cell No. 2.

e. <u>Special Control</u>

In dark rooms, a special system shall be provided in order that it shall be impossible to switch-on the general lighting during film processing.

8.1.1.4 <u>Class of Luminaires and Accessories</u>

Except in special location like Battery Room and Climatic Test Room, standard class of enclosure for luminaires shall be used. In Battery Room vaporproof enclosure for luminaires shall be used. In Climatic Test Room where temperatures variations are between + 65^{o}C to -25^{o}C and relative humidity up to saturation, special anti-corrosion waterproof luminaires (cast brass enclosure) shall be used.

8.1.1.5 <u>Special Mountings</u>

Special Mounting of luminaires shall be provided in High Voltage Test Area, Corona Room and in Pollution Room as shown on drawing No. 211. This special mounting is done to prevent movement of air between the Test Area and the Attic and to facilitate evacuation of heated air around luminaire. The hot air in Attic is eliminated by the ventilating system.

3.1.2 Emergency Lighting

Emergency lighting shall be provided as shown on drawing No. 212. All the emergency lights shall be fed by "normal-emergency" panels, except for the emergency lights of the Control Rooms of High Voltage Test Area, the Observation Rooms and the High Current-Direct Current Laboratory which are fed by "emergency" panels. The level of illumination shall be sufficient to permit safe evacuation of the premises.

3.1.3 Exit Lights

Exit lights fed by "normal-emergency" panels shall be provided as indicated on drawing No. 212. They shall be located such as to indicate the direction of all exterior access to facilitate emergency evacuation of the building.

3.2 Outdoor Lighting

3.2.1 Street Lighting

Metal poles and luminaires shall be installed where necessary along roads and parking areas. High intensity discharge lamps like mercury, metal halids or high pressure sodium vapor shall be used. When roads ars located in areas where light from luminaires can interfere with the field of vision of the Control Room, they shall be manually controlled by switches located in Control Room.

3.2.2 Area Lighting

3.2.2.1 Outdoor 220 KV/22 KV Substation, Main 22 KV Substation and distribution areas, and outdoor area around auxiliary transformer, shall be lighted as described above with the exception that the switching shall be done by a photoelectric cell.

3.2.2.2 Lighting in Outdoor High Voltage Test Area and Test Yards No. 1 and No. 2 shall be dons by using wall projectors with high intsnsity discharge lamps and controlled by respective Control Rooms.

4- AUXILIARY SYSTEMS

4.1 Telephone

A complete system for telephone facilitiss shall be provided in rooms indicated on drawing No. 212. A main terminal room shall be provided as shown on drawing No. 202.

4.2 Interphone

Except in Pollution Room and its Control Room, intercommunication shall be provided between each Test Area and its Control Room. This shall be accomplished with an interphone system assisted by loudspeaker paging. Interior communication shall also be provided between the rooms indicated on drawing No. 212 with this interphone system. An equipment room shall be provided as shown on drawing No. 202.

4.3 Clocks

A synchronized clock system with a master control clock shall be provided. This system shall permit adjustment of all clocks at the same time from a central control. This system could be operated manually. Size of clocks shall be in accordance with the room dimensions. Clocks shall be installed in rooms indicated on drawing No. 212.

4.4 Chronometers

Elapsed time chronometers shall be provided in all Control Rooms to facilitate timing of tests.

4.5 Watchman Tour

A watchman tour shall be provided in rooms indicated on drawing No. 212. This system shall consist of station boxes containing registering keys, fastened on walls of the different rooms. A portable watchclock shall house a paper tape which will serve to register each key station number and time of registration.

4.6 Security

The main functions of the security system are to give a continuous indication of entry inside test areas, to give an alarm, to stop the tests in progress if there is any danger of personnel injury and to control the signalization in test areas. Locking doors, photoelectric cells, chain link fences and signalization lamps shall be provided for that purpose.

During tests, all entrance doors to the test area shall be electrically locked. The entry inside test areas shall be controlled by two means: if there is a door, this door shall be provided with an electrical contact which shall close when the door is unlocked. If there is no door a photoelectric cell shall be provided to actuate the system when the beam is interrupted by the passage of somebody. These signals could be registered and kept in a memory; if so, they shall be verified by the operator before any test; it shall be impossible to make any test before the memory has been cleared. When the test is in progress and a door is opened, or a beam interrupted, the test shall immediately be shut down. Chain link fences shall be provided for the High Voltage Test Areas and the Transformer Test Area. (See photo No. 11).

The signalization in the different areas shall be the following:

- The red lamps shall indicate that it is forbidden to enter the area.
- The yellow lamps shall indicete that it is permittad to enter the araa but that it is dangarous.
- The green lamps shall indicate that it is permittad to entar the area without any danger.

These signalisation lamps shall be installad on tha walls or above the doors and on the chain link fances.

Red and grean lamps shall be provided at tha entrance of the following rooms and araas:

- High Voltaga Test Areas
- Corona Room
- Transformer Test Areas
- Reactor, Resistanca, Condenser Rooms
- Reactor, Transformer, Ractifier Rooms
- Test Cells No. 1 and No. 2
- High Current and Diract Current Laboratory
- Climatic Test Room
- Synthetic Test Hall
- High Voltage Outdoor Test Area
- Outdoor Test Yards No. 1 and No.2
- Roof of Block "E"
- Pollution Room

These red and green lamps shall also be provided inside the High Current and Direct Current Laboratory, inside the High Voltage Test Areas (on the chain link fences) and inside Pollution Room.

Yellow lamps shall be provided at the entrance of Reactor - Resistance - Condenser Rooms, Reactor - Transformer - Rectifier Rooms, Corona Rooms and inside Test Cells No. 1 and No. 2, High Voltage Test Areas, Transformer Test Areas, High Voltage Outdoor Test Areas, Outdoor Test Yards No. 1 and No. 2, in High Current and Direct Current Laboratory and in Pollution Room.

All these lights shall be controlled from their respective control rooms.

4.7 Fire Alarm

An electrically supervised, non-coded fire alarm system shall be installed as indicated on drawing No. 212. Alarm initiating devices shall be grouped in zones. Actuation of any alarm initiating devices shall cause all audible devices to sound continously in their respective evacuation zone only. The zone of fire shall be indicated by an electrically supervised lamp annunciator which shall be located in Block "G". The alarm system shall be supplied by "normal-emergency" power and a trouble bell shall be incorporated with the panel to indicate any faults in the wiring to the initiating or audible signal devices. Size of bells and horns shall be appropriate for the surface covered and the ambient noise level.

8- CRANES, MONORAILS AND CHAIN BLOCKS

8.1 General

The following type of control shall be provided for the cranes, monorails and chain blocks shown on drawing No.205 and described in Chapter V, article 2.3.3 - "Vertical Movements".

8.1.1 Radio Remote Control for

- Two 10 ton cranes in High Voltage Test Areas (A-104 and A-105).

8.1.2 Cabin Operated for

- 150 ton cranes (one present and one future) in the Transformer Test Area (C-101) and in Mounting Hall (C-103).

8.1.3 Pendant Push Button Stations for

- 2 ton crane in Corona Room (C-104).
- 10 ton crane in Shipping and Receiving Area (D-108).
- 5 ton crane in Assembly Rooms (F-106, F-107, F-108 and F-109).
- 2 ton jib cranes in Test Cells No. 1 and No.2 (F-114 and F-115).
- 5 tons crane in Main Machine Hall (E-101).

8.1.4 Wall Mounted Push Button Stations

At each end:

- 2 ton monorail in Pollution Room (C-102).

- 2 ton monorail in Synthetic Test Hall (B-101)
- 5 ton monorail in High Voltage Test Areas (A-104 and A-105).

Beside:

- 1 ton chain blocks in High Voltage Test Areas (A-104 and A-105).

5.2 Radio Remote Control

When there is a radio remote control system, the system shall be protected against any malfunction due to a defectiveness in the equipment or in the circuit and interfering noise or electromagnetic waves. As the system features solid state electronics it must be capable of withstanding temperature encountered in High Voltage Test Area (60°C).

All the radio remote control system shall be designed to eliminate the possibility of exact duplication by any other transmitting or random radiation. The system shall be protected to prevent operation by unauthorized personnel. The system shall operate the cranes in a range of 60 metres. All auxiliary functions shall be controlled by the transmitter. If the radio remote control shall fail to operate it shall be possible to operate the crane manually with a push button station. The radio remote control system shall be highly protected against any transient over-voltage or electromagnetic waves that may occur in a high voltage test area.

5.3 Cabin Operated Controls

When there is a cab, all control equipment shall be located so as to permit the operator to have an unobstructed view of the work area below the crane.

5.4 Pendant Push Button Stations

Where control is from the floor by means of a pendant push button station, shielded flexible cables shall be used. The push button station shall be mounted on a separate monorail by means of ball-bearing runners.

5.5 Wall Mounted Push Button Stations

Where two wall mounted stations at each end of a monorail are provided an interlocking system shall be provided between the two stations so that the user has the total control of the monorail.

5.6 Miscellaneous

All controls shall be of the dead-man type. Controllers shall be of the magnetic type designed to provide smooth acceleration.

Each bridge and trolley shall be provided with an electrohydraulic brake (bridge) controlled by a pedal when there is a cab or with a solenoid operated brake becoming automatically applied when power is cut-off. Each hoist drive shall have two separate means of braking: one of the braking systems shall consist of a solenoid operated brake acting on the hoist pinion shaft, becoming automatically applied when power is cut-off. The other system operating directly through the hoist motor shaft shall provide controlled speeds of lowering at each notch of the controller. The braking shall be proportional to the load on the hook.

6- SHIELDING

6.1 Shielding of High Voltage Test Areas, Corona Room and Control Rooms No. 6, No. 7, No. 8, No. 9 and No. 10

Faraday cages shall be provided in these areas to obtain an electromagnetic wave attenuation of 60 db minimum for frequencies of 0.1 to 10 MHz. In the High Voltage Test Areaa and in Corona Room, the metallic structure of walls and ceiling shall form part of thia shielding. The copper grid described in article 7.6 of this chapter used as ground return in the concrete floor shall form the other part of the Faraday cage. The various sections of walls and ceiling shall be electrically welded to the supporting structure at every metre in the High Voltage Test Area and at every 25 cm. in Corona Room in order to make a good electrical continuity between all parts of walla and ceiling and between each wall and ceiling. The copper grid shall be welded with exothermic connections to the metallic walls at the same respective distance mentioned previously, and as shown on drawing No. 209. The exothermic welding is a molecular weld. This process is a reduction of copper oxide by aluminum into a semi-permanent graphite mold, producing molten, super-heated copper which gives the welding heat.

Under luminaires, a glavanized steel grid shall be electrically welded to the metallic ceiling as indicated on drawing No. 211.

In Control Rooms, the Faraday Cage shall be constituted by the copper grid embedded in the concrete floor, by a copper grid fastened to the masonry walls and by steel plates on the ceiling. The copper grid fastened to the masonry walls shall have the same characteristics as the copper grid embedded in the concrete floor.

The steel structure supporting the windows shall form part of the Faraday Cage. The floor copper grid shall be "heliarc" welded at every contact points to the wall copper grid and at every 25 cm. to the wall metallic structure."Heliarc" inert gas-shielded arc welding is a process in which the arc is struck between a single tungsten electrode and the work piece. The inert gas, usually argon, flows around the electrode and the weld area, shielding the metal and preventing oxydation. The wall copper grid and wall metallic structure of the Control Rooms shall be "heliarc" welded to the copper grid fastened to the walls and the metallic structure of the Control Rooms at every 25 cm. Parallel wires inside window glass shall be provided to complete the Faraday Cage. Since the majority of flashovers will be vertical, the disturbing magnetic field will generally be horizontal. So vertically arranged parallel wires shall be provided inside window glasses. These parallel wires shall be separated at a distance of 15 mm and shall have a diameter of 0,3 mm. They shall be short circuited by a proper copper frame which shall surround the glass. The copper frames shall be attached and electrically connected with "heliarc" welding to the wall metallic structure of the Control Room at every 25 cm.

All small doors giving access to Faraday cages shall be of metallic material and be bonded with a bolted flexible link in order to uninterrupt the continuity of the Faraday cage. Large doors in High Voltage Test Area shall be provided with steel brushes making contact with the steel door tracks. The Corona Room door shall be provided with copper brushes making contact on a copper bus bar embedded in the floor concrete topping. The copper bus bar of Corona Room door shall be "heliarc" welded to the copper grid at every 25 cm.

The door tracks in High Voltage Test Area shall be connected to the copper grid at every metre with exothermic welding as shown on drawing No. 209. The purpose of the installation is to uninterrupt the continuity of the Faraday cage. All the electrical equipment inside these Faraday cages shall be positively connected to the shielding; in fact, all door frames shall be welded to the metallic wall at every metre, all electrical boxes and receptacle steel plates, lighting fixture boxes, etc. shall be welded to the metallic walls of these Faraday cages.

6.2 Shielding of Control Rooms No. 1 and No. 2

The shielding of these rooms shall consist of structural

RF (Radio Frequency) panels assembled in such a way as to form a self supported enclosure which will be erected inside the structural concrete walls, floors and ceilings of rooms provided for Control Rooms No. 1 and No. 2.

These structural RF panels shall be laminated by a layer of galvanized steel, on each side of special 20 mm exterior grade plywood. The joint between structural RF panels shall form a positive, flat contact, producing a tight RF seal at every mating surface. It shall have the lowest possible joint impedance for high electromagnetic and electrostatic attenuation. All windows shall be provided with a wire mesh inside to complete the shielded enclosure.

Performance of these shielded Control Rooms shall be as follows:

- Magnetic field attenuation of 4 db at 60 Hz, 15 db at 1 KHz, 60 db at 14 KHz and 100 db at 200 KHz for Control Room No. 1.
- Magnetic field attenuation of 4 db at 5 Hz, 15 db at 60 Hz, 45 db at 1 KHz, 60 db at 14 KHz and 100 db at 200 KHz for Control Room No. 2.
- Electric field attenuation of 110 db between D.C. and 50 MHz.
- Plane waves attenuation of 100 db at frequencies between 50 MHz and 10 GHz.

The shielded enclosure shall be constructed without any grounding point and with a minimum ground resistance of 1 000 ohms. After the construction, it shall be connected to ground at a unique point on the wall grounding bus bar system located in the Equipment Room below.

Wave guide type air vents, which provide RF attenuation equal to the enclosure shall be provided for ventilating and air conditioning systems.

Every pipe or conduit penetrating the enclosure shall use wave guide penetrations to make the enclosure functional. These wave guide penetrations shall be non-conductive couplings preventing multiple grounds without affecting the rated attenuation.

Every wire (including neutral and ground wires) entering the RF shielded enclosure shall be provided with a RF filter to prevent conducted signals from entering the enclosure. Wave guide penetrations shall also be provided with these filters. These filters shall be designed to provide 100 db attenuation from 14 KHz to 10 GHz. No filters shall be provided for telephone, interphone, measurements and control cables.

7- GROUNDING

7.1 Main Peripheral Grounding Cable

7.1.1 All grounding network shall be connected to the main peripheral grounding cable; this 400 mm^2 bare, stranded, tinned, copper cable shall be direct burial at 2 metres, below ground level and installed as follows: first, 200 mm of organic soil, then the cable and after, organic soil without any rocks, filling the rest of the trench.

7.1.2 All splices below grade shall be exothermic process welding connection.

7.1.3 All inside accessible connections of the cable link between main peripheral grounding cable and inside main grounding bus bar shall be made with solderless lugs, bolted to the main grounding bus bar.

7.1.4 All outside cubicles, transformers, steel structures for aerial lines, etc..., shall be connected to the main peripheral grounding cable as shown on drawings.

7.1.5 Copper weld grounding rods shall be installed along the main peripheral grounding cable as shown on drawings. The rods shall be welded with an exothermic connection.

7.1.6 Grounding cable installed in duct bank, and also grounding cable used for the grounding of outdoor electric equipment shall be bare, stranded, tinned, copper cables.

7.2 <u>Grounding Bus Bar</u>

7.2.1 All bus bars used for grounding purposes shall be flat type, half hard temper, copper, mounted on wall, floor ceiling or roof, as shown on drawing. Sleeves shall be provided for concrete beam crossing. Bus bars shall be tinned when used outdoor.

7.2.2 On wall or ceiling, grounding bus bars shall be installed with special brackets as detailed on drawing.

7.2.3 Grounding bus bars, flush mounted in floors shall be installed as detailed on drawing. These grounding bus bars shall be well leveled with the concrete floor.

7.2.4 In rooms D-003, E-103, E-201 and F-002, the connection between grounding bus bars coming from floor or ceiling and ths main grounding bus bar shall be made with bolted connections in such a way as to permit test on these parts of the grounding network.

7.2.5 Each section of flat bus bar shall bs spliced with the inert gas-shielded arc welding process (Heliarc type).

7.3 <u>Grounding Pedestal</u>

Grounding Pedestals shall be provided for the grounding of the test equipment and shall be built as detailed on drawing. One (1) metre length of bare copper cable shall be left when pouring the concrete to permit the connection to the main grounding cable.

7.4 Grounding of Cable Trays

Grounding of cable trays shall be made with a 50 mm^2 insulated copper wire connected at each 15 metres to the suspension rods. This wire shall be continuous on all its length and the extremities shall be welded to the copper grid or to the copper grounding bus bar.

7.5 Special Grounding of Cranes and Motorized Doors

Special grounding of cranes and door main runway conductors shall be provided in the High Voltage Test Area and in Corona Room as shown on drawing No. 211. The main runway conductors shall be grounded to the copper grid at both ends, during tests. Control of the contactors shown on the scheme, shall be done from Control Rooms No. 6 and No. 7 in the High Voltage Test Area and locally in the Corona Room.

7.6 Copper Grid

A copper grid shall be provided as indicated on drawing No. 208. This copper grid shall be used as ground return. This copper grid shall also serve as a part of Faraday cage as seen in previous article. Details of this copper grid are shown on drawing No. 209. This copper grid shall have the following characteristics: 99,98% of copper, 0,02% phosphorus, 2 mm wide x 2 mm thick, openings of 76 mm x 38 mm, a weight of 20 kilograms per 9 sq. m. and a conductivity of 84%. The sheets shall have a minimum of 7,5 m x 2,5 m and a strip (non expended) of 25 mm, shall be left at one end of the expanded copper grid to facilitate welding. All weldings to the grid shall be made with inert gas-shielded arc welding (Heliarc welding). This copper grid shall be layed on the structural concrete and covered by the concrete floor topping. This copper grid shall be connected to the peripheral conductor at intervals and in the manner shown on drawings No. 208 and No. 209.

7.7 Grounding of Railroad, Cranes and Motorized Door Tracks

The grounding of each railroad and motorized door tracks in concrete floor shall be as shown on drawing No. 209. In blocks "B","D","E" and "F" grounding of crane, monorail and jib crane tracks shall be provided. Each track shall be connected to the grounding conductor as shown on drawing No. 208 with an exothermic welding. In blocks "A" and "C" no grounding of cranes and monorails track shall be provided as the grounding is done by the structural members. (See photo No. 12).

7.8 Grounding of Measuring Cables Conduits

Conduits used for measuring cables shall be grounded as follows:

7.8.1 In High Voltage Test Areas No.1 and No. 2 they shall be grounded to the copper grid by welding the grid on each conduit at six different points.

7.8.2 In High Voltage Outdoor Test Area, they shall be grounded at one end to the copper grid and at the other end to the copper ground wire. Grounding shall be done by six points of welding.

7.8.3 In Synthetic Test Hall, grounding shall be done by welding the conduit to a grounding bus bar in the Synthetic Test Hall and to a grounding bus bar when entering the patch panel No. PP-4 in Control Room No. 1.

7.8.4 In Outdoor Test Yards No. 1 and No. 2, one end of conduits on the roof of block "E" shall be grounded to the grounding bus bar on that same roof while the other ends in Control Room No. 1 shall be grounded to a grounding bus bar located near the patch panel No. PP-4.

7.9 Grounding of Steel Structural Columns

All steel structural columns located in blocks "A" and "C" shall be grounded. A 20 x 5 mm copper bus bar shall be used and connected to copper grid (4 point connections minimum) or nearest grounding bus bar. The connections to the columns shall be of exothermic welding type and to grid, it shall be of "Heliarc" type.

7.10 Grounding of Primary Testing Points

The primary testing points located in blocks "A" and "C" shall be grounded with a 20 x 5 mm bus bar welded at 40 contact points to the copper grid and at one contact point in the cubicle.

7.11 Grounding of Patch Panels

Patch panels No. PP-1, No. PP-2 and No. PP-3 shall be grounded with a 20 x 5 mm copper bus bar welded at 40 contact points to the copper grid and one contact point in the cubicle. Grounding bushings shall be provided for each conduit entering the panel and all these grounding bushings shall be interconnected and grounded to the copper grid in the floor. Patch panel No. PP-4 shall be grounded with a 95 mm^2 insulated copper wire, installed in conduit, to the same unique grounding point as the shielding of the Control Room is grounded. All the conduits entering the patch panel shall be provided with grounding bushings which shall be interconnected and grounded to the grounding bus bar of the patch panel. All the measuring cable conduits shall be grounded ahead of the special wave guide penetrations outside the shielded enclosure.

7.12 Grounding of Metallic Bases

All metallic bases of reactors and circuit breakers located in room E-103, E-201 and F-002 shall be grounded to the copper bus bars installed in ceiling or floor. The exact location of these copper bus bars installed in floor shall be determined by the location of the electrical equipment.

7.13 Grounding Cables

Grounding cables used inside the building shall be bare, stranded, copper cable and all splices shall be done with exothermic connections. Cables shall be attached to the wall or ceiling at every 1,5 m.

7.14 Grounding of Electrical Equipment

7.14.1 All the non-current carrying metal parts of the electrical equipment, such as conduits, boxes, enclosures, hardware in manhole, etc.. shall be grounded in an effective and permanent manner.

7.14.2 All steel structures for aerial lines, outdoor and indoor cubicles, fences shall be grounded as shown on drawings.

7.14.3 Neutral points of transformers and regulators shall be grounded.

7.15 Grounding of Equipment Supplied and Installed by Mechanical Contractors

7.15.1 All metallic equipment through the building as floor drains, and floor outlets, access covers, supply, exhaust, or return diffusers or grilles, etc., shall be grounded. The ground connection shall be with a 20 x 30 mm soft bare copper bar welded to the copper grid or a 35 mm copper, cable, connected to the main grounding system of the building. (See photo No. 13).

7.15.2 All metallic conduits, pipes, ventilation ducts, etc.., shall be grounded. The grounding connection to the pipes shall be at a maximum of 5 m. from an outlet that can be reached by people.

Elsewere conduits or pipes shall be grounded at every 20 m.

7.16 Special Grounding Outlets and Boxes for Chain Link Fence In Floor Slab

The copper grid embedded in concrete floor shall be accessible by means of permanent connections. These connections as detailed on drawing No. 210 shall also serve as boxes for chain link fence. Their location is shown on drawing No. 204. Normally, these boxes shall be closed with a threaded plastic cap because of the air suspension transportation system and liquids that may enter. Details and location of boxes for chain link fence shall be as shown on drawings No. 204 and No. 210. For the same reason mentioned previously, these boxes shall be normally closed with a cover. The dimensions of these boxes shall be according to the fence post diameter. The exterior surface of these boxes in contact with concrete shall be corrugated in order to provide a good grip. (See photo No. 14).

7.17 Miscellaneous

All incoming supply systems such as water, gas, drains, etc., or other metallic pipes shall be isolated from the earthing system of the Experimentation Centre by a non-conductive length of conduit.

8. PATCH PANELS, MEASURING CABLES AND BOXES

8.1 Patch Panels

Patch panels for measuring cables shall be provided in Control Rooms No. 1, No. 6, No. 7 and No. 8. These panels es shown on drawing No. 209 shall be made of cold rolled steel and of an entirely welded construction except for the receptacle plates. Brushed aluminum and anodized finish shall be provided for these plates. (See photo No. 15).

8.2 Coaxial Cables and Connectors

All measuring cebles shall be provided with female terminations at both extremities, complete with mounting plate.

Coaxial cebles shall be provided as indicated on drawing No. 209 between the patch panels and the special floor boxes for measuring cebles, junction boxes in suspended ceiling for potentiel divider and weatherproof junction boxes for potential transformers and current trensformers.

The different types of coaxial cables (type No. 1, No. 2 and No. 3) shell be provided in accordance with the requirements of the equipment to be connected.

The coaxiel cebles between the measurement boxes No. 1a, No. 1b, No. 1c, No. 1d and No. 1 shall be of equal length.

8.3 Boxes for Measurements

Details of special boxes and junction boxes for the potential divider are shown on drawing No. 209.

Details of special boxes for measuring cables and utility outlets of measurement boxes for the potential and current transformers, and of the combined pedestal measurement boxes and grounding outlet are shown.

9. FALSE FLOORS AND CEILINGS

False floors of the "data" type for measurement and control cables and false ceiling for lighting fixtures (and filters in Control Rooms No. 1 and No. 2) shall be required in Control Rooms No. 1, No. 2, No. 3 and No. 4. False ceilings shall also be required in Control Rooms No. 6, No. 7, No. 8, No. 9 and No. 10.

MECHANICAL ENGINEERING

VIII - MECHANICAL

1- GENERALITIES

1.1 Introduction

This mechanical performance specification and the annexed drawings are to be used by the Architectural Contractor as a general guide for the design of the mechanical system and sub-systems within the Electrical Experimentation Centre for the testing of equipment from the Spanish Electrical Industry.

Standard Services and systems, such as sanitary services, roof drainage and the detailed calculations for sizing piping, ducting, etc.. are not covered in this report.

Special attention should be given to the fact that this Chapter treats only the recommended systems and sub-systems related to the building concept itself, for example:

- Low and High Pressure air systems
- Water Treatment system
- Plumbing system for the building
- Heating systems for the building
- Ventilation and air conditioning systems for the building.

Any mechanical considerations relative to equipment needed for the operation of the Laboratory are described in equipment reports.

1.2 Mechanical Drawings

The mechanical drawings that are supplied indicate suggested locations of equipment, services and diagrams of these systems. These diagrams show only the essential components in order to permit better understanding of the operation of the systems.

The location, quantity and capacity of equipment shown shall be determined when the final architectural and other drawings shall be carried out.

1.3 Codes

All mechanical systems shall be designed to comply with all codes, by-laws or regulations which have jurisdiction in the project area. This covers requirements for fire protection, plumbing systems, oil handling piping, storage tanks, ventilation practices, etc.

1.4 Grounding

Mechanical equipment installed in the shielded areas shall be connected to the grounding system of the Laboratories as mentioned in article # 7.15 of Section VII - Electrical. Thoseareas are:

a) H.V. Section: Floor, walls and ceiling of H.V. Test Areas Nos 1 and 2, Corona Room and Control Rooms

Nos 6, 7, 8, 9 and 10.

b) H.P. Section: Floor, walls and ceiling of control rooms Nos.1 and 2.

1.5 Thermal Insulation

1.5.1 Cold Surfaces

All pipe, duct or equipment surfaces which are colder than the ambient dew point temperature shall be insulated with suitable thermal insulating material of adequate thickness to maintain a surface temperature higher than the normal ambient dew point temperature. This insulation will prevent any condensation of water vapor. Onthe warmer side insulation shall be covered with a vapor barrier to prevent water vapor from reaching colder surface and condensing.

1.5.2 Hot Surfaces

In areas where mechanical cooling or ventilation is provided to remove heat gains and to maintain a temperature within prescribed limits, all hot ducts, pipes or other items of equipment shall be insulated to reduce the size of the cooling or ventilating systems.

In other areas, all pipes, ducts or other items of equipment having a temperature more than 30°C above the ambient temperature shall be insulated to minimize heat losses.

1.6 Noise and Vibrations

All equipment which generates vibrations shall be installed with suitable inertia bases, vibration isolators, flexible connectors, etc., to prevent any propagation of the vibrations. All equipment shall be selected to maintain noise levels below maximum valves. Silencers and acoustical insulating material shall be used, where required, to reduce noise transmission to permissible levels.

Sound levels are rated in terms of sound power level (PWL) in decibels (reference 10^{-12} watt) and in terms of sound pressure level (SPL) in decibels (reference 0.0002 microbar). A noise level (NC level) specified for a room means the sound pressure level in this room shall not exceed the values given for each frequency band of the NC level curve.

Refer to latest edition of the A.S.H.R.A.E. (American Society of Heating, Refrigerating and Air Conditioning Engineers) Guide and Data Book for the NC level curves.

Maximum values of noise levels shall be as follows:

Room	Noise Level
Conference Room	NC-30
Offices	NC-35
Library	NC-35
Control Room	NC-40
Client Observation Room	NC-40

Dark Room	NC-40
Corridor	NC-40
High Voltage Test Areas	NC-40
Rest Room	NC-45
Corona Room	NC-50
Transformer Test Area	NC-50
Mounting Room	NC-50
Assembly Rooms	NC-50
High Current and Direct Current Laboratory	NC-50

1.7 Roof Mounted Equipment

All equipment installed on the roof shall be located within prescribed distances from high voltage electrical lines. This equipment shall be suitably designed and installed to resist wind forces.

1.8 Motor Driven Equipment

When selecting motor driven equipment, such as ventilators and pumps, where speed of rotation might affect its characteristics, it is advisable, for more flexibility, to use V-belt rather than direct drive.

1.9 Meteorological Data

1.9.1 Climatic Conditions

The following meteorological data are averages computed for the years 1931 to 1960 incl. in Madrid.

Climatic Condtion		Days per year
a) Clear		107,7
b) Cloudy		179,7
c) Overcast		77,6
Rain (included in cond. b & c)	82,5	
Rain intense (included in cond. c)	17,9	
Snow (included in cond. c)	3,5	
Fog (included in cond. b)	37,6	
Drizzle (included in cond. b)	4,6	
Hoar-Frost (included in cond. c)	12,4	
Storm (included in cond. c)	10,5	
Hail (included in cond. c)	1,9	
TOTAL:		365,0

1.9.2 Outdoor Temperature and Humidity

The following outdoor temperature (Dry Bulb) and relative humidity are monthly averages computed for the years 1931 to 1961 incl. in Madrid.

Month	Temper.(°C)	Rel. Humidity (%)
January	6,2	78,4
February	7,0	72,9
March	9,8	65,0
April	12,5	61,6
May	17,0	52,8
June	20,6	49,9
July	24,4	41,1
August	23,7	42,8
September	20,0	55,9
October	15,0	67,6
November	8,8	76,1
December	5,4	76,8

1.9.3 Temperature and Humidity Control

To overcome variable outdoor test results, due to unfavorable weather conditions, indoor facilities with adequate temperature and humidity control are recommended for most test areas and rooms.

2- TRANSFORMER OIL HANDLING SYSTEM

2.1 Definition

The transformer oil handling and treatment system is required to fill with suitable treated oil and to drain equipment to be tested which will be transported to and from the Laboratories without oil. This system is divided into the following sub-systems:

- Oil Storage Tanks
- Pumps
- Distribution Headers
- Piping Networks
- Oil Treatment Unit

2.2 Oil Storage Tanks

2.2.1 Purpose

The storage tanks shall be used to recover oil drained from equipment at various locations in the Laboratories. They are classified as follows:

- One tank for storage of usable oil (75 000 litres)
- One tank for storage of used oil (50 000 litres)
- One tank for storage of unusable oil (5 000 litres)

2.2.2 Location and Installation

The storage tanks shall be located as close as possible to both service road and railway. Underground installation of the tanks overcomes the need to heat the oil when the outside temperature is below 5°C.

Each tank shall have a manhole for emptying, inspecting and cleaning purposes and shall be equipped with level indicators conveniently located inside the building near the headers and the pump controls.

Each tank shall be mounted on a reinforced concrete base and secured in place by steel straps anchored to the concrete fondations.

A paint coating and cathodic protection shall be provided for all storage tanks.

2.2.3 Usable Oil Tank

Usable oil is oil free of contaminants and of adequate quality for filling the equipment. Usable oil shall be stored in a tank having a minimum capacity of 75 000 litres. The tank shall have a filling pipe with an air tight cap, a vent pipe with a silicagel desiccant vent cap to prevent water vapor entering the tank, a supply pipe and a return pipe. The supply pipe shall have a foot valve in the tank and a check valve inside the building to keep the pipe filled with oil to insure proper operation of the pumps.

2.2.4 Used Oil Tank

Used oil is oil which is returned to the usedoil tank for treatment before further use. The used oil shall be stored in a tank having a minimum capacity of 50 000 litres. The tank shall have a filling pipe with an air tight cap, a vent pipe with a silica-gel desiccant vent cap to prevent water vapor entering the tank, a supply pipe and a return pipe. The supply pipe shall have a foot valve in the tank and a check valve inside the building to keep the pipe filled with oil to insure proper operation of the pumps.

2.2.5 Unusable Oil Tank

Unusable oil is oil which has become so contaminated that it can no longer respond to treatment and cannot be reused. The unusable oil shall be accumulated in a tank having a capacity of 5 000 litres. The tank shall have a vent pipe with a standard weatherproof cap and a return pipe. This oil shall be removed and discarded in an appropriate manner, for this purpose a suitable fitting must be provided.

2.3 Pumps

2.3.1 Purpose

An oil pumping system is required mainly for these operations:

- filling the equipment
- transfering oil from one storage tank to another.
- draining the equipment or tanks.

2.3.2 Feed Pumps

Oil is supplied to the equipment or to the oil treatment unit by a feed pump having a capacity of 2,5 litres/sec. against the head required to pump the oil to the farthest point and to the top of the equipment (10 metres). With a zero flow, the pressure shall not exceed the maximum inlet pressure of the oil treatment unit which will allow proper operation of the unit, approximately 315 kPa (3,2 kg/cm^2). A second pump with the same characteristics may be required to increase the capacity when the oil treatment unit is not in use and also to serve as a spare pump.

2.3.3 Mobile Pump

Equipment is drained by use of a mobile pump. This pump may be similar to the feed pump and may be used also as a spare if only one feed pump is installed.

2.4 Distribution Headers

2.4.1 Purpose

The suction, discharge and return headers with shut-off valves allow easy selection of pipes to be interconnected to form the required piping network. All tanks, feed pumps, and distribution networks are permanently connected.

2.4.2 Suction Header

The following pipes and accessories shall be connected to the suction header and shall have shut-off valves:

- a suction pipe from the usable oil tank
- a suction pipe from the used oil tank
- a suction pipe to feed pump No. 1
- a suction pipe to feed pump No. 2
- a "quick connect" coupling for removable hose to allow connection of another pump to the tanks.
- a thermometer (0° - 150°C range)
- a compound gauge (0 - 76 Cms and 0-10 kg/cm^2 range).

2.4.3 Discharge Header

The following pipes and accessories shall be connected to the discharge header and shall have shut-off valves:

- a return pipe to the usable oil tank.
- a return pipe to the used oil tank.
- a discharge pipe from feed pump No. 1
- a discharge pipe from feed pump No. 2
- a "quick connect" coupling for removable hose to allow connection of another pump or the outlet of the oil treatment unit to supply pipes to local outlets or to return pipes to storage tanks.
- a supply pipe to local outlets
- a thermometer (0° - 150°C range)
- a pressure gauge (0-10 kg/cm^2 range).

In addition, on the discharge pipe of each feed pump, before the header, a quick connect coupling with a shut-off valve is required to allow connection of the inlet of the oil treatment unit to the discharge of feed pumps.

2.4.4 Return Header

The following pipes and accessories shall be connected to the return headers and have shut-off valves:

- a return pipe from the local inlets
- a return pipe to the unusable oil tank
- a return pipe to the used oil tank
- a "quick connect" coupling for removable hose installed to allow manual pouring of oil into the tanks or to connect the discharge from a pump.
- a pressure gauge (0-10 kg/cm^2 range).

2.5 Piping Networks

2.5.1 Purpose

The piping networks consist of three pipe networks as follows:

- piping from the tanks to the headers
- piping from the headers to the pumps
- piping from the headers to the local supply outlets and return inlets.

2.8.2 Regulations

All piping networks shall comply with all local codes and regulations related to this type of oil installation.

2.8.3 Local Supply Outlets and Return Inlets

For the purpose of flexibility, local supply outlets and return inlets shall be provided to permit the use of hoses of appropriate lengths to fill and drain the equipment. These inlets and outlets shall have shut-off valves, "quick connect" couplings, pressure gauges and a thermometer on the supply line. A by-pass with a shut-off valve is required to drain residual oil in order to eliminate contamination when filling other equipment with useble oil. A small vent pipe with a valve is also required to remove air from the piping.

2.8.4 Flexible Hoses

Flexible hoses with "quick connect" couplings are required to connect pieces of equipment to the mobile pump, the oil treatment unit, a supply outlet or a return inlet.

These hoses shall be of sufficient length to reach any piece of equipment in the large hall from the nearest outlet or inlet when using the oil treatment unit or the mobile pump and two (2) lengths of hose. Elsewhere, as in the outdoor test areas, one or more lengths of hose may be used to cover longer distances. These hoses are specified in the "Second Equipment Report" Section HV28.

Each hose shall be mounted on a mobile hose reel for ease of handling and storage (See photos Nos. 16 and 17).

2.6 Mobile Oil Treatment Unit

2.6.1 Purpose

The mobile oil treatment unit is specified in detail in the "Second Equipment Report", Section HV28.

This unit will remove water vapor, dirt particles, air, gases, etc., from the oil.

2.6.2 Connections

This unit will be connected in series with the feed pump to supply "treated" oil to the equipment or to the usable oil tank. The unit will be connected with hoses to the headers when transferring oil into the usable oil tank and to the local supply outlets when filling the equipment.

2.6.3 Capacity

This unit will treat oil at a maximum rate of 2,8 litres/sec. The inlet pressure shall not exceed a prescribed maximum, approximately 315 kPa ($3,2\ kg/cm^2$) in order to allow the proper operation of the inlet pump and heater.

2.7 Drawings

A complete diagram of the oil system, except for piping to the local outlets, is shown on drawing No. 306. Details of the local outlets and inlets are shown on drawings Nos.306, 307 and 308. Suggested locations of the oil pumps, headers and local outlets and inlets are also shown on drawings Nos. 301, 302, 303.

3- LOW PRESSURE AIR SYSTEM 685 kPa ($7,0\ kg/cm^2$)

3.1 Definition

This system will be used for such general purposes as small compressed air tools and cleaning by blowing. A major purpose will be to supply air to modular platforms equipped with air cushions which are recommended for moving equipment up to 300 metric tons within the building and later to outside test areas.

The low pressur air system consists of the following sub-systems:

- compressors and accessories
- piping and local air outlets

8.2 Compressors and Accessories

8.2.1 Purpose

This sub-system includes the air compressors and their controls, one air receiver and one aftercooler to generate and to store compressed air.

8.2.2 Air Requirements

The maximum air quantity required for the air cushion platforms is approximately 0,285 m^3/sec. at atmospheric pressure, compressed to 685 kPa (7,0 kg/cm^2).

8.2.3 Compressor Characteristics

The compressors shall compress the air in two stages with an air cooled intercooler between the stages. The motors may be connected directly to the compressors or with V-belt drives. The compressors shall be piston type, oil lubricated.

8.2.4 Compressor Capacities

One compressor will handle the maximum requirements for pneumatic tools. One or two additional compressors are required to assist the smaller compressor to meet the maximum air requirement of 0,285 m^3/sec. (at atmospheric pressure).

8.2.5 Unloading

All the compressors shall be equipped with automatic unloaders in order to:

a) Unload the compressors when starting to prevent overloading the electric motors.

b) Unload the compressors when 685 kPa (7,0 kg/cm^2) is attained in the receiver and reload the compressor when the pressure has reduced to 620 kPa (6,3 Kg/cm^2).

3.2.6 Receiver

The compressors shall discharge into an air receiver. The air receiver shall have the required capacity to absorb pulsations and prevent the cycling of the small compressor when there is a small intermittent demand.

3.2.7 Aftercooler

The compressed air shall pass through an aftercooler before entering the receiver. The function fo the aftercooler is to cool the air and reduce the moisture content in the air. It may be water cooled or air cooled.

3.3 Piping and Air Outlets

3.3.1 Purpose

This system consists of the complete piping network serving all the low air pressure outlets and the connections between the compressors and the receiver.

3.3.2 Piping

The compressors shall discharge into a common main pipe. Connections to this main shall be made at the top to prevent condensation from flowing into the idle compressors. The main shall be sloped down toward the receiver. Supply piping shall be equipped with "drip legs" wherever there is a riser.

3.3.3 <u>Local Air Outlets</u>

Two sizes of local outlets are required:

- small outlets to supply pneumatic tools.
- large outlets to supply air to platforms equipped with air cushions.

Small outlets shall be standard type air hose connectors with an integral air valve installed with a manual shut-off valve, pressure gauge, filter and an oiler. They shall be installed in all workshops, assembly rooms, erection areas, etc., where compressed air is required to operate tools.

Large outlets shall be of "quick connect" coupling type with a separate shut-off valve and pressure gauge. When needed a reducer can be adapted to these outlets with a "quick connect" coupling to supply pneumatic tools. The minimum pressure at each outlet when the maximum air capacity is fed to a platform shall be 515 kPa (5,25 kg/cm^2)

(See photos Nos. 1, 2 and 16).

3.3.4 Flexible Hoses

The hoses shall be long enough to cover the entire area where the platforms will be used except for outdoor use where it may be more practical to connect more than one hose in series to obtain the proper length. Hoses shall be equipped with "quick connect" coupling and shall be mounted on movable hose reels for ease of handling and storage (See photos Nos. 16 and 17).

3.4 Drawings

Suggested locations of compressors and local air outlets are shown on drawings Nos. 301, 302, 303.

4- HIGH PRESSURE AIR SYSTEMS 24,5 MPa (250 kg/cm^2) and 5,4 MPa (55 kg/cm^2)

4.1 Definition

The major purpose of these systems will be to actuate pneumatically operated electrical apparatus such as circuit breakers.

4.2 Description of the System

The principal system consists of three (3) compressors, each supplying approximately 0,023 m^3/sec. of air at atmospheric pressure compressed to 24,5 MPa (250 kg/cm^2). Provision for an additional compressor shall be foreseen.

The compressed air will be fed to local outlets in two separate piping networks, one at 24,5 MPa (250 kg/cm^2), and the other at 5,4 MPa (55 kg/cm^2). The reduced pressure will be ontained through a central pressure reducing station. Four (4) spherical pressure vessels will be used to accumulate the air at 24,5 MPa (250 kg/cm^2). These receivers will have a volume of 0,8 m^3 each and will be installed in pairs, one on top of the other. Four (4) cylindrical pressure vessels will be used to accumulate the air at 5,4 MPa (55 kg/cm^2). These receivers will have a volume of 1,2 m^3 each.

It is important that the high pressure 24,5 MPa (250 kg/cm^2) vessels shall be located in a room where the ambient temperature is lower than the supply piping, so that any moisture present in the air will tend to condense in the recievers rather than in the piping. These receivers shall be located in the basement in a location as cool as possible, away from adjacent sources of heat. If receivers feeding air to outdoor equipment are located in this room, the temperature of this room shall be equal to or lower than the outside temperature, even in winter. This room shall be cooled with outside air when the outside temperature is lower than the room temperature, and shall be kept cool when the outdoor temperature is higher. This room shall be appropriately insulated.

4.3 Piping

The piping used for this system shall be either stainless steel or copper tubing with welded or compression type fittings. The sizes of the piping will vary from 1/8" to 1" (outside diameter).

4.4 Local Outlets

Outlets for both systems (250 kg/cm^2 and 55 kg/cm^2) will be needed wherever pneumatically operated electrical apparatus will be used or tested.

4.5 Drawings

Suggested locations of compressors and receivers and air outlets are shown on drawings Nos. 301, 302, 303.

5- WATER TREATMENT SYSTEM FOR RAIN TESTS

5.1 Definition

Water having a resistivity, controllable within a specified range, is required to achieve tests under simulated rain conditions. These tests will be performed in the High Voltage Test Areas. Rain tests may be also conducted in the Outdoor Test Area.

This system is divided into the following sub-systems:

- deionizer and charcoal filter
- storage tanks
- pump
- piping, controls and outlets.

5.2 Deionizer and Filter

5.2.1 Purpose

This sub-system permits the treatment of water to obtain a composition similar to that of rain.

5.2.2 Quantity and Quality of Water

The required quantity of water is based on one test per day using 11,5 litres per second during 60 minutes (approximately 40 000 litres). The water resistivity shall be controllable in the range of 50 to 250 ohm metres with a maximum deviation of ± 10%.

5.2.3 Rain Water Supply

The resistivity of the raw water supply available for rain tests may vary. Two values have been given, 150 and 186 ohm metres, these are in the middle of the desired range. In order to obtain the full range, the larger portion of the water (over 80%) must be deionized (demineralized) to increase its resistivity, and salt must be added to the other portion to decrease its resistivity. The final resistivity will be obtained by controlled mixing of the two components.

5.2.4 Deionizer

The deionizer shall be of the two bed type with separate cation and anion exchangers connected in series and with automatic regeneration. There is no need for a costly mixed bed unit which would require many manual operations for regeneration. The efficiency of a two bed unit (over 1 500 ohm metres) is well over the required 250 ohm metres.

The size of the deionizer and the quality of the chemicals to be used for regeneration of the anion and cation exchangers shall be determined after a complete analysis of the water. If the water analysis shows that salt must be added to decrease its resistivity, the resistivity of the deionized water should be maintained at a maximum value of 300 ohm metres to minimize the amount of salt to be added. If analysis of the raw water shows a resistivity lower than 50 ohm metres, there will be no need for salt addition, and the resistivity of the deionized water would have to be higher than 250 ohm metres but with no maximum limit.

The deionizer shall have the capacity to operate on a cycle which can deliver 40 000 litres of deionized water and be regenerated within a maximum period of 23 hours.

5.2.5 Charcoal Filter

A charcoal filter is required to remove chemicals and impurities such as chlorine from the water in order to permit efficient operation of the deionizer.

Water to which salt has been added shall not pass through the charcoal filter. This would absorb salt and increase the resistivity whereas a decrease is desired.

The raw water pressure shall be sufficient to overcome losses through the filter and deionizer and to fill the storage tank to the top. Pressure required will be approximately 345 kPa (3,5 kg/cm^2).

5.3 Storage Tanks

5.3.1 Purpose

The purpose of these tanks is to store the treated water and to deliver it at the outlets as required.

5.3.2 Deionized Water Storage Tanks Capacity and Construction

The water delivered by the deionizer shall be stored in one or two storage tanks having a total capacity of 40 000 litres. Tanks shall be resistant to very corrosive deionized water. Fiberglass tanks are suitable for this application. They resist corrosion, will not contaminate the water and are not too expensive. Steel tanks lined internally with glass or plastic are acceptable but may cause some problems if any metal should come into contact with the corrosive water.

Tanks shall be atmospheric pressure type with level controllers to actuate the operation of the deioniser which shall start when the level drops to 35 000 litres and stop when the tank is full. Tanks shall have the following accessories:

- a top mounted manhole
- a drain valve
- an overflow
- a water level indicator
- a high level safety and alarm switch
- a low level safety and alarm switch.

5.3.3 Tank Dimensions and Location

If two vertical tanks are used, the dimensions of each tank would be approximately 4 meters high and 2,5 meters in diameter, according to the country standards. Lower tanks could be used to fit available space but they will probably be more expensive.

5.4 Deionized Water Pump

5.4.1 Purpose

This pump will serve to transfer and to supply deionized water to the outlets at the required pressure.

5.4.2 Pump Capacity

The pump shall be of adequate capacity (11,5 litres per second). The outlet pressure shall be approximately equal to the pressure of the raw water in order to allow satisfactory operation of the mixing valve. If necessary a pressure reducing valve shall be installed in the supply line to the outlets to prevent excessive pressure at the outlet with zero flow. The artificial rain apparatus will have its own pumps and pressure regulators and will need only a minimum pressure of approximately 98 kPa (1,0 kg/cm^2) - (See photo No. 20). The artificial rain apparatus is specified in the Equipment Report HV17.

5.4.3 Pump Construction

The pump shall be made of selected material such as a stainless steel shaft and impeller in a cast iron body to minimise corrosion and contamination.

5.5 Controls, Piping and Outlets

5.5.1 Purpose

This section comprises test water quality control and the piping network.

5.5.2 Mixing Valve

A mixing valve actuated by a conductivity controller shall be used to mix the deionized water and salt water in the required ratios to obtain the desired conductivity (or resistivity). The valve shall be made of suitable materials to minimize contamination of the water. A recorder could easily be used to supervise the operation of the system and keep a record of the variations of the resistivity of the water during the test.

When the resistivity of the raw water is lower than that of the water to be used for a test, it would be possible to prevent operation of the brine pump by an appropriate switch and obtain the desired resistivity by mixing deionized water with raw water.

5.5.3 Piping and Fittings

Piping and fittings, including valves, shall be made of non metallic materials such as polyvinyl chloride and shall be designed for the appropriate pressure range.

5.5.4 Outlets

For purpose of flexibility, outlets are required in the High Votlage Test Areas and for the Outdoor Test Area. Each outlet shall have a shut-off valve, a "quick connect" coupling, a pressure gauge and a thermometer. Each flexible hose used for connecting an outlet to the rain making apparatus shall be mounted on a movable hose reel for ease of handling and storage (See photos Nos. 18 and 19).

5.6 Drawing

A complete diagram of the water treatment system for rain tests is shown on drawing No. 306.

Suggested locations of equipment and water outlets for rain tests are shown on drawings Nos. 301 and 302.

6- PLUMBING SYSTEM FOR THE BUILDING

6.1 Definition

This section consists of the following needs:

- floor drainage
- water outlets and service modules
- fire protection

Note: The regular plumbing systems such as roof drainage, sanitary sewers, domestic water systems, sanitary fixtures, etc., are not included in this report.

6.2 Floor Drainage

6.2.1 Purpose

The floor drainage system is required for floor cleaning and in some areas for removal of water during rain tests. The water to be removed may be mixed with transformer oil from the hoses or the equipment. The system shall be designed to remove oil from the waste water.

6.2.2 Platform Area Drain

In area where platforms equipped with air cushions will be used, drains shall be installed flush with the floor. In order to permit use of the platforms, they shall be temporarily covered with a piece of thin sheet metal.

Use of a drain with a solid cover is not recommended.

6.2.3 Electrical Outlets Area Drain

In area where electrical outlets will be installed in the floor, drains shall be installed in such way that the floor will drain rapidly to prevent any water from reaching the electrical wires and conduits.

These outlets shall be installed in drain boxes connected to the drainage system. These electrical boxes shall be connected to drain piping with an air gap in order to avoid flooding the electrical conduits in case of a drainage pipe should block. In this case, it is better to have water in the basement where it will be absorbed by the soil.

Suggested locations and details of drains are shown on drawings Nos. 302 and 308.

6.2.4 Test Cells Area Drain

In areas where explosions are apt to occur, such as in the indoor test cells, drains shall be installed near a wall instead of in the center of the room.

6.2.5 Water and Oil Outlets Area Drain

It is recommended, for practical purposes, that a floor drain be installed in the vicinity of each water or oil outlet, mounted in a service module or not, and wherever it would be useful for cleaning purposes.

6.2.6 Oil Interceptor

Through the floor drainage system some oil could reach the collection system, it is therefore neccessary to provide an oil interceptor. Oil will usually come from spillage when connecting and disconnecting hoses from outlets and inlets or from equipment. The quantity of oil in these cases will be relatively small.

The oil removed from the drainage system by the oil interceptor shall be stored in a tank having a minimum capacity of 5 000 litres. The tank shall be equipped with a conveniently located level meter, a manhole and a suitable fitting for draining (For details, see drawing No. 309).

Oil shall never be poured intentionally into the drainage system. A special inlet is provided on the return header of the transformer oil handling system for this purpose.

A transformer under test could accidentally break and a large amount of oil (up to 65 000 litres) could get into the drainage system. This becomes a disaster without any treatment.

For this above reason, it is advisable not to connect the floor drainage system to the public sewers but to discharge it into an open ditch to serve as storm sewer or basin where the water can evaporate. Should oil accidentally reach the ditch, it can be removed and taken away.

6.2.7 Pollution Room (C-102)

Due of the presence of a high concentration of salt in the water drainage after a test, it is not advisable to connect the floor drainage system of the pollution room to the public sewer. It may be discharged into an exterior open ditch or basin (See Laboratory Implementation of this Building Report).

6.3 Water Services

6.3.1 Purpose

This sub-sytem contains the piping network, outlets and other services required for water supply for convenient usage.

6.3.2 Water Outlets

Water outlets with hose connection shall be provided wherever they would be useful for cleaning and convenience such as in rooms or areas where floor drains are installed. These outlets shall be 3/4" in diameter. Larger outlets would be needed to supply water to water-cooled equipment under test. These outlets shall be added only if they are required later, since no testing of water-cooled equipment is foreseen

6.3.3 Dark Rooms

Dark rooms need special sinks which shall be resistant to acids used for processing films and prints, dilution tanks to dilute the acid prior to contact with the sanitary drain and a hot and cold water mixing valve with an appropriate temperature controller.

6.3.4 Service Modules

In areas where different utilities are needed, it would be convenient to group them in service modules which would offer the following advantages:

- ease of locating and identifying the services
- reading of pressure and temperature by use of pressure gauges and thermometers.
- ease of repairs.

The following utilities can be grouped in the service modules (see drawing No. 302):

- compressed air at (7,0 kg/cm^2) 685 kPa
- compressed air at (250 kg/cm^2) 24,5 MPa
- compressed air at (55 kg/cm^2) 5,4 MPa
- oil supply
- oil return
- rain water
- fire hose
- fire extinghisher.

In addition, convenient services can be added to the service modules such as sink, drinking fountain, paper tower dispenser and a paper disposal (See photos Nos. 19 and 21 and drawings Nos. 307 and 308 for suggested arrangements of various modules).

6.4 Fire Protection

6.4.1 Purpose

This sub-system contains the standpipe network, automatic CO_2 system and portable Chemical units.

6.4.2 Regulations

Fire protection systems shall conform to requirements of local codes, by-laws and insurance companies.

6.4.3 Protection Requirements

An acceptable system, if no specific requirements are prescribed by the authorities having jurisdiction, is a standpipe system with fire hose cabinets and protable fire extinguishers suitable for inflammable liquids and for electrical equipment.

In the indoor test cells, automatic system using carbon dioxide or dry chemical shall be installed. As supplementary protection, a few movable units using carbon dioxide or dry chemical are recommended, say 2 per test cell room.

6.5 Drawings

Details and diagrams of these systems are shown on drawing Nos. 302, 303, 307, 308 and 309.

7- HEATING SYSTEM FOR THE BUILDING

7.1 Definition

This system is needed to provide the temperature control necessary for satisfactory electrical equipment testing and to maintain comfortable conditions for the working staff.

This system is described under two headings:

- Design criteria and heating equipment.
- Areas to be heated and equipment location.

Detailed design of this system shall be in conjunction with the Architect and Structural designers.

7.2 Design Criteria and Heating Equipment

7.2.1 Purpose

The following design criteria and equipment selection will provide the most effective environment from the stand point of test efficiency, personnel confort and capital cost.

7.2.2 Design Criteria

Except as otherwise voted the following design criteria will be used for heating system design:

- Design minimum outdoor Dry Bulb temperature: $-7^{\circ}C$.
- Design indoor Dry Bulb temperatures (winter) shall be maintained in within $\pm$ $1^{\circ}C$ of the mentioned values for the different areas.
- Design indoor humidity (winter) shall be maintained in within ± 5% of the mentioned values for the different areas.
- Design wind velocity: 24 km/hr.
- Transmittance of wall and roof 0,045 cal./(hr.-cm^2 -$^{\circ}C$)

The specified transmittance value for wall and roof takes into consideration the cost of the wall or the roof and the cost of Electricity.

7.2.3 Electric Heating Coils

The heating coils shall be open type with bare helical heating elements in direct contact with the air.

The coils shall be circuited to heat uniformly across the face area even at part load. The capacity shall be modulated either by staging or will full modulation. The maximum differential between stages shall be 3°C. A higher differential would cause frequent cycling and overheating.

7.2.4 Electric Unit Heaters

The electric unit heaters shall give a maximum temperature rise of 25°C to the air passing through the heater so as to minimize air stratification. The maximum capacity of each unit shall be limited to 10 kw.

7.2.5 Thermostat Location

The thermostats may be located on the unit heaters or on the wall about 1,6 m above the floor.

7.2.6 Humidifiers

Steam humidifiers are recommended because they have better efficiency and need less maintenance than water type. Small electrical boilers are suitable to produce steam using water having low hardness to prevent blocking the humidifiers with scale and carrying scale dust into the rooms.

7.3 Areas to be Heated and Equipment Location

7.3.1 Purpose

This section describes the locals to be heated and their heating conditions.

BLOCK "A"

7.3.2 Basement (A-001, A-002, A-003)

The minimum temperature under the first floor slab shall be 24°C to maintain a suitable level to minimize air movement caused by a cold floor in the Test Areas (A-104, A-105).

These basements shall be heated to compensate for heat losses and maintain the required temperature. Electric Unit heaters controlled by individual thermostats shall be suspended from the ground floor slab.

7.3.3 Control Rooms Nos. 8, 6, 7 (A-101, A-102, A-103)

Dark Room (A-106)

Corridors (A-107, A-205)

Client Observation Rooms (A-201, A-202)

Conference Room (A-203)

The heating system of these areas is incorporated into the air conditioning system (see 8.3.2)

7.3.4 <u>High Voltage Test Areas Nos. 1 and 2 (A-104,A-105)</u>

The temperature and humidity in these Test Areas shall be maintained as follows:

- At floor level 20°C minimum
- At ceiling level 40°C maximum
- Temperature differential from floor level to a height of 6 m. 5°C maximum
- Relative humidity 35% minimum

To minimize temperature variations due to height in these very high areas (higher than 25 m) the following systems shall heat the High Voltage Test Area:

- Heating system for the Service Corridor between walls.
- Heating of the Test Area.

<u>Heating Requirements:</u>

Heating System for the Service Corridors between walls:

For better acoustics, heating, structure and access to services, the walls around the High Voltage Test Areas shall be double wall type.

The spacing between the outside wall and the interior acoustical and electrical shielding partition shall be 1,0 metre. These spaces shall be divided into four equal levels of corridors. To provide uniform temperatures in the Test Areas, the heat losses through the wall will be compensated by heating systems in the corridors between walls at each level. These systems will consist of electric unit heaters installed 3 metres above the floor at each level. The units shall be spaced to provide uniform heating throughout. Each unit heater shall be controlled by a thermostat set at 18°C.

Heating of Test Area

The heating system of this Area is incorporated into the ventilating system (See 8.3.3.c).

7.3.5 Mechanical Room (A-204)

The mechanical room shall be heated to maintain a temperature of 20°C to minimise heat transfer from the adjacent rooms by a thermostatically controlled electric unit heater.

7.3.6 Washroom (A-206)

In this room, thermostatically controlled baseboard heating elements shall be installed to maintain 24°C.

BLOCK "B"

7.3.7 Synthetic Test Hall (B-101)

The temperature in the Synthetic Test Hall shall be maintained at 20°C minimum. Electric unit heaters shall be installed along the wall perimeter at a height of 3 metres above the floor and shall be controlled by wall thermostats. The large door will be opened only occasionally, preferably after working hours. If it should be opened during a cold day and the room temperature should drop, the heating system should be able to raise the temperature back to normal level within 12 hours maximum after the door has been opened.

BLOCK "C"

7.3.8 Basement (C-001)

To maintain the required floor temperature in the rooms above, the temperature in this basement shall not drop below 18°C. The necessary heat shall be provided by thermostatically controlled unit heaters.

7.3.9 Transformer Test Area (C-101)

The design temperature at floor level shall be 20°C. The maximum temperature permitted at roof level shall be 43°C.

Electric unit heaters shall be installed approximately 3 m above the floor, along the perimeter of the test area. Additional electric unit heaters shall be installed where infiltration of outside air may occur and to provide additional heat to restore the temperature after the door has been opened. Heaters shall be controlled by wall thermostats.

7.3.10 <u>Entrance Adjacent to Transformer Test Area</u>

The room temperature shall be maintained at 20°C at floor level.

The calculated heating load shall include:

Transmission losses through the wall, roof and door. Infiltration around the perimeter of the door. Cold transformers or other equipment brought in from outside for testing and to be reheated to room temperature within 12 hours maximum.

Air shall be supplied near the floor level and returned from the ceiling level.

The heating unit shall comprise an electric heating coil and a fan.

A wall thermostat shall modulate the capacity of the coil to maintain the room temperature.

Normally the fan shall be operated continuously during winter time and be off during the summer time.

7.8.11 Pollution (C-102)

In the pollution room, the heating system shall be of the radiant panel type with heating elements installed in the exterior walls, in order to avoid having these elements being in contact with the very corrosive atmosphere in this room. This system shall maintain a minimum temperature of 20°C at floor level.

7.8.12 Mounting Room (C-103)

The temperature in this area shall be maintained at 20°C at floor level.

Electric unit heaters shall be installed approximately 3 m above the floor along the perimeter. Each heater shall be controlled by a wall thermostat.

7.8.13 Corona Room (C-104)

The heating system of this Area is incorporated into the ventilating system (see 8.3.10).

7.8.14 Control Rooms Nos. 9, 10 (C-105, C-106)

The heating system of these areas is incorporated into the air conditioning system (see 8.3.11).

BLOCK "D"

7.3.15 Emergency Generator Room (D-001)

Distribution Centre (D-003)

The temperature of these areas shall be maintained at 18°C by thermostatically controlled unit heaters.

7.3.16 Basement Corridor (D-004)

The temperature of this basement shall be maintained at a minimum of 18°C by means of thermostatically controlled unit heaters.

7.3.17 Interphone Equipment Room (D-005)

Telephone Equipment Room (D-006)

The heating system of these areas is incorporated in the air conditioning system (See 8.3.15).

7.3.18 Oil Treatment Room (D-101)

The temperature of this room shall be maintained at approximately 20°C by thermostatically controlled unit heaters.

7.3.19 Auxiliary Machines (D-102)

Corridor (D-103) - Store (D-106) - Shipping and Receiving Area (D-108)- Repair Shop (D-109) - Pipe Shop (D-203) - Corridor (D-204)

The temperature of these rooms shall be maintained at 20°C by thermostatically controlled unit heaters.

7.3.20 **Rest Area (D-104)**

Washroom (D-107)

In these rooms, thermostatically controlled baseboard heating elements shall be installed on the exterior walls to maintain 24°C.

7.3.21 **Sheet Metal & Welding Shop (D-105)**

Woodwork Shop (D-202)

Mechanical Workshop (D-205)

The temperature of these rooms shall be maintained at 20°C minimum by thermostatically controlled unit heaters.

7.3.22 **Auxiliary Machines Mezzanine (D-201)**

The temperature in this area shall be maintained at 20°C minimum.

Electric unit heaters controlled by wall thermostats shall be installed along the exterior walls.

BLOCK "E"

7.3.23 **Rotary Machine Auxiliary Equipment (E-001)**

Corridor (E-002) - Distribution Centre (E-003)

Electrical Room (E-004)

The temperature shall be maintained at 18°C by thermostatically controlled unit heaters.

7.3.24 Interphone Equipment Room (E-005)

Telephone Equipment Room (E-006)

The heating system of these areas is incorporated into the air conditioning system (See 8.3.23).

7.3.25 Main Machine Hall (E-101)

Reactors, Resistances and Condensers (E-103,E-201)

The temperature in these areas shall be maintained at 20°C minimum. Electric unit heaters controlled by thermostats shall be installed along the exterior walls.

7.3.26 Control Room No. 5 (E-102)

The heating system of this area is incorporated into the air conditioning system (See 8.3.25).

BLOCK "F"

7.3.27 Equipment Rooms (F-001, F-003)
Reactors, Transformers, Rectifiers (F-002)

In these rooms the temperature shall be maintained at 18°C minimum.

Thermostatically controlled unit heaters shall provide heat.

7.3.28 Control Rooms Nos. 1, 2, 3, 4 (F-101, F-112, F-113, F-125)
Client Observation Rooms (F-102, F-103, F-116,

<u>F-117, F-202, F-203)</u>

<u>Dark Rooms (F-104, F-105, F-118)</u>

<u>Offices (F-119, F-120, F-121, F-122)</u>

<u>Observation Room (F-201)</u>

<u>Conference Room (F-205)</u>

<u>Corridor (F-206)</u>

The heating system of these areas is incorporated into the air conditioning system (See 8.3.28).

7.3.29 <u>Assembly Rooms (F-106, F-107, F-108, F-109)</u>

The heating system is incorporated into the ventilation system (See 8.3.29).

7.3.30 <u>Storage (F-110)</u>

The temperature of this room shall be maintained at 20°C by thermostatically controlled unit heaters.

7.3.31 <u>High Current and Direct Current Laboratory (F-111)</u>

The heating system is incorporated into the ventilation system (See 8.3.31).

7.3.32 <u>Test Cells Nos. 1, 2 (F-114, F-115)</u>

These cells shall be maintained at 20°C by thermostatically controlled unit heaters. If an explosion should occur the damaged heaters can be replaced.

7.3.33 <u>Climatic Room Equipment (F-124)</u>
<u>Climatic Test Room (F-126)</u>
<u>Ante-Chambre (F-127)</u>

For detailed description of equipment and system in these areas, see Equipment Report HP 15.

7.3.34 <u>Corridors (F-123, F-131)</u>

The temperature of the corridors shall be maintained at 20°C by thermostatically controlled unit heaters or baseboard heating elements.

7.3.35 <u>Lockers (F-128) - Rest Area (F-129)</u>
<u>Washroom (F-130)</u>

In these areas, thermostatically controlled baseboard heating elements shall be installed on exterior walls to maintain 24°C.

7.3.36 <u>Mechanical Equipment Room (F-204)</u>

The Mechanical Equipment Room shall be heated to maintain a temperature of 20°C by a thermostatically controlled unit heater, to minimize heat transfer from adjacent rooms.

<u>BLOCK "G"</u>

7.3.37 <u>Basement (G-001)</u>

This basement shall be heated by thermostatically controlled unit heaters to maintain a minimum temperature of 18°C.

7.3.30 Offices (G-101, G-201)

The heating system of these areas is incorporated into the air conditioning system (See 8.3.35).

7.4 Drawings

Typical diagrams and details are shown on drawings Nos. 301, 302, 303 and 305.

8- VENTILATION AND AIR CONDITIONING SYSTEMS FOR THE BUILDING

8.1 Definition

This system is necessary to provide the temperature and humidity control necessary for a satisfactory electrical equipment testing and to maintain comfortable conditions for the working staff.

This system is described under two headings:

- Design criteria and equipment.
- Areas requiring air conditioning or ventilation.

The detailed design of this system shall be carried out in conjunction with the Architect and Structural designers.

8.2 Design Criteria and Equipment

8.2.1 Purpose

The following design criteria and equipment selection will provide the most effective environment from the stand point of test efficiency, personnel comfort and capital cost.

8.2.2 Design Criteria

Except as otherwise noted the following design criteria will be used for ventilating and air conditioning system design:

- Design minimum outdoor temperature: -7°C.
- Design maximum outdoor temperatures: 35°C dry bulb. 23°C wet bulb.
- Design indoor Dry Bulb temperatures (winter or summer) shall be maintained in within ± 1°C of the mentioned values for the different areas.
- Design indoor humidity (Winter or Summer) shall be maintained in within ± 5% of the mentioned values for the different areas.
- Design wind velocity: 24 km/hr.
- Transmittance of walls and roof: 0,045 cal/(hr. - cm^2 - °C).

The specified transmittance value for walls and roof takes into consideration the cost of the wall or roof and the cost of electricity.

8.2.3 Fans

Fans shall be centrifugal or axial type for systems having ductwork resistance.

Propeller fans shall be used when there is no resistance.

8.2.4 Grilles and Diffusers

Grilles and diffusers shall be selectad to provide an uniform distribution of the air without drafts and noise, especially in the air conditioned areas. Direction and volume control shall be provided.

8.2.5 Thermostat Location

Thermostats shall be located preferably on the wall at about 1,6 m above the floor.

8.2.6 Filters

In the Control Rooms, High Voltage Test Areas, Corona Room, etc., where delicate testing instruments are used, the air supply shall be adequately filtered by standard filters, having a dirt holding efficiency of approximately 37% for dirt size of 0 to 5 microns. Higher efficiency filters may be required depending on the environmental conditions at the site.

8.2.7 Air Intakes

All outside air intakes through the walls, shall be equipped with weatherproof louvres. The louvres shall be sized for a maximum velocity of 2,5 m/sec. At higher velocities rain or snow can be drawn in by the air.

Roof air intakes shall be equipped with hoods or penthouses having louvres.

8.2.8 **Air Exhausts**

Wall exhausts shall be equipped with weatherproof louvres sized for a maximum velocity of 3 m/sec. to minimise noise and pressure drop. Roof exhausts shall be equipped with hoods or penthouses having louvres.

8.2.9 **Birdscreens**

All air intakes and exhausts shall be equipped with birdscreens on the building side of louvres to prevent birds from entering the ducts.

8.3 Areas requiring Air Conditioning or Ventilation

8.3.1 **Purpose**

Locals where air conditioning and/or ventilation are required are described in this sub-section and environmental requirements are outlined.

BLOCK "A"

8.3.2 Control Rooms Nos. 5, 6, 7 (A-101, A-102, A-103)
Client Observation Rooms (A-201, A-202)
Conference Room (A-203)
Dark Room (A-106)
Corridors (A-107, A-205)

In these rooms, in winter as well as in summer, temperature and humidity shall be maintained as follows:

- Relative Humidity 50%
- Winter temperature 22°C.
- Summer temperature 24°C.

Ventilation:

A positive pressure shall be maintained in these rooms to prevent infiltration of air and dust, except in the dark room where a negative pressure shall be maintained. This will prevent escape of odors which will thus be exhausted rather than recirculated.

For adequate ventilation there shall not be less than 6 air changes per hour, with a minimum of 0,00166 m^3/sec. per m^2 of floor area of fresh air.

Air Conditioning Systems:

The air conditioning systems shall be designed to meet the above mentioned criteria. Individual controls shall be provided in each room to compensate for variations in heat gains or losses.

8.3.8 High Voltage Test Areas Nos 1 and 2 (A-104, A-105)

The temperature and humidity in these Test Areas shall be maintained as follows:

- At floor level 20°C minimum

- At ceiling level 40°C maximum
- Temperature differential from floor level to a height of 6 metres 5°C maximum
- Humidity 35% minimum

The Test Areas shall be kept under positive pressure to prevent infiltration of air and dust from the outside and adjoining areas.

To minimize temperature variations due to height the following systems shall heat and/or ventilate the High Voltage Test Area:

a) Ventilation system for the Service Corridor between walls.
b) Attic ventilation system
c) Test Area ventilation and humidifying system
d) Smoke evacuation system.

Ventilation Requirements

a) Ventilation system for the service corridor between walls:

Ventilation systems, at each level, will supply fresh air and exhaust the warm air when the inside temperature exceeds 20°C and is higher than the outside temperature. This will be accomplished by using appropriate outdoor and indoor thermostats controlling operation of exhaust fans and fresh air intakes. The quantity of air shall be equal to a minimum of 4 air changes per hour.

b) Attic Ventilation System

The suspended ceiling in the Test Area will form the floor of an attic that will permit access to lights and to fixed points that will be used to suspend equipment in the area below. This attic shall be ventilated by two or more thermostatically controlled exhaust fans and two or more fresh air intake fans to remove the heat generated by the lighting system and other sources such as heat transferred from the hall to the attic through the ceiling and the effect of the sun on the roof. This system shall operate when the attic temperature exceeds 24°C. The quantity of air required shall be calculated for a differential of 5°C maximum to limit the temperature in the attic to 40°C when the outside temperature is 35°C.

c) Test Area Heating, Ventilation and Humidifying System:

In order to compensate for the heat and humidity losses due to the large door, the ventilation system shall be designed to heat and humidify the areas in addition to supplying fresh air and maintaining a positive pressure.

The large door will be opened only occasionally, preferably after working hours. If it should be opened during a cold day and the room temperature should drop, the heating and the humidifying system shall have enough capacity to overcome the losses and to raise the temperature and humidity level back to normal in 12 hours after the doors have been opened.

Sufficient outside air shall be admitted continuously to maintain a positive pressure in the area relative to the outside and adjacent areas

The heating coil shall have sufficient capacity to raise the inside temperature from 4°C to 20°C in a maximum period of 12 hours with the intake dampers closed. This low temperature condition may occur after the large door has been opened in cold weather. A separate system with supply grilles preferably located on the walls near the floor may be used to supply the additional heat and humidity to compensate for the large losses due to opening of the door. This system will recirculate air without any fresh air make up and will heat and humidity only when the normal system is not able to maintain the temperature and humidity.

Air supply capacity must be sufficient to provide a minimum of one (1) air change in four (4) hours. This air shall be supplied at low level to heat the coldest air and the return air grilles shall be placed at high levels to remove the warmest air.

The supply air temperature, during the winter, shall not exceed 40°C to minimize air stratification. A higher temperature would cause a too large difference between the temperatures at floor and ceiling levels. A gravity exhaust ventilator installed on the roof will be used to exhaust air when fresh air is supplied.

d) Smoke Evacuation System

The main purpose of this system is to exhaust the smoke and hot air and relieve the pressure which would be caused by a

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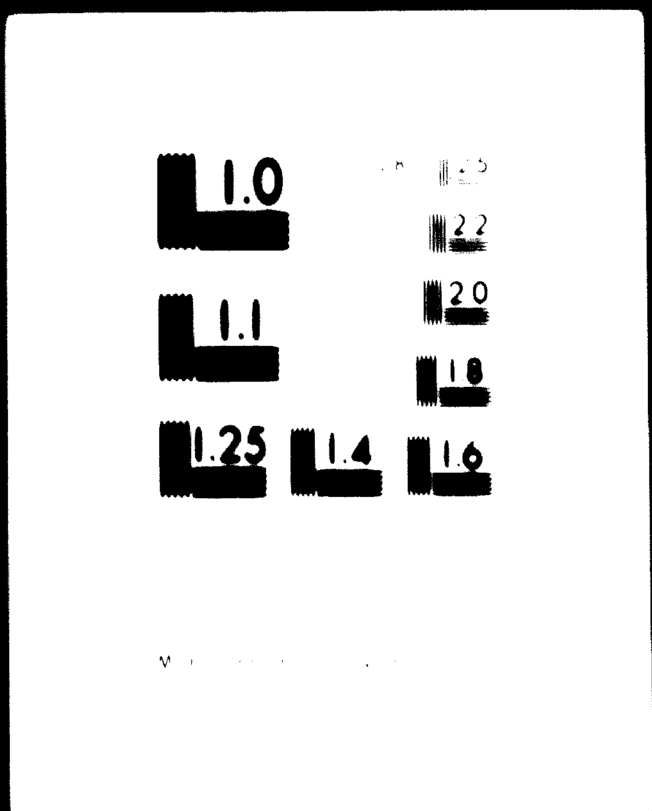

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fire and to ventilate the area. Gravity type ventilators shall be operated manually and/or automatically by fire detecting devices and installed on the roof.

The minimum area of these ventilators shall be equal to one (1) square metre for each 150 square metres of floor area.

6.3.4 Mechanical Room (A-204)

The Mechanical Room shall be ventilated by a thermostatically controlled exhaust fan and fresh air intake to remove the heat gains when the temperature is above 24°C.

The quantity of air shall be sufficient to prevent the temperature from exceeding 40°C.

6.3.5 Washroom (A-206)

In this area air shall be exhausted at a minimum rate of 10 air changes per hour to remove odors and to prevent these odors from seeping into adjacent areas through transfer grilles. The air will come from adjacent locals.

BLOCK "B"

6.3.6 Synthetic Test Hall (B-101)

Thermostatically controlled fresh air intakes and exhaust fans shall operate when the temperature rises above 24°C. The air quantity shall be sufficient to provide a minimum rate of one (1) air change per hour.

BLOCK "C"

8.3.7 **Transformer Test Area Supply Plenum (C-002)**

This room is a supply chamber for the ventilation system of the Transformer Test Area. The floor of this room shall have a suitable finish and shall be drained to prevent any carry-over of dust and water in the Transformer Test Area. The ceiling of this room shall be adequately insulated to prevent condensation on the above floor.

8.3.8 **Transformer Test Area (C-101)**

In the Transformer Test Area (C-101) tests will be performed on equipment that may generate a large amount of heat, approximately 2 000 kw.

In order to maintain a satisfactory temperature in this room, a separate ventilation system shall be designed to operate when tests are performed.

To obtain a reasonable rate of ventilation, the temperature differential between the outside air and the maximum permissible inside temperature of 43°C must be as large as possible. If 11°C is taken as the minimum temperature differential, 150 m^3/sec. of air must be circulated. This would permit testing the largest transformers when tha outdoor temperature does not exceed 32°C. For smaller transformers the outdoor temperature may be higher because of the lower heat output.

The ventilating air shall be discharged at the perimeter of the test area as uniformly as possible. The maximum velocity at the supply grilles shall be 7,5 m/sec. If floor grilles are used instead of wall grilles, they should withstand the same loading as the floor and be depressad slightly to parmit the installation of steel platea which would be flush with tha floor. These plates are necessary to permit the transportation of the transformers on air cushion platforms. The grilles shall be equipped with manual balancing dampers.

The exhaust air hoods shall be located at roof laval and shall be equipped with motorisad dampera and appropriate birdscreens.

Outdoor air intakes shall be located away from sources of contimination and shall be equipped with motorized dampers and weatherproof louvres or hoods with birdscreens.

Outdoor air and room air shall be mixed automatically to obtain a supply of air at a minimum temperature of 13°C.

There shall be at least 4 supply fans controlled by room thermostats in such a way that the minimum number of fans shall operate simultaneously depending on the temperatures and loading.

The exhaust, air intake and recirculation dampers shall be divided into the same number of sections as there are fans. Thereby each fan shall operate with its sections of dampers only to obtain better control.

Each fan shall be equipped with a motorised or gravity damper to prevent "by-passing" through the fans not in operation.

Fans shall be selected to have the most reasonable power requirements consistent with economical sizing.

The friction and dynamic losses of the air flow shall be as small as possible. Propeller fans would probably be the best selection.

Due to the large surface area of the required outdoor intake and exhaust dampers, they should be equipped with neoprene on the blade edges and a sealing mechanism at the blade ends, to reduce as much as possible the infiltration of air to and from the building.

Another possibility would be to have sliding or

A room thermostat shall modulate the outdoor air and the return air dampers as well as the heating coil to maintain the room temperature.

A low limit thermostat in the supply duct shall prevent the supply air from dropping below 13°C. Normally, the fan shall operate continuously.

8.3.11 <u>Control Rooms Nos. 9, 10 (C-105, C-106)</u>

In these rooms, in winter as well as in summer, temperature and humidity shall be maintained as follows:

- Relative humidity 50%
- Winter temperature 22°C.
- Summer temperature 24°C.

<u>Ventilation</u>:

A positive pressure shall be maintained to prevent infiltration of air and dust.

For adequate ventilation there shall not be less than 6 air changes per hour, having a minimum of 0,00166 m^3/sec. per m^2 of floor area of fresh air.

<u>Air Conditioning Systems</u>:

The air conditioning systems shall be designed to meet the above mentioned criteria. Individual controls shall be provided in each room to compensate for variations in heat gains or losses.

BLOCK "D"

8.3.12 **Emergency Generator Room (D-001)**

In this room the temperature shall not exceed 40°C and the ventilating system shall be designed to remove the heat created by the generator.

8.3.13 **Battery Room (D-002)**

In this room a ventilation system designed to exhaust air at a minimum rate of 10 changes per hour would be required if batteries containing acid are used. This system shall be made of materials resistant to such acid.

8.3.14 **Basement Corridor (D-004)**

The ventilation system shall remove the heat generated by the compressors.

Calculate the air quantity required using a minimum temperature differential of 8°C between the incoming and exhaust air temperatures. The amount of heat to be removed per hour will depend upon the power requirements of the compressors and the percentage of time the compressors operate at peak air demand.

The system will include exhaust fans and air intakes. A room thermostat shall control the system as follows:

- The intake and exhaust dampers shall open when there is a rise in temperature.
- The thermostat shall start the fans in series until the ventilation rate equals the heat output of the compressors when there is further rise in temperature.
- The sequence shall be reversed when there is a decrease in temperature.

8.3.18 <u>Interphone Equipment Room (D-001)</u>
<u>Telephone Equipment Room (D-006)</u>

Temperature and humidity:

In these rooms, for purposes of efficient operation of the electronic equipment, temperature and humidity shall be maintained as follows in each room:

- Relative humidity 50%
- Winter temperature 18°C.
- Summer temperature 24°C.

Air Conditioning System:

The air conditioning system shall be designed to meet the above mentioned criteria and to provide a positive pressure to prevent infiltration of dust. All the air supplied to these rooms shall be adequately filtered.

8.3.16 High Pressure Compressed Air Room (D-007)

It is important that high pressure compressed air storage receivers be located in a room where the ambient temperature is lower than the supply piping, so that any moisture present in the air will tend to condense in the receivers rather than in the piping which is exposed to outdoor temperature. The condensed moisture in the receivers can be easily removed by blowing-down the receivers periodically, while condensed moisture in the piping system will end up in the equipment being served. The condensate tank shall be located outside of the receiver room and the pipe between the air receivers and the tank shall be heated with an electrical element to prevent freezing.

The compressed air receiver shall be placed in the basement in a location as cool as possible and insulated from adjacent sources of heat. The walls, ceiling and floor of this room shall be adequately insulated because the temperature in this room will be maintained below or equal to the outdoor temperature, especially in winter.

A fan shall supply outside air into the compressed air receiver room with an exhaust to the outside. A room thermostat and an outside air sensor shall ventilate the room when the room air temperature is higher than the outside air temperature.

8.8.17 <u>Oil Treatment Room (D-101)</u>

An exhaust fan combined with a fresh air intake shall ventilate the room when the temperature is above 24°C. The air quantity shall be four (4) air changes per hour minimum.

8.8.18 <u>Auxiliary Machines (D-102)</u>

The temperature of this room shall not exceed 40°C. The machines in this room will generate large amounts of heat and adequate ventilating capacity will be required. The method used for removal of heat will depend upon the type of machine which generate it. In some cases, heat will be removed by ventilation of the room and in others by ventilating systems directly connected to the machine. Some machines may require water cooling. The ventilation systems can be designed only when the characteristics of the machines are know. The average heat generated in this room will be approximately 500 kw.

8.8.19 <u>Corridor (D-103) - Store (D-106) - Shipping and Receiving Area (D-108) - Repair Shop (D-109) - Pipe shop (D-203) - Corridor (D-204)</u>

Exhaust fans combined with fresh air intakes shall ventilate the rooms when the temperature is above 24°C. There shall be four (4) air changes per hour minimum.

8.3.20 **Rest Area (D-104) - Washroom (D-107)**

In these areas air shall be exhausted at a minimum rate of 10 air changes per hour to remove odors and to prevent these odors from seeping into adjacent areas through transfer grilles. The air will come from adjacent locals.

8.3.21 **Sheet Metal and Welding Shop (D-105) - Woodwork Shop (D-202) - Mechanical Workshop (D-205)**

Exhaust fans combined with fresh air intakes shall ventilate the rooms when the temperature is above 24°C. The air quantity shall be four (4) air changes per hour minimum. Exhaust systems shall be provided where required for welding, paint hoods, etc. Make-up air units shall provide fresh air to replace air exhausted. Each unit shall have a supply fan and a heating coil.

8.3.22 **Auxiliary Machines Mezzanine (D-201)**

The temperature shall not exceed 40°C. In this area the equipment will generate heat and ventilation shall be provided having a minimum rate of one (1) air change per hour.

Exhaust fans and fresh air intakes shall be used when the temperature is above 24°C.

BLOCK "E"

6.3.23 **Interphone Equipment Room (E-001)**
Telephone Equipment Room (E-006)

Temperature and humidity:

In these rooms, for purposes of efficient operation of the electronic equipment, temperature and humidity shall be maintained as follows in each room:

- Relative humidity 50%
- Winter temperature 18°C.
- Summer temperature 24°C.

Air Conditioning System:

The air conditioning system shall be designed to meet the above mentioned criteria and to provide a positive pressure to prevent infiltration of dust. All the air supplied to these rooms shall be adeuetely filtered.

6.3.24 **Main Machine Hall (E-101)**

The temperature of this room shall not exceed 40°C. The machine in this room will generate a large amount of heat therefore a separate cooling system will be required. The heat that will be liberated directly into the room by the main machine and the auxiliary equipment will be approximately 1 000 kw and the heat removed by the machine cooling system will be approximataly 2 000 kw. Some machines may require cooling water. The ventilating systems can be designed only when the characteristics of the machines are known.

Provision should be made for another machine with auxiliary equipment which will be added in the future.

6.3.28 <u>Control Room No. 2 (E-102)</u>

In this room, in winter as well as in summer, temperature and humidity shall be maintained as follows:

- Relative humidity 50%
- Winter temperature 22°C.
- Summer temperature 24°C.

<u>Ventilation:</u>

A positive pressure shall be maintained in this room to prevent infiltration of air and dust.

For adequate ventilation there shall not be less than 6 air changes per hour, with a minimum of 0,00166 m^3/sec. per m^2 of floor area of fresh air.

<u>Air Conditioning System</u> :

The air conditioning system shall be designed to meet the above mentioned critaria. Room control shall be provided in the are to compensate for variations in heat gains or losses.

8.3.26 **Reactors, Resistances and Condensers (E-102, E-201)**

The temperature shall not exceed 40°C maximum. In these areas, the equipment will generate heat and ventilation shall be provided having a minimum capacity of one (1) air change per hour.

Exhaust fans and fresh air intakes shall be used when the temperature exceeds 24°C.

BLOCK "F"

8.3.27 **Equipment Rooms (F-001, F-003)**
Reactors, Transformers, Rectifiers (F-002)

In these rooms the temperature shall not exceed 40°C. Ventilation shall be provided to remove heat gains and have a minimum capacity of one (1) air change per hour.

Exhaust fans and fresh air intakes shall be used when the temperature is above 24°C.

8.3.28 **Control Rooms Nos. 1, 3, 2, 4 (F-101, F-112, F-113 and F-125**
Client Observation Rooms (F-102, F-103, F-116, F-117, F-202, F-203)
Dark Rooms (F-104, F-105, F-110)

Offices (F-119, F-120, F-121, F-122)
Observation Room (F-201)
Conference Room (F-205) - Corridor (F-208)

In these rooms, in winter as well as in summer, temperature and humidity shall be maintained as follows:

- Relative humidity 50%
- Winter temperature 22°C.
- Summer temperature 24°C.

Ventilation:

A positive pressure shall be maintained in these rooms to prevent infiltration of air and dust, except in the dark rooms where a negative pressure shall be maintained. This will prevent escape of odors which will thus be exhausted rather than recirculated.

For adequate ventilation there shall not be less than 6 air changes per hour having a minimum fresh air rate of 0,0066 m^3/sec. per m^2 of floor area.

Air Conditioning System:

The air conditioning system shall be designed to meet the above mentioned criteria. Individual controls shall be provided in each room to compensate for variations in heat gains or losses.

8.3.29 Assembly Rooms (F-106, F-107, F-108, F-109)

In these assembly rooms the temperature shall be maintained at 20°C.

A central heating and ventilating unit shall be suspended from the roof and shall supply air at a minimum rate of four (4) changes per hour in each room. This unit shall be composed of a mixing box, filters, a fan, and individual heating coils for each room.

A mixed air thermostat shall modulate the fresh, exhaust and recirculation air dampers to maintain a minimum temperature of 13°C.

A manual selector switch shall permit an increase in the minimum volume of outdoor air admitted.

The unit fan shall operate continuously unless manually stopped.

8.3.30 Storage (F-110)

An exhaust fan combined with a fresh air intake shall ventilate the room when the temperature is above 24°C. The air quantity shall be one (1) air change per hour minimum.

8.3.31 High Current and Direct Current Laboratory (F-111)

In this room the temperature shall be maintained at 20°C and shall not exceed 40°C.

The calculated air quantity shall be based on the equipment heat gain, lighting gain and the maximum inside temperature permissible at the maximum design outdoor temperature. The heat gain from the equipment will be approximately equivalent to 50 kw, continuous operation even if more heat is generated but not continuously. The minimum outside air intake shall be 0,0066 m^3/sec. per m^2 of floor area.

A heating and ventilating unit located at ceiling level shall direct the supply air toward the floor level and withdraw the return air at ceiling level. This unit shall be composed of a mixing box, filters, electric heating coil and a fan. The unit will be installed outside of this room.

A room thermostat shall modulate the outdoor, recirculation and exhaust dampers as well as the heating coil.

A low limit thermostat, set at 13°C, shall be installed in the supply duct to prevent admission of colder air into the room.

Normally the fan shall operate continously.

A manual selector switch shall permit an increase in the minimum volume of outdoor air admitted, as desired. Air admission would normally be controlled by the room thermostat.

8.3.32 <u>Test Cells Nos. 1, 2 (F-114, F-115)</u>

Appropriate wall or roof panels shall be provided to open under the pressure produced by an explosion in the cells to relieve the pressure and vent the smoke.

8.3.33 <u>Lockers (F-128) - Rest Area (F-129) - Washroom (F-130)</u>

In these areas air shall be exhausted at a minimum rate of 10 air changes per hour to remove odors and to prevent these odors from seeping into adjacent areas through transfer grilles. The air will come from adjacent locals.

8.3.34 <u>Mechanical Equipment Room (F-204)</u>

The room shall be ventilated by a thermostatically controlled exhaust fan and fresh air intake to remove heat gains when the temperature is above 24°C. The quantity of air shall be sufficient to prevent the temperature from exceeding 40°C.

<u>BLOCK "G"</u>

8.3.35 <u>Offices (G-101, G-201)</u>

In these offices, in winter as well as in summer, temperature and humidity shall be maintained as follows:

- Relative humidity: 50%
- Winter temperature 22°C.
- Summer temperature 24°C.

Ventilation:

A positive pressure shall be maintained to prevent infiltration of air and dust.

For adequate ventilation, the rate shall not be less than six (6) air changes per hour having a minimum fresh air flow of 0,00166 m^3/sec. per m^2 of floor area.

Air Conditioning System

The air conditioning system shall be designed to meet the above mentioned criteria. Individual controls shall be provided in each room to compensate for variations in heat gains or losses.

8.4 Drawings

Typical diagrams and details of ventilating and air conditioning systems are shown on drawings Nos. 301, 302, 303 and 305.

9- SPECIAL ACOUSTICAL RECOMMENDATIONS FOR THE HIGH VOLTAGE TEST AREAS

9.1 Definition

In the High Voltage Test Areas the acoustical problems are two-fold:

- the internal noise problem when high voltage tests are in progress.
- the transmission of high intensity noise to adjacent areas and outdoors.

The recommendations given here are of a general nature and the Architectural Contractor may modify the details or materials, but the basic concept must be maintained if the desired results are to be achieved.

9.2 Internal Acoustical Treatment

9.2.1 Purpose

The purpose is to give general recommendations for the construction of several areas to obtain a satisfactory working environment for the personnel, and to provide the required testing conditions.

9.2.2 Reverberation Time

The reverberation time of the hall must be limited to the following values:

- Low frequencies: 2,25 seconds
- Medium frequencies: 1,50 seconds
- High frequencies: 1,00 seconds

9.2.3 Inner Walls Construction

Absorption panels shall be installed at a minimum distance of 1 m from the outer walls to obtain an air space. These panels will form an inner wall which shall be continuous from the floor to the ceiling and all-around the hall.

The inner wall shall be constructed of perforated sheet metal shaped to add rigidity and to produce uneven surfaces. A 10 cm semi-rigid layer of fiberglass or other similar insulation shall be installed at the back of the inner wall. Plastic sheeting must be installed between the sheet metal and the insulation or behind the insulation to prevent air movement from the hall through the inner wall.

9.2.4 Ceiling

A suspended ceiling with a minimum clearance of 1,8 m shall be installed. The ceiling will be a perforated steel deck with a 10 cm layer of fiber-glass covered with a grated catwalk. This ceiling must be sufficiently rigid to walk on for maintenance.

9.3 Wall Construction

9.3.1 Purpose

To prevent the transmission of high intensity noise to adjacent areas to block "C" and outdoors.

9.3.2 Wall Adjacent to the Block "C"

To obtain a maximum of 50 dbA in Block "C", when high voltage tests are in progress in the High Voltage Test Areas, the outer wall common to both areas must be double masonry construction. One wall shall be made of 25 cm solid concrete block and the other shall be 25 cm hollow concrete block. The walls shall be separated by a 6 cm air space and a semi-rigid fiberglass insulation having a thickness of 10 cm glued to the blocks facing the High Voltage Test Areas.

9.3.3 Inside Doors

The inside doors shall have a rating of STC-35.

9.3.4 Outside Walls

The outside walls must be insulated according the coefficient of transfer given in article 7.2.2. The inner wall is purely an acoustical necessity and must not be relied on for other purposes (except as an electromagnetic shield).

9.4 Drawings

Typical wall and ceiling details are shown on drawing No. 304.

FINAL

BUILDING REPORT

VOLUME IV
TERMINAL SECTION & APPENDICES

TO

UNIDO (CONTRACT 72/17)

FOR

SPAIN ELECTRICAL TESTING AND
EXPERIMENTATION TESTING

IN

MADRID

SPAIN

Lalonde Girouard Letendre & Associates Ltd.
in Association with IREQ
Montreal, Canada

TERMINAL SECTION

IX- TERMINAL SECTION

As stated in the previous Sections, this Building Report is to be used as a general guidance for the Architectural Contractor in the design of the required facilities for the High Voltage and High Power Laboratories forming part of the Electrical Testing and Experimentation Centre in Madrid.

We have exposed all the main aspects and, in many cases, a lengthy description of:

1- The principles of site location
2- The motives of laboratory implementation
3- Characteristics for the design of the structural, electrical and mechanical layouts.
4- Equipment Reports

Throughout our study we have taken into consideration that the Laboratory facilities are to be developed in stages to meet the actual needs with possible expansions for future conditions.

The laboratories have been designed to meet with the conditions set forth in the contractual documents related to reports prepared previously by two Consultants to UNIDO. We have gone beyond certain of their recommendations and modified others to meet the requirements of industrial testing and to enlarge the possibilities in experimentation.

Once the volume of theverious halls are determined on the basis of their fonctions it becomes mainly a question of selecting meterials to remein economical while keeping the set forth requirements. These buildings are considered as more of the industrial type then institutional.

The Equipment is the most important part of such laboretories and this is why a good percentege of our time has been spent in the preparation of specificatione for this equipment.

The concept is based on total mobility of the testing equipment in the High Voltage section enebling a high degree of flexibility without increasing the invest-ment. The same principle hee been applied to the High Power Laboratory by offering three independent sectione. Mobility is equelly important on equipment to be tested.

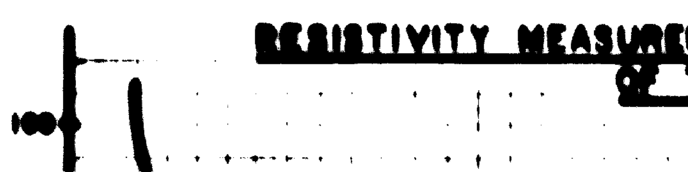
Some featuree of the Centre have not been treated in thie Report as they can be designed readily by local specielists according to the Spanish practice. Those are: the Office Building, weter and eewerage networks, road and railway designs, etc. all in eccordance with Contract documente.

The Laboratories as recommended in this Building Report will principally serve the Spanish manufacturers in making acceptance tests on their products according to international standards.

Further correspondance will be exchanged between the Spanish Government and our group for the setting up of a programme for the training of technicians to operate the various sections of the Laboratory.

RESISTIVITY MEASUREMENTS OF THE SOIL - ALCOBENDAS

AT POINTS A & B



APPENDIX I

APPENDIX I

Boring Schedule No I

1- **BUILDING DATA**

The building to be erected is an industrial type with laboratory test facilities.

1. Number of storeys - one or two - 10m to 24m clear height.
2. Number of basements - one.
3. Type of construction anticipated - concrete or steel.
4. Appxorimate column spacing - 10m tp 30m.
5. Approximate column load - moderate 200^{T} to 500^{T}.
6. Type of foundation expected - spread footings.
7. Expected elevation of bottoms of spread footings - 2m ± below grade.
8. Special considerations - water table elevation.

2- **SOIL INVESTIGATION REQUIREMENTS**

a) The boring positions as located on the attached plan 001 are to be established.

b) The elevation of the ground at each borehole location is to be established, relating same to a bench mark and identifying the bench mark used.

c) Drill holes BH 2 to 3 to a depth of 15m and holes BH 1 to a depth of 30m below existing grade. If extremely poor soil is encountered or if the soil investigator is of the opinion that holes should be drilled to a greater or lesser depth, immediately inform this office. If major obstructions are encountered within the depth of drilling specified above which may impede the drilling, immediately inform this office.

d) In the event that bedrock is encountered at any of the boreholes stop all holes after drilling them, using a A x L size diamond core drill, 5 meters into the rock.

e) The soil profile is to be determined, samples being taken at each significant stratum. The extent of fill, if any, is to be indicated. Samples of the soil are to be retained for three months in sealed airtight containers.

f) Standard testing of the soil is to be conducted using methods dictated by the character of the soil to ascertain the maximum permissible bearing capacity. Tests shall be taken near the top of each layer of different soil and for each 2m of depth below existing grade.

g) If the soil investigator considers necessary he shall recommend additional soil tests which may be required to establish the safe bearing value or probable footing settlement under total load.

h) Establish the elevation of the stabilised water table at BH No 1, using piezometer installations where the soil investigator deems necessary.

3- <u>INFORMATION REQUIRED IN THE REPORT</u>

a) A detailed log of the soil investigation is to be submitted, including details of the method of soil boring used, a description of the general geology of the area and a drawing showing the actual location and elevation of the boreholes.

b) A description of the various soil strata including fill found in each borehole and the elevation of the stabilised water table is to be included.

c) Include recommendations concerning the following:

i) Safe bearing values for strip and isolated spread footings at the levels indicated in item 2(f) above.

ii) The most suitable alternative type of foundation, if strip or isolated spread footings do not appear to be suitable. Particularly, under these circumstances, discuss the relative merits of the different types of caissons or piles, having regard for the nature of the overburden and the condition of the bearing stratum.
Include allowable bearing values for caissons or for end bearing piles.

iii) Horizontal pressures which should be used in the design of the following:

a) Foundation walls of the building and isolated cantilever retaining walls.

b) Shoring, sheet piling or cribbing to be used during construction.

SONDAX, S. A.

iv) Long-term drainage requirements around the building foundation, beneath paved areas and behind retaining walls.

d) Report upon the following:

i) The anticipated total and differential footing settlement.

ii) Possible effects of ground water during construction if the water table is close to or above the likely elevation of the bottom of excavations.

iii) Special or unusual conditions revealed during the soil investigation.

iv) The corrosive effects of ground water if any.

v) Likely effects upon the footing bearing stratum of ground water or surface water which may accumulate adjacent to unloaded or loaded footings.

vi) Sensitivity of the soil, e.g. will it lose strength when remoulded. Should special precautions be employed to avoid disturbance of soil as occurs due to ordinary building operations.

vii) Suitability of excavated material as backfill.

4- EARTH - RESISTIVITY MEASUREMENT

Earth resistivity shall be measured by means of a hand-driven earth-tester. Four test spikes consisting of approximately 13mm diameter mild steel rods shall be driven to a depth of up to 1 metre. (Not exceeding one twentieth of their separation as illustrated diagrammatically in fig. 1).

SONDAX, S. A. MADRID	SONDEO N.º -A-	Hoja N.º
	FECHA 11-1-73	SONDISTA RAIMUNDO
CENTRO DE ENSAYOS Y EXPERIMENTACION PARA LA	PLANO DE SITUACION	

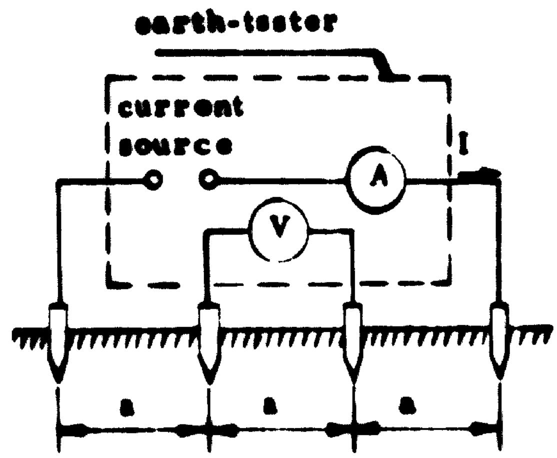


Figure 1

The value obtained will be the average resistivity to a depth of "a" meter. Repeating the measurement with different values of "a", the average resistivity to various depths will be found.
Care should be taken during measurements to ensure that the presence of stray currents do not affect the readings.

The presence of stray currents in the soil is indicated by a wandering of the instrument pointer but an increase or decrease of generator handle speed will cause this to disappear.

The earth-resistivity shall be obtained at the following depths: 1, 2, 3, 4, 5, 6, 8 and 10 metres.

For additional information the resistance of a specific ground electrode shall be determined. The following method shall be used.

5. EARTH-ELECTRODE RESISTANCE MEASUREMENT

The three electrode method of measurement by means of a hand driven earth-tester is illustrated diagrammatically in fig. 2.

SONDAX, S. A. MADRID	SONDEO N.º BH-1	Hoja N.º 1
	FECHA 30-1-73	SONDISTA RAIMUNDO
CLIENTE: CENTRO DE ENSAYOS Y EXPERIMENTACION PARA LA	PLANO DE SITUACION:	

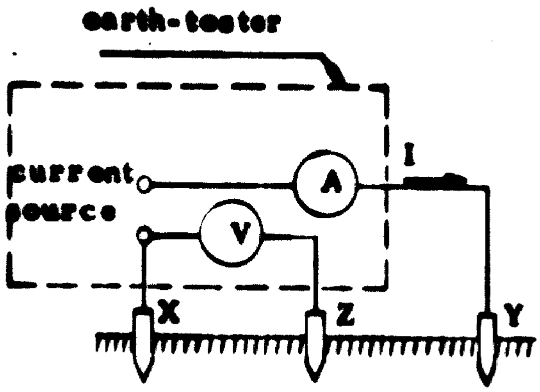


Figure 2

A measured current is passed between the electrode X to be tested and an auxiliary current electrode Y. The voltage drop between X and a second auxiliary electrode Z is measured and the resistance of the test electrode is then the voltage between X and Z divided by the current following between X and Y. This resistance is read directly on the earth-tester. The auxiliary electrodes Y and Z shall consist of a approximately 13mm diameter mild steel rod driven up to 1 metre into the ground. The earth-electrode X under test shall consist of a approximately 20mm round copper rod, 4 metres long. The current electrode shall be placed at 35m from the test electrode X and the potential electrode Z placed midway between. A reading shall be taken and then two further tests made with Z moved 7 metres nearer to X and 7 metres nearer to Y respectively. When earth resistance is being measured, it is important to ensure that the resistance areas of the electrodes do not overlap. If the three results agree within the accuracy of 5% then the mean value can be taken as the correct value of the test electrode resistance. If the results do not agree then the current electrode Y must be moved further away (50m) and the procedure repeated. This whole process must be repeated until the three readings give the required agreement.

Such readings shall be obtained for the following depths of the earth-electrode to be tested (electrode X): 1, 2 and 3m.

RESISTIVITY AND RESISTANCE TESTS

In the first part of December 1972, resistivity and resistance measurements were made on the site by the Laboratorio Central of Madrid at the points A and B which coordinates are as follows:

Point A	X = 22,250	
	Y = 30,250	
Point B	X = 22,400	
	Y = 30,150	

Results of those foundings appear on the following tables.

RESISTIVIDAD DE TIERRAS EN LOS TERRENOS DEL NUEVO CENTRO DE ENSAYOS E INVESTIGACION PARA LA INDUSTRIA ELECTRICA.

PUNTO MEDIDO: "A" — OIENTACION: NORTE-SUR

SEPARACION DE PIQUETAS a (m)	PENETRACION DE PIQUETAS b (cm)	PROFUNCIDAD EQUIVALENTE DEL TERRENO h=3/4.a(m)	LECTURA DE RESISTENCIA INSTRUMENTO R (Ω)	RESISTIVIDAD ρ = 2πaR (Ω x m)	OBSERVACIONES
1	5	0'75	4'90	30'8	
2	10	1'50	1'50	18'9	
3	10	2'25	1'00	18'9	
4	15	3'00	0'70	17'6	
5	20	3'75	0'66	20'7	
6	25	4'50	0'60	22'6	
8	30	6'00	0'46	23'1	
10	35	7'50	0'32	20'1	
15	40	11'25	0'28	26'2	

CONDICIONES DEL TERRENO: MUY HUMEDAS. Madrid, 15 diciembre de 1.972

RESISTIVIDAD DE TIERRA EN LOS TERRENOS DEL NUEVO "CENTRO DE ENSAYOS E INVESTIGACION PARA LA INDUSTRIA ELECTRICA"

PUNTO MEDIDA: "A" **ORIENTACION: ESTE-OESTE**

SEPARACION DE PIQUETAS a (m)	PENETRACION DE PIQUETAS b (m)	PROFUNDIDAD EQUIVALENTE DEL TERRENO h=3/4a (m)	LECTURA DE RESISTENCIA INSTRUMENTO R (Ω)	RESISTIVIDAD = 2 aR (x m)	OBSERVACIONES
1	5	0,75	4,20	26,4	
2	10	1,50	1,50	18,8	
3	10	2,25	1,02	19,2	
4	15	3,00	0,85	21,3	
5	20	3,75	0,54	17,0	
6	25	4,50	0,47	17,8	
8	30	6,00	0,43	21,6	
10	35	7,50	0,37	23,2	
15	40	11,25	0,34	32,0	

CONDICIONES DEL TERRENO: MUY HUMEDAS Madrid 15 de diciembre de 1.972

(signature)

RESISTIVIDAD DE TIERRAS EN LOS TERRENOS DEL NUEVO "CENTRO DE ENSAYOS E INVESTIGACIÓN PARA LA INDUSTRIA ELECTRICA"

PUNTO MEDIDO: "B" ORIENTACIÓN: ESTE-OESTE

SEPARACIÓN DE PIQUETAS a (m)	PENETRACION DE PIQUETAS b (cm)	PROFUNDIDAD EQUIVALENTE DEL TERRENO h=3/4.a(m)	LECTURA DE RESISTENCIA INSTRUMENTO R (Ω)	RESISTIVIDAD $\rho = 2\pi aR$ (Ω x m)	OBSERVACIONES
1	5	0'75	16'9	106'0	
2	10	1'50	5'2	65'3	
3	10	2'25	3'1	58'4	
4	15	3'00	2'1	52'7	
5	20	3'75	1'5	47'1	
6	25	4'50	1'2	45'2	
8	30	6'00	0'7	35'2	
10	30	7'50	0'5	31'4	
15	35	11'25	0'3	28'3	

CONDICIONES DEL TERRENO: MUY HÚMEDAS

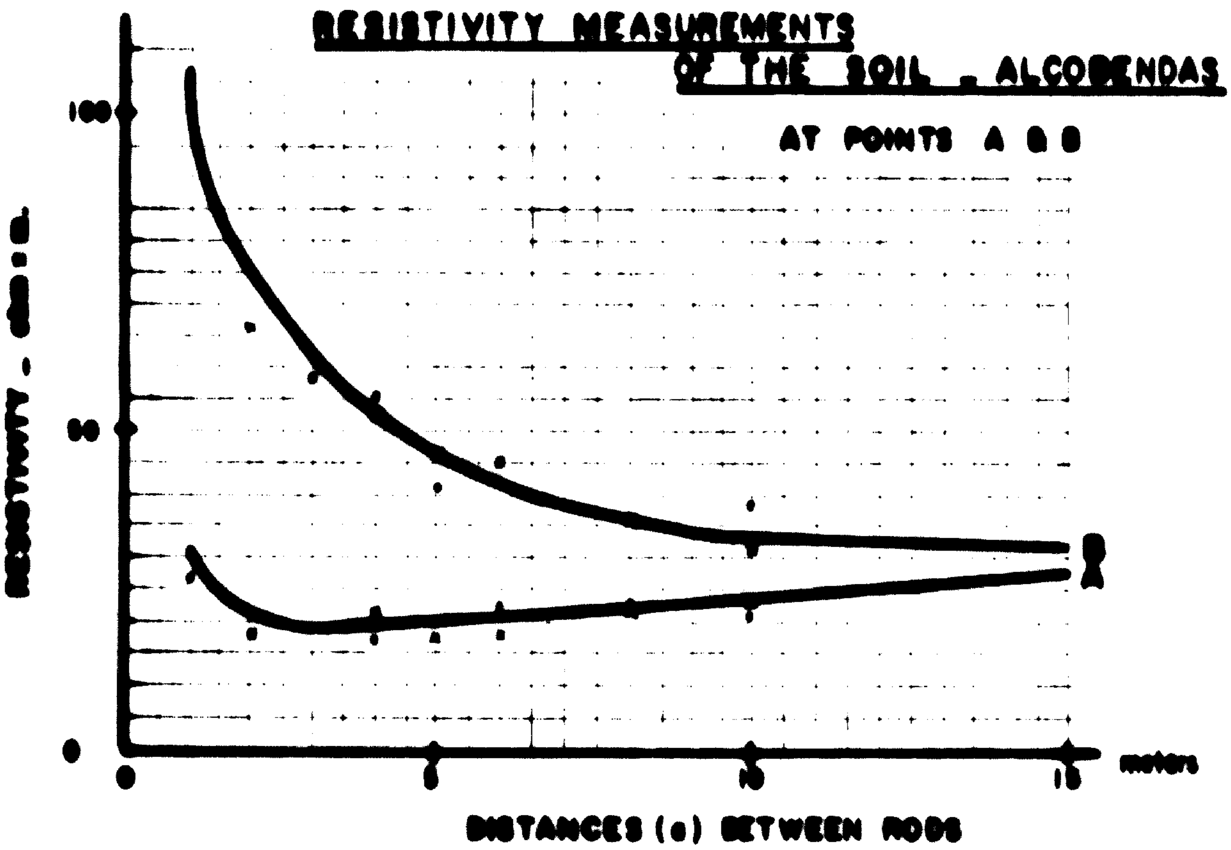
Madrid-15 de diciembre de 1.972

RESISTENCIA DE UN ELECTRODO (BARRA CILÍNDRICA) EN LOS TERRENOS DEL NUEVO "CENTRO DE ENSAYOS E INVESTIGACIÓN PARA LA INDUSTRIA ELÉCTRICA

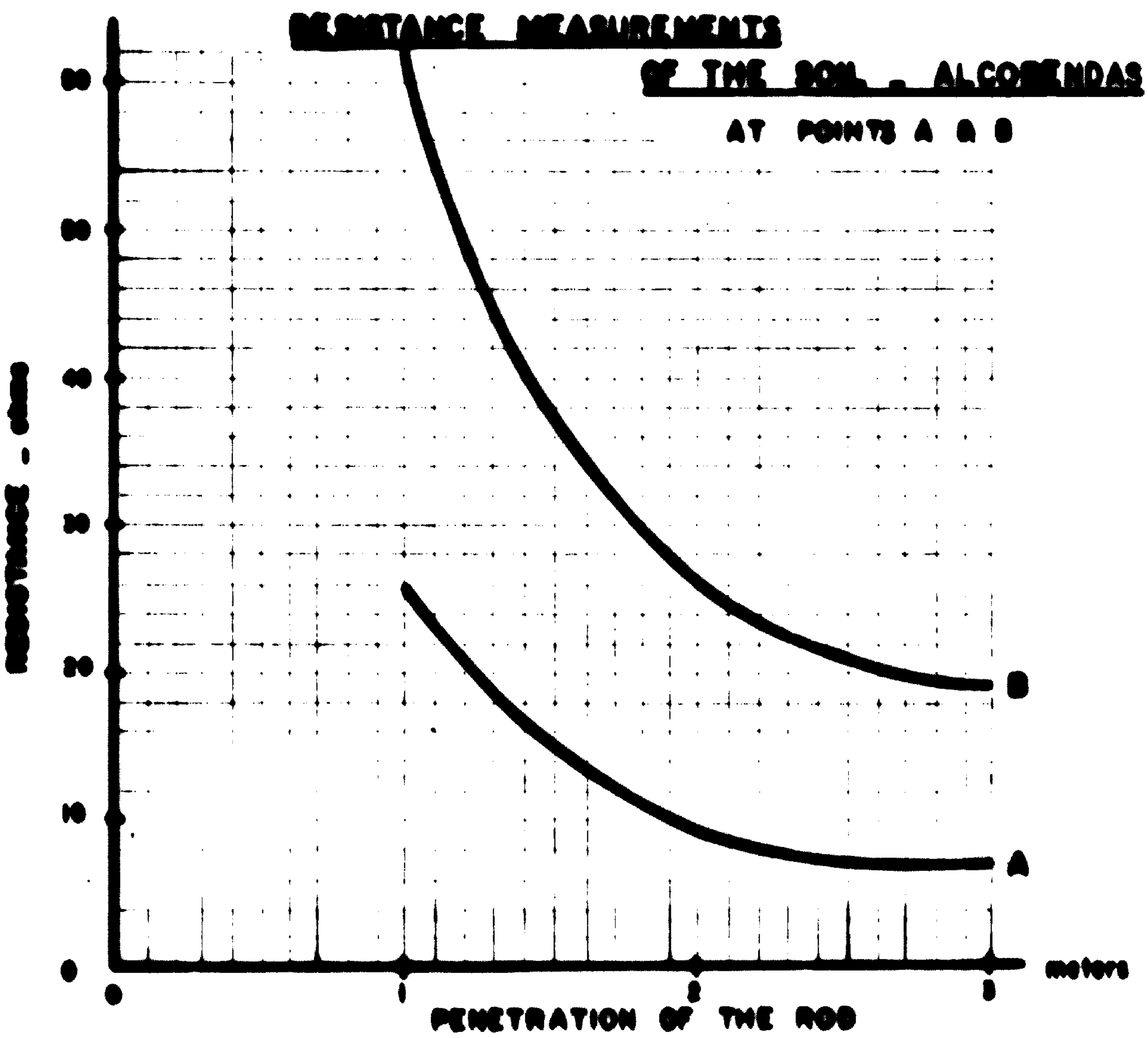
PUNTO MEDIDO	PENETRACIÓN DEL ELECTRODO DE TIERRA h (m)	DISTANCIA DEL ELECTRODO AUXILIAR C_2 (m)	DISTANCIA DEL ELECTRODO INTERMEDIO P_2(m)			RESISTENCIA (Ω)			
			1	2	3	1	2	3	MEDIA
A	1	34	14	17	20	25,9	25,5	26,2	25'9
	2	34	14	17	20	9'2	9'2	9'4	9'3
	3	34	14	17	20	7'1	7'2	7'2	7'2
B	1	34	14	17	20	65	65	66	65
	2	34	14	17	20	25	26	27	26
	3	34	14	17	20	21	18	18	19

ESTADO DEL TERRENO: MUY HÚMEDO

Madrid, 15 de diciembre de 1.972



RESISTIVITY MEASUREMENTS
OF THE SOIL _ ALCOBENDAS
AT POINTS A & B
100
50
0
RESISTIVITY
0
5
10
15
meters
B
A
DISTANCES (a) BETWEEN RODS



RESISTANCE MEASUREMENTS
OF THE SOIL _ ALCOBENDAS
AT POINTS A & B
60
50
40
30
20
10
0
RESISTANCE _ ohms
0
1
2
3
meters
B
A
PENETRATION OF THE ROD

L.O.L. 7-9-73

REPORT ON BORINGS

by

SONDAX, S.A.

SONDAX, S. A.

SONDEOS · INYECCIONES · ALUMBRAMIENTOS · PILOTAJE · HINCA · CIMENTACIONES ESPECIALES

TELÉFONOS 261 63 64 - 261 81 84

DIRECCION TELEGRAFICA: SONDAX - MADRID

CUENTAS CORRIENTES:

BANCO DE MADRID - SAN JERONIMO, 15
BANCO POPULAR ESPAÑOL - ALCALA, 60
BANCO IBERICO - MARIA MOLINA, 50
P.º DELICIAS, 51

SONDAX, S. A. · PASEO DE LA HABANA, 17-4.º · MADRID-16

Centro de Ensayos y Experimentación
para la Industria Eléctrica
José Gutiérrez Abascal, 2
MADRID

Atención: Sr. Archambault

S/REF. DE FECHA N/REF. 70/73 MADRID 8.2.73

ASUNTO **SONDEOS DE RECONOCIMIENTO EN ALCOBENDAS.**

Muy señores nuestros:

Adjunto les remitimos 4 ejemplares del corte geológico del terreno investigado con sondeos de reconocimiento en los puntos: A, BH.1, BH.2, BH.3 y BH,4, en su parcela del término municipal de Alcobendas (Madrid).

Igualmente incluímos 4 ejemplares del plano nº 157/1a, con indicación de la situación de dichos sondeos de reconocimiento dentro de la parcela.

Por la observación de los resultados obtenidos en los ensayos de penetración "Standard" (S.P.T.), podríamos admitir que en las zonas correspondientes a los sondeos A, Bh.2, BH.3 y BH.4, podría cimentarse un edificio con zapatas, y en la zona del sondeo BH.1 habría que practicarse una cimentación con pilotes de unos 8 m. de profundidad. No obstante sería preciso delimitar, con más sondeos, la zona de influencia de dicha cimentación.

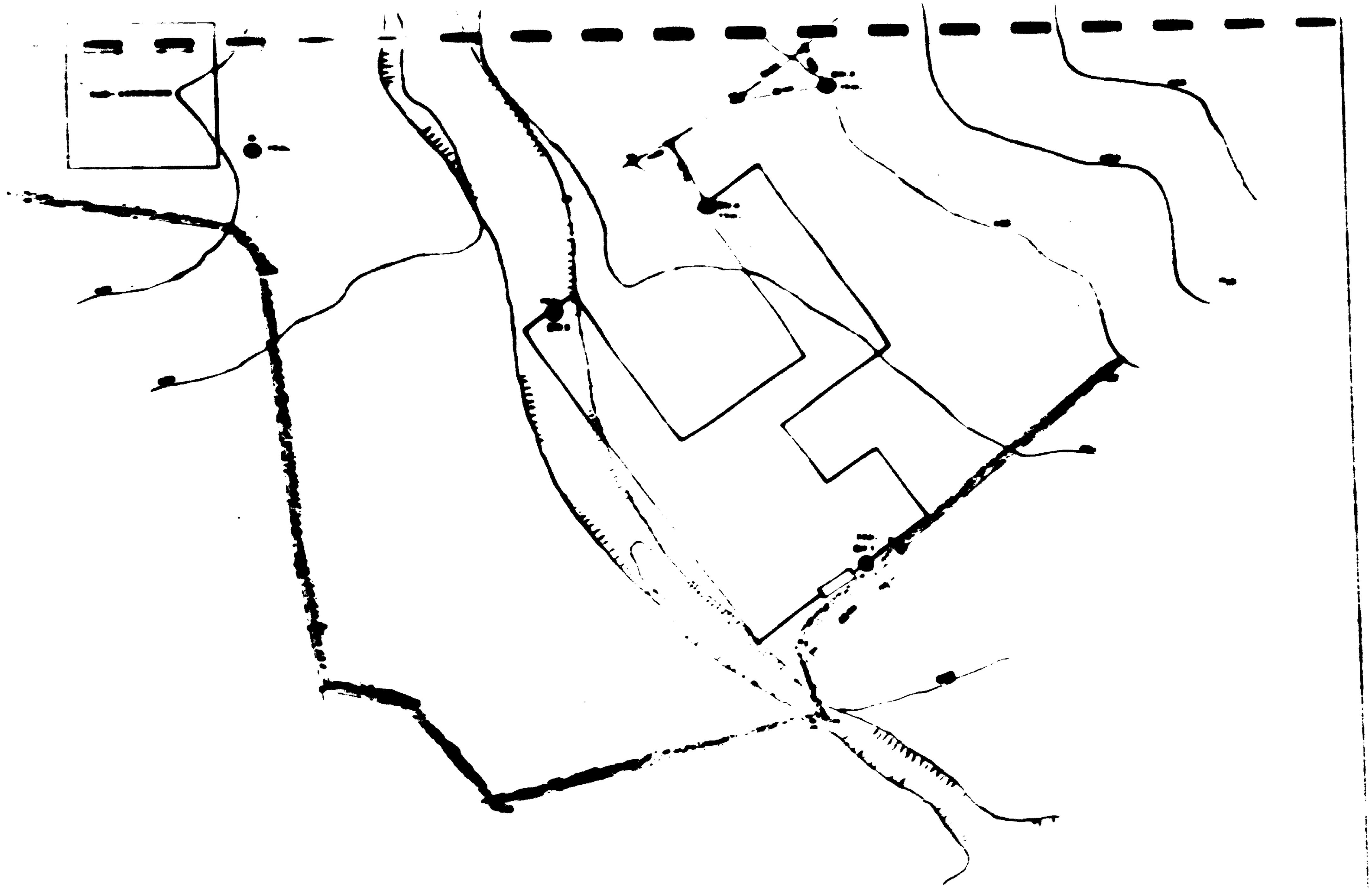
Sin otro particular, aprovechamos la ocasión para saludarles,

Muy atentamente,

SONDAX, S. A.
EL DIRECTOR GENERAL

Fdo.: PEDRO [illegible]

ANEXO: El mencionado.



SONDAN, S.A.-MADRID.- | **PLANO Nº157/**

SONDAX, S. A.

SONDEOS · INYECCIONES · ALUMBRAMIENTOS · PILOTAJE · HINCA · CIMENTACIONES ESPECIALES

CENTRO DE ENSAYOS Y EXPERIMENTACION PARA LA INDUSTRIA ELECTRICA

Sondeos de Reconocimiento del Terreno en su Parcela en el Término Municipal de Alcobendas (Madrid).

Contiene:

- Plano nº 157/1a. de situación sondeos.
- Gráfico sondeo A.
- Gráfico sondeo BH.1 (2 hojas).
- Gráfico sondeo BH.2.
- Gráfico sondeo BH.3
- Gráfico sondeo BH.4

Madrid, 8 de Febrero de 1.973

SONDAX, S. A. MADRID

SONDEO N.º -A- | Hoja N.º

FECHA: 11-1-73 | SONDISTA: RAIMUNDO

CLIENTE: CENTRO DE ENSAYOS Y EXPERIMENTACION PARA LA INDUSTRIA ELECTRICA

PLANO DE SITUACION:

PROYECTO: SONDEOS DE RECONOCIMIENTO EN ALCOBENDAS

X | Y | Z ~ 674,2

PERFORACION	NIVEL FREATICO	PROFUNDIDAD (m.)	REPRESENTAC. GRAFICA DEL TERRENO	MUESTRAS Número	Tipo	Recuperado	Golpes N30	DESCRIPCION DEL TERRENO	CLASIFICACION	DATOS GEOTECNICOS
ROTACION 86 mm.								ARCILLA ARENOSA		
		1.60		1	SPT		122	2.10		
								ARENA DE MIGA ARCILLOSA		
		4.05		2	SPT		R	4.05		
		5,00						ARCILLA CON ARENA		
				3	SPT		R	6,00		
		6,50						ARENA ARCILLOSA		
				4	SPT		R	8,15		
	8,50	8,50						ARENAS FINAS CON ALGUNA ARCILLA		
		10,00		5	SPT		R	10,00		
		10,60						ARCILLAS ARENOSAS		
		12,00		6	SPT		R	12,00		
								ARENAS FINAS LAVADAS		
		14,20		7	SPT		R	14.20		
		15,00						ARCILLA ARENOSA		
		15,60		8	SPT		R	15,60		
		20,00								

DATOS GEOTECNICOS: γ Mp.m³ | qu kg.cm² | Lím. Líq. % | Lím. Plast. % | H %

SONDAX, S. A. MADRID

SONDEO N.º BH-1	Hoja N.º 1
FECHA 30-1-73	SONDISTA RAIMUNDO

CLIENTE: CENTRO DE ENSAYOS Y EXPERIMENTACION PARA LA INDUSTRIA ELECTRICA

PLANO DE SITUACION:

PROYECTO SONDEOS DE RECONOCIMIENTO EN ALCOBENDAS

X	Y	Z≈667,00

PERFORACION: ROTACION 86 mm.

PROFUNDIDAD (m.)	MUESTRAS Número	Tipo	Recuperado	Golpes N30	Prof. muestra	DESCRIPCION DEL TERRENO	CLASIFICACION	DATOS GEOTECNICOS
0,00–1,10						ARENA ARCILLOSA		
1,10–3,50	1	SPT	-	11	2,15	ARCILLA DE COLOR NEGRUZCO		
3,50–3,80						ARENA CON ALGO DE ARCILLA		
3,80–6,35	2	SPT	-	15	4,10	ARCILLA		
5,00	3	SPT	-	12	6,05			
6,35–8,20	4	SPT	-	65	8,20	ARENA GRUESA CON ARCILLA Y ALGUNA GRAVA SUELTA		
8,20–10,00						ARENA ARCILLOSA		
10,00–10,25	5	SPT	-	R	10,25	ARENA FINA		
10,25–14,25	6	SPT	-	R	12,00	ARCILLA ARENOSA		
	7	SPT	-	R	14,25			
14,25–17,75 (15,00)	8	SPT	-	R		ARENA CON ALGO DE ARCILLA		
17,75–20,00	9	SPT	-	R		ARCILLA MUY ARENOSA		
20,00	10	SPT	-	R				

DATOS GEOTECNICOS: Qu kg/cm² · Lím. Líq. % · Lím. Plást. % · H %

SONDAX, S. A. MADRID	SONDEO N.º BH-1	Hoja N.º 2
	FECHA:	SONDISTA: RAIMUNDO
CLIENTE:	PLANO DE SITUACION:	
PROYECTO:	X	Y	Z

PERFORACION	NIVEL FREATICO	PROFUNDIDAD (m.)	REPRESENTAC. GRAFICA DEL TERRENO	MUESTRAS Número	Tipo	Recuperación	Golpes N30	DESCRIPCION DEL TERRENO	CLASIFICACION	DATOS GEOTECNICOS: I Mp n	qu kg/cm²	Lim. Liq. %	Lim. Plast. %	H %
		20,00						ARCILLA MUY ARENOSA						
		22,10		11	SPT	-	R.							
				12	SPT	-	R.	24,16 ARENA DE MIGA Y GRANITO DESCOMPUESTO						
		25,00												
				13	SPT	-	R.	26,10 ARENA DE MIGA CON ARCILLA						
		28,00		14	SPT	-	R.	28,00 ARCILLA ARENOSA						
		30,00												
		30,40		15	SPT	-	R.	30,40						
		35,00												
		40,00												

SONDAX, S. A. MADRID

SONDEO N.º BH-2	Hoja N.º
FECHA 17-1-73	RAIMUNDO

CLIENTE: CENTRO DE ENSAYOS Y EXPERIMENTACION PARA LA INDUSTRIA ELECTRICA (MADRID)

PLANO DE SITUACION:

PROYECTO: SONDEOS DE RECONOCIMIENTO EN ALCOBENDAS (MADRID)

X | Y | Z ~ 675,0

PERFORACION	NIVEL FREATICO	PROFUNDIDAD (m.)	MUESTRAS Número	Tipo	Recuperado	Golpes N30	Profundidad	DESCRIPCION DEL TERRENO	CLASIFICACION	DATOS GEOTECNICOS
ROTACION 86 mm.			1	SPT	-	109	2,05	ARENAS ARCILLOSAS		
		3,60	2	SPT	-	R.	4,10	ARCILLA ARENOSA		
		5,00 / 5,20	3	SPT	-	R.	6,05	ARENAS CON ALGUNA ARCILLA		
		7,70	4	SPT	-	R.	8,00	ARCILLA CON ARENA		
		10,00	5	SPT	-	R.	10,15	ARENA DE MIGA ARCILLOSA		
		12,10	6	SPT	-	R.	12,10	ARENAS MUY ARCILLOSAS		
			7	SPT	-	R.	14,00			
		15,00	8	SPT	-	R.	15,50			
		20,00								

DATOS GEOTECNICOS: γ t/m³ | qu kg/cm² | Lim. Liq. % | Lim. Plast. % | H %

SONDAX, S. A. MADRID

SONDEO N.º	BH-3	Hoja N.º
FECHA	3-1-73	SONDISTA: RAIMUNDO

CLIENTE: CENTRO DE ENSAYOS Y EXPERIMENTACION PARA LA INDUSTRIA ELECTRICA (MADRID)

PLANO DE SITUACION.

PROYECTO. SONDEOS DE RECONOCIMIENTO EN ALCOBENDAS (MADRID)

X	Y	Z ~ 667,30

PERFORACION	NIVEL FREATICO	PROFUNDIDAD (m.)	MUESTRAS (Número, Tipo, Golpes N30)	Prof.	DESCRIPCION DEL TERRENO
ROTACION					ARENA FINA SUELTA
		1,00	1 SPT - 66	2,00	ARENA CON ARCILLA Y TROZOS DE GRANITO DESCOMPUESTO
		3,10	2 SPT - R.	4,00	ARENA ARCILLOSA
		5,00	3 SPT - 42	6.10	
	▽	6,70			ARENA DE MIGA CON ARCILLA
		7,20	4 SPT - 59	8,05	ARENA SILICEA GRUESA LIMPIA
		10,00	5 SPT - 45	10,00	
		10,20			ARCILLA CON ALGUNA ARENA
		11,10			ARENA DE MIGA
		12,46	6 SPT - R	12,10	ARCILLA ARENOSA
			7 SPT - R	13,90	ARCILLA CON ALGUNA ARENA
		15,00			
		15,30	8 SPT - R.	15,30	
		20,00			

CLASIFICACION	DATOS GEOTECNICOS: γ t/m³	Qu kg/cm²	Lim. Liq. %	Lim. Plast. %	H %

SONDAX, S. A. MADRID

SONDEO N.º BH - 4 | Hoja N.º

22-1-73 | RAIMUNDO

CLIENTE: CENTRO DE ENSAYOS Y EXPERIMENTACION PARA LA INDUSTRIA ELECTRICA (MADRID)

PLANO DE SITUACION:

PROYECTO: SONDEOS DE RECONOCIMIENTO EN ALCOBENDAS (MADRID)

X | Y | Z ~ 671,00

PERFORACION	NIVEL FREATICO	PROFUNDIDAD (m)	MUESTRAS (Numero / Tipo / Recuperado / Golpes N30)	Cota	DESCRIPCION DEL TERRENO	CLASIFICACION	DATOS GEOTECNICOS
ROTACION 86 mm			1 SPT - 40	2,00	ARCILLA ARENOSA		
			2 SPT - 42	4,10			
	▽	5,00					
		6,15	3 SPT - 51	6,15	ARCILLA BLANDA CON ARENA		
			4 SPT - 59	8,00	ARCILLA		
		8,60					
		9,20			ARENAS Y GRAVAS		
		10,00	5 SPT - R.	10,05	ARENA CON ARCILLA		
		11,00					
		12,10	6 SPT - R.	12,10	ARENAS SILICEAS LAVADAS		
		14,25	7 SPT - R.	14,25	ARCILLA COMPACTA		
		15,00 / 15,40	8 SPT - R.	15,40	ARENA ARCILLOSA		
		20,00					

DATOS GEOTECNICOS: γ Mp/m³ | qu kg/cm² | Lim. Liq. % | Lim. Plast. % | H %

APPENDIX 2

TYPICAL TEST CIRCUITS IN H.P. LABORATORY IN MADRID, SPAIN.

SYNOPSIS:

This report shows a review of possible test circuits diagrams in the H.P. Laboratory in Madrid, Spain.

The diagrams were prepared in order to check whether it is possible to make up all basic test circuits with available bus bar systems and connection possibilities.

A. INTRODUCTION

In the description which follows and the attached diagrams, all basic circuit diagrams, supposed to be used for testing circuit breakers, and other pieces of equipment, in the two H.P. - H.V. test yards of the H.P. laboratory are shown.

At the beginning only one short-circuit generator will be provided with one transformer set. Two test yards are, however, proposed to be arranged from the very beginning, which give the station a higher flexibility.

Two extension stages are proposed:

1. In the first stage, a second generator-transformer set will be added as shown by dotted lines.

2. In the second stage, a third high-power source may be added. It is left to later decision whether this will be a third generator-transformer set, or a transformer set fed from the 220 kV network. At this stage a third test yard may be added as well, having in mind the overall extension of station activity at that stage.

B. BUS BAR SYSTEMS

The following 220 kV bus systems are provided:

Two "vertical" three-phase bus bars for two generator-transformer sets (No. I and No. II) will be built at the beginning, even though this generator-transformer set No. 2 will be added later on.

"Vertical" bus system No. III will be built at a later stage in connection with the decision to be taken as mentioned above, but necessary space is provided for it.

System No. IV is the connecting line coming from 220 kV sub-station to the 500 MVA transformer set. Besides this main purpose there are many other cases to use this system as shown further on. Horizontal bus bar No. I, on the supply side of the tested object serves mainly the paralleling of the sources, whereas the horizontal bus bar No. II is used for connecting different types of loads and for synthetic test circuits. For this last reason the central cable of this system is insulated for 765 kV.

C. TYPICAL CIRCUIT DIAGRAMS

The tests made in H.P. laboratory can be classified in the following groups:

1. Short-circuit switching tests on H.V. circuit breakers or modules of EHV circuit breakers using direct methods.

2. Short-circuit switching tests on complete EHV circuit breakers or groups of modules thereof, using synthetic methods.

3. Tests on circuit breakers when switching capacitive currents of condensor banks, no-load cables and long unloaded transmission lines.

4. Tests on circuit breakers when switching small inductive currents of no-load transformers, H.V. shunt reactors and H.V. motors.

5. Tests on circuit breakers and load switches when switching ohmic load currents.

6. Short-circuit tests on power transformers and current limiting reactors.

7. Short-circuit interruption tests on H.V. fuses.

8. Open power-arc tests on insulators.

9. Different other tests on bus bars, switchgear assemblies, lightning arresters, etc.

1. Short-circuit switching tests on breakers using direct methods.

1.1 Terminal short-circuit (See diagrams No. 1 and No. 2 .)

a) Short-circuit current is generated by main generator (G_1) limited if necessary, by reactors and supplied through transformers T_1 into the test yard No. 1 or No. 2. The short-circuit is made on load-side terminals of the tested breaker.

b) When two short-circuit generators and two sets of transformers will be installed, it will be possible to use the two sets in parallel as shown in diagram No. 2 .

c) Later on, when an agreement with the utilities will be reached, the possibility exists to install a set of transformers T_3 connecting the 220 kV network in parallel with the two generator-transformer sets (see diagram No. 3). In such an arrangement a test power of the order of some 8000 to 10,000 MVA three-phase could be reached in the future.

1.2 Short-line fault tests (See diagrams No. 4 and No. 5)

a) Connection as in previous case, except that the load side terminals are connected via Bus-bar II to the test yard No. 2, where an artificial circuit, simulating a short-line is installed. This connection can be used for voltages up to 220 kV. This connection will be used mainly for test on modules, rated at voltages from about 40 kV up to say, 100 kV, making parts of the breakers for rated voltages from 100 kV up to highest voltages used nowadays (765 kV, 1100 kV).

b) At 220 kV it will be possible to make similar tests, according to diagram No. 5 , avoiding the artificial circuit and using a real 220 kV line instead, on which a short-circuit is made at a distance of 2 to 3 km from the breaker.

c) Referring to case 1.1.c, it will be possible to make short-line fault tests, the short-circuit current being supplied by two short-circuit generators and 220 kV network in parallel, with the tested breaker in one test yard and the artificial circuit simulating the short section of a line being installed in the other test yard. This is shown in diagram No. 6 .

1.3 <u>Out-of-phase switching tests</u>

a) When two generators are available, they can be used as shown in diagram No. 7. The two generators are maintained during the test in a specified phase position, one with respect to the other, supplying the voltages on the opposite terminals of the breaker having a specified phase shift. The two circuits will be controlled individually as to the value of the reactance and T.R.V. shape.

b) When two generators and 220 kV network connection are available, it will be possible to make out-of-phase switching tests at that voltage. Diagram No. 8, shows a case with two generators on one side of the breaker and 220 kV network on the other side. The two machines must be maintained at a specified phase position with respect to the 220 kV network.

2. <u>Short-circuit switching tests using synthetic methods.</u>

For the time being only simple interruption tests using synthetic methods are specified in I.E.C. The making tests and make-break tests are under consideration and it is hoped, standard specifications for those tests will be available in the near future. Besides, it is possible to make such tests as development tests and, as acceptance teste according to an agreement between the manufacturer and the user.

2.1 <u>Terminal short-circuit making or breaking</u>

a) One or two main generators and corresponding transformers deliver the short-circuit current at reduced voltage through the auxiliary breaker AB and tested breaker TB (See diagram No. 11). At a suitable moment the injected current is sent into the T.B. from synthetic H.V. circuit. The same circuit creates the T.R.V. after the opening of A.B. and T.B.

b) For higher voltages, see diagram No. 12, a symmetrical circuit is shown, using two oscillating circuits installed in the synthetic circuit hall, one positive and one negative. In the high current circuit the tested breaker T.B. is inserted between two auxiliary breakers AB1 and AB2.

2.2 Short-line fault test, using synthetic method

The diagram No. 13, is similar to that shown in diagram No. 12, except that the artificial line simulating the short-line, which is inserted in one branch.

2.3 Out-of-phase switching test, using synthetic circuit.

The test will be made single-phase only, and the diagram No. 12, will be used. It is possible to adjust in such a circuit the voltage proportion of the two sides and their T.R.V. shapes independently.

3. Capacitive current switching tests

The basic circuits for these tests are shown in diagrams No. 16 and No. 17.

For higher voltage tests, say 100 kV and up, the diagram No. 16 will be used. One, or two short-circuit generators will be used, according to the condition to be met, as prescribed by IEC rules. The capacitive load circuit in synthetic test hall will use the condensor elements of the synthetic circuit. Either a concentrated condensor bank or an artificial circuit simulating a long unloaded line may be used according to the case.

For the tests of dropping no-load lines, a real 220 kV line can be used. This possibility is shown at the diagram No. 5, with the exception that a long no-load line is used at the load side of the breaker, instead of a short, short-circuited line.

The second connection, shown in diagram No. 17 will be used at lower voltages, say up to 72 kV, is using a set of condensors installed on the roof of assembly hall and belonging normally to the 500 MVA test section.

4. Small inductive current switching tests

The diagram No. 14, shows the basic possibility, using the 500 MVA transformers loaded by reactances of the same section and damping resistors, which are connected in a sort of artificial circuit simulating either an unloaded transformer, or a shunt reactor, or a reactor loaded transformer.

In a similar way, the diagram No. 15 shows another possibility. This time one generator-transformer set (G_1 - T_1) is used as the source, and the other transformer set T_2, loaded by the reactances (and resistances if necessary) as artificial circuit. At lower voltages, as shown in diagram No. 18, the test can be supplied from 220 kV system through 500 MVA transformers, and at the load side the transformer-reactor group T_1 or T_2 is used as artificial circuit.

5.

Circuit breakers and load switches will be tested for ohmic load switching in a diagram according to No. 14. In this case, however the 500 MVA transformers will be loaded by ohmic resistances only or by a combination of resistors and inductors giving the required power factor.

6, 7, 8.

The tests according to these three items do not present any problems as to the circuit diagram. Connections shown in diagram Nos. 1, 2 and 3 can be used, the tested breaker being replaced by a transformer, reactor, fuse or any other tested object.

D. LIST OF DIAGRAMS

1. Terminal short-circuit supplied from one generator.

2. Terminal short-circuit supplied from two generators in parallel.

3. Terminal short-circuit supplied from two generators and 220 kV network, all in parallel.

4. Short-line fault test on a module of an E.H.V. circuit breaker, with artificial short-line.

5. short-line fault test at 220 kV, with real short-line.

6. Short-line fault test, supplied from two generators and 220 kV network in parallel, with artificial circuit.

7. Out-of-phase switching tests with two short-circuit generators.

8. Out-of-phase switching with two generators on one side and 220 kV network on the other side.

9. Diagram of two tests made independently: one in 500 MVA test area from 220 kV network, the other from 22 kV substation, in high-current test area.

10. Alternative feeding of high current test area from 220 kV network through 500 MVA transformers.

11. Short-circuit switching test in an asymmetrical synthetic circuit.

12. short-circuit switching test in a symmetrical test circuit.

13. Short-line fault test in a synthetic circuit.

14. Small inductive current test, with an artificial circuit made up of 500 MVA transformers and its load circuit.

15. Small induction current test, with artificial circuit made up of the second two transformers and reactor group.

16. Capacitive current switching. Load capacitors (or artificial line) in synthetic test hall.

17. Capacitive current switching. Load capacitors in 500 MVA section.

18. Small inductive current switching at lower voltage. Supply from 220 kV network, load circuit made up from 2100 MVA transformers and reactors.

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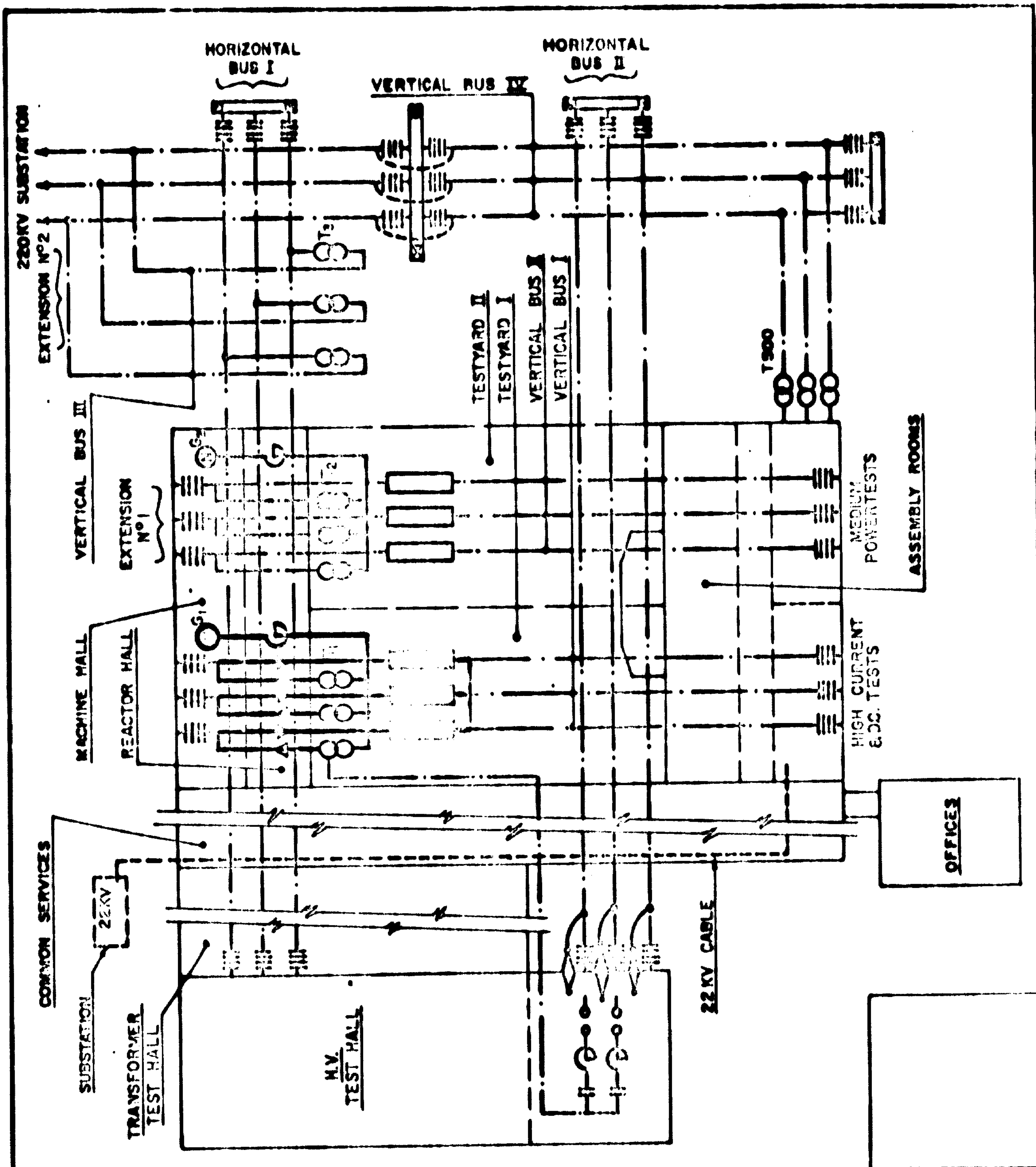

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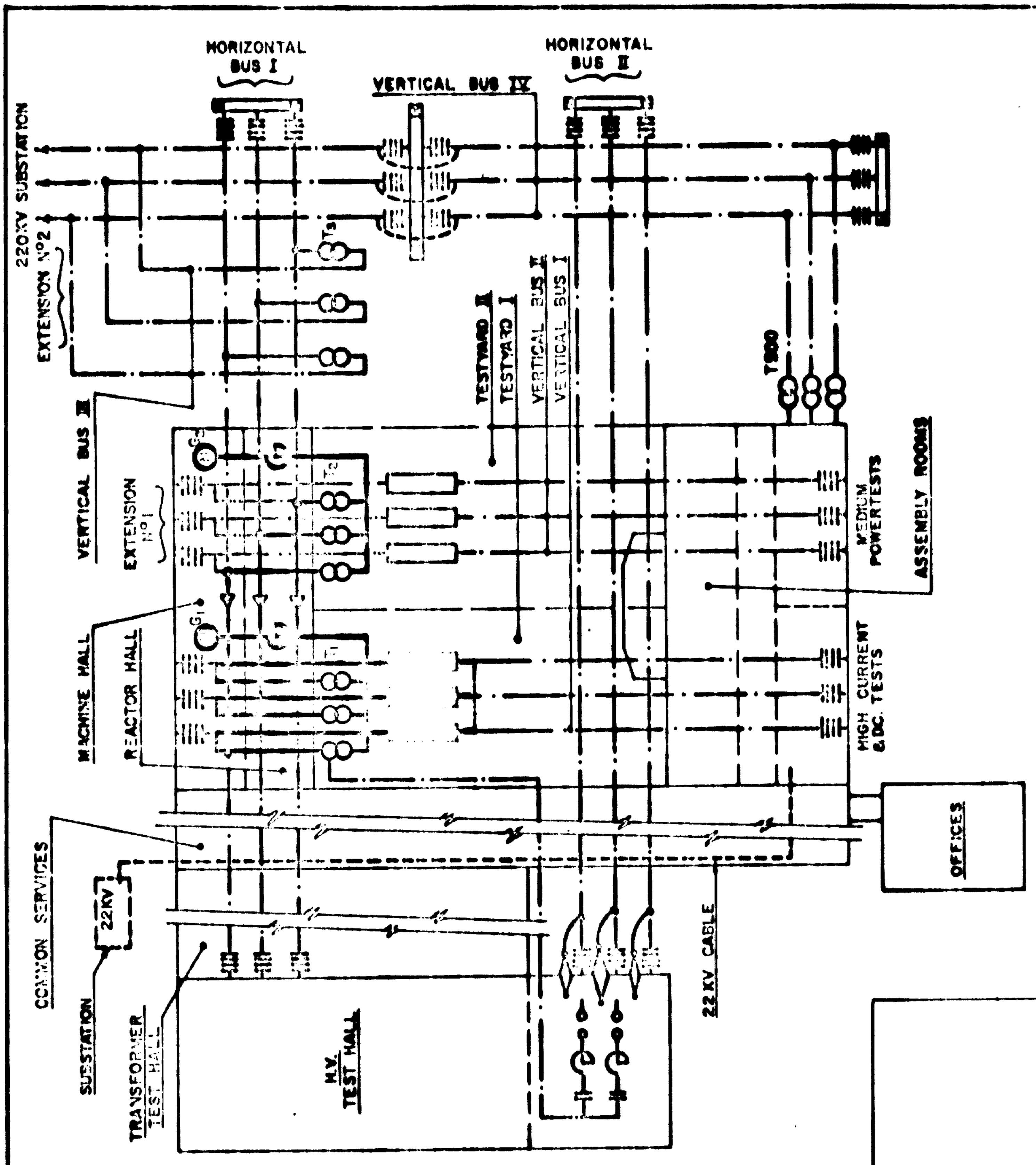

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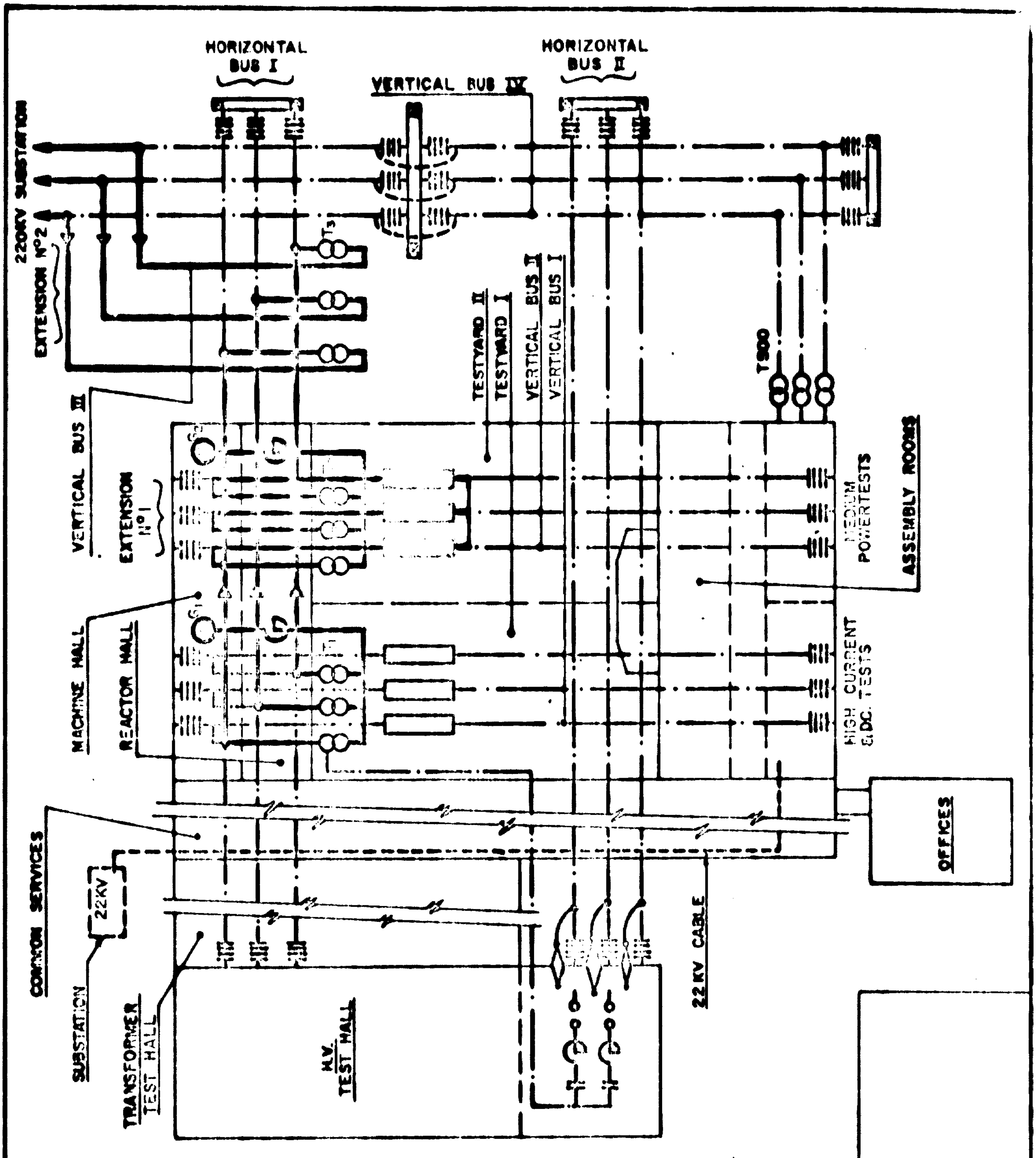

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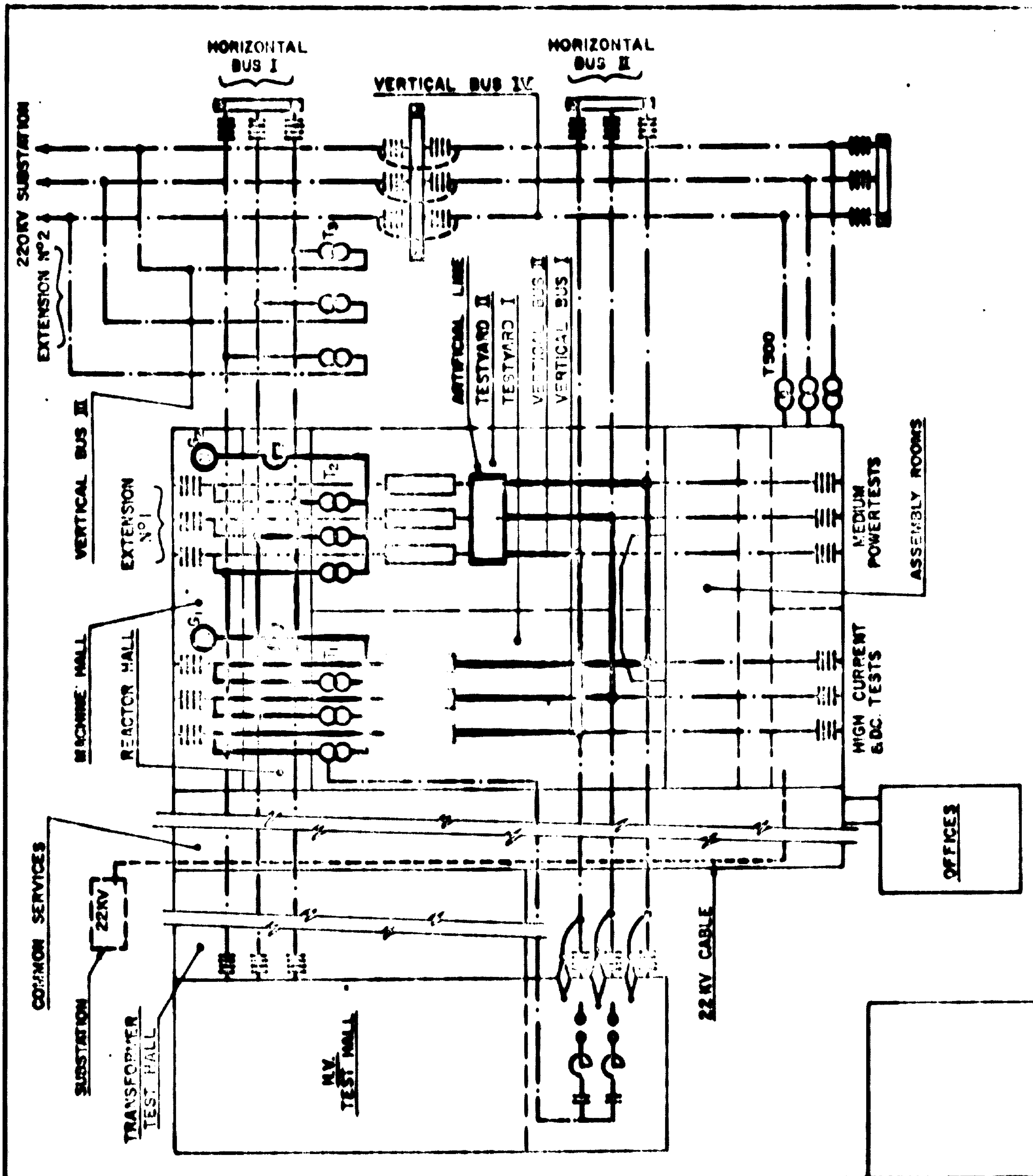

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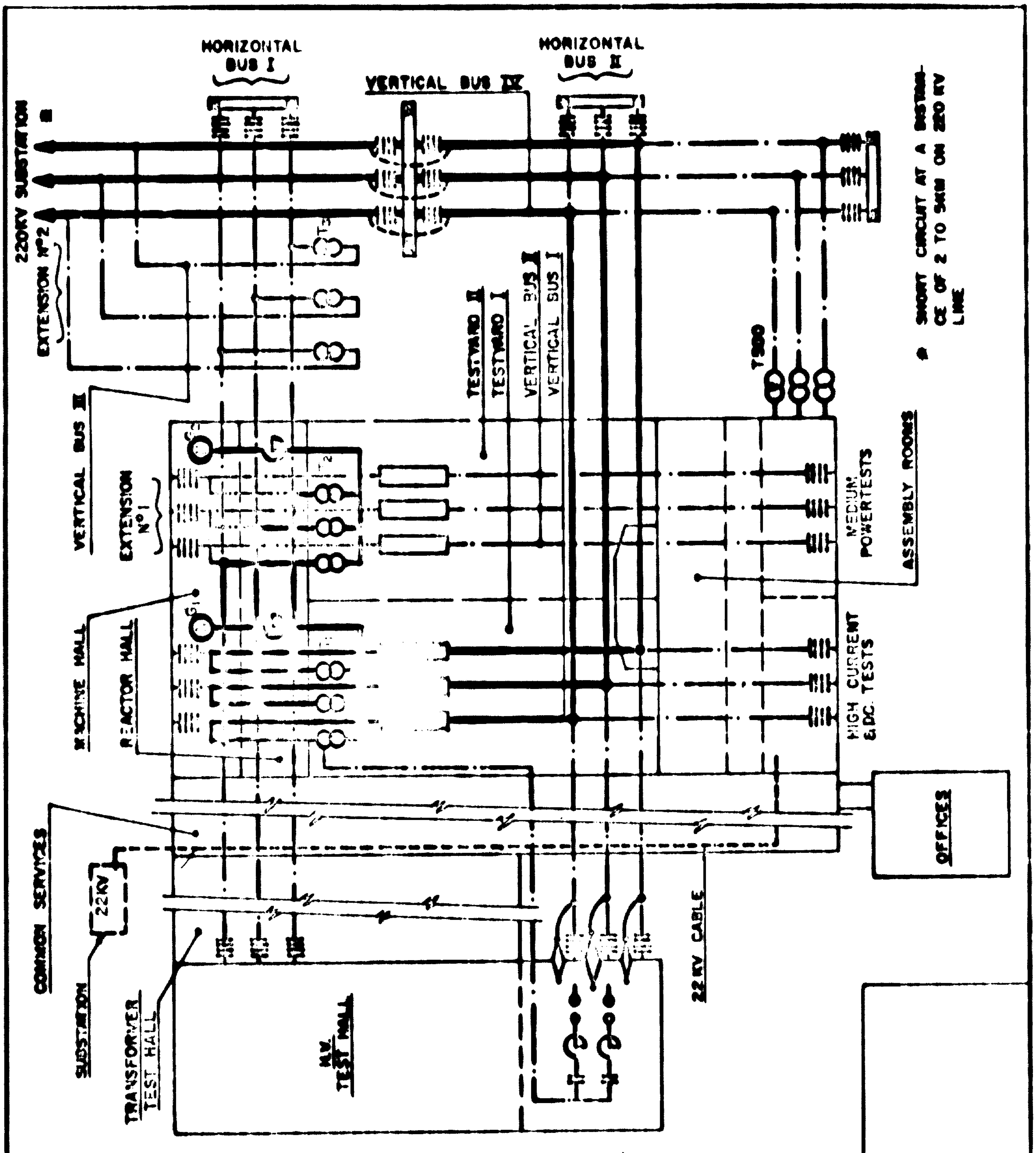

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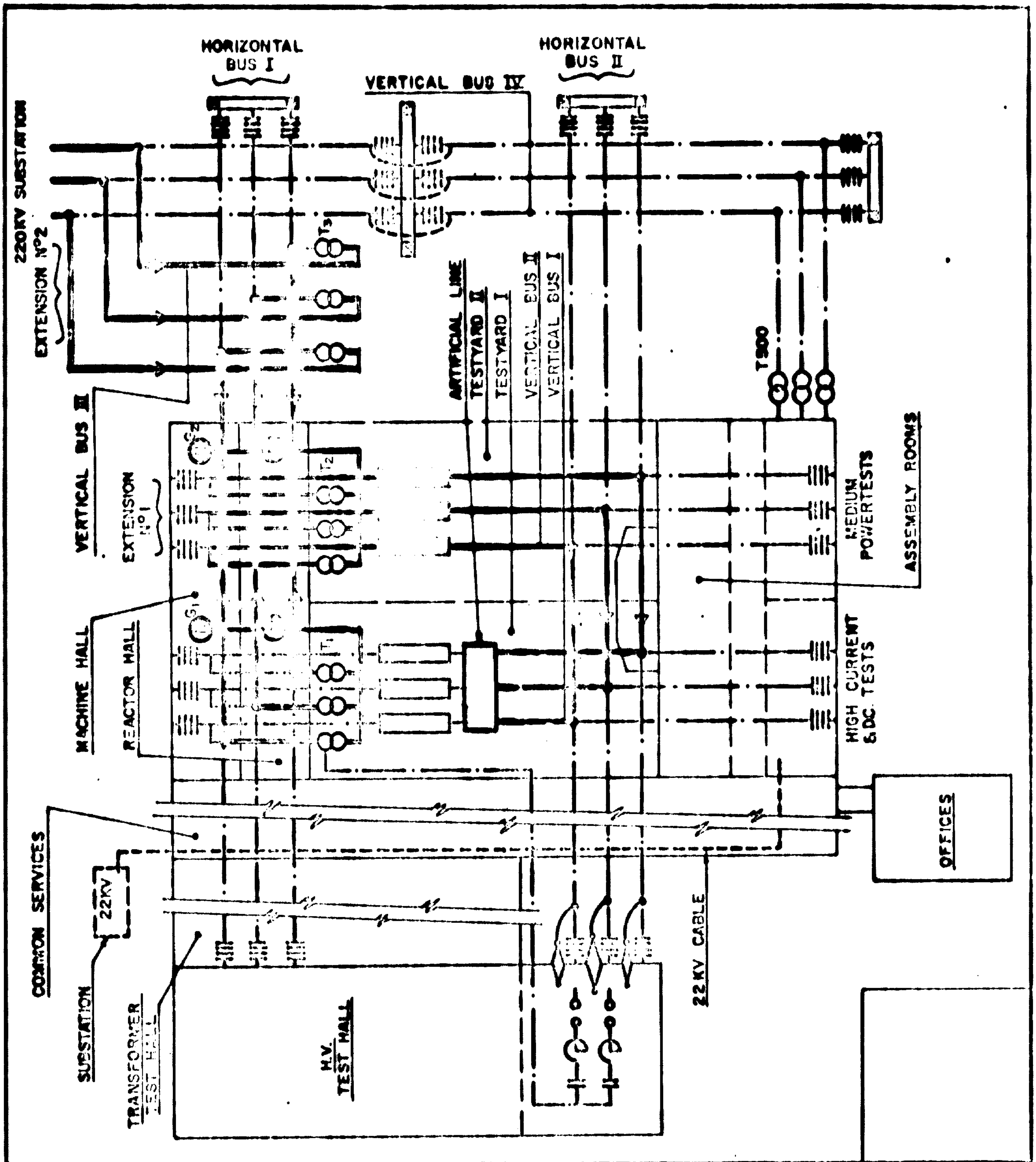

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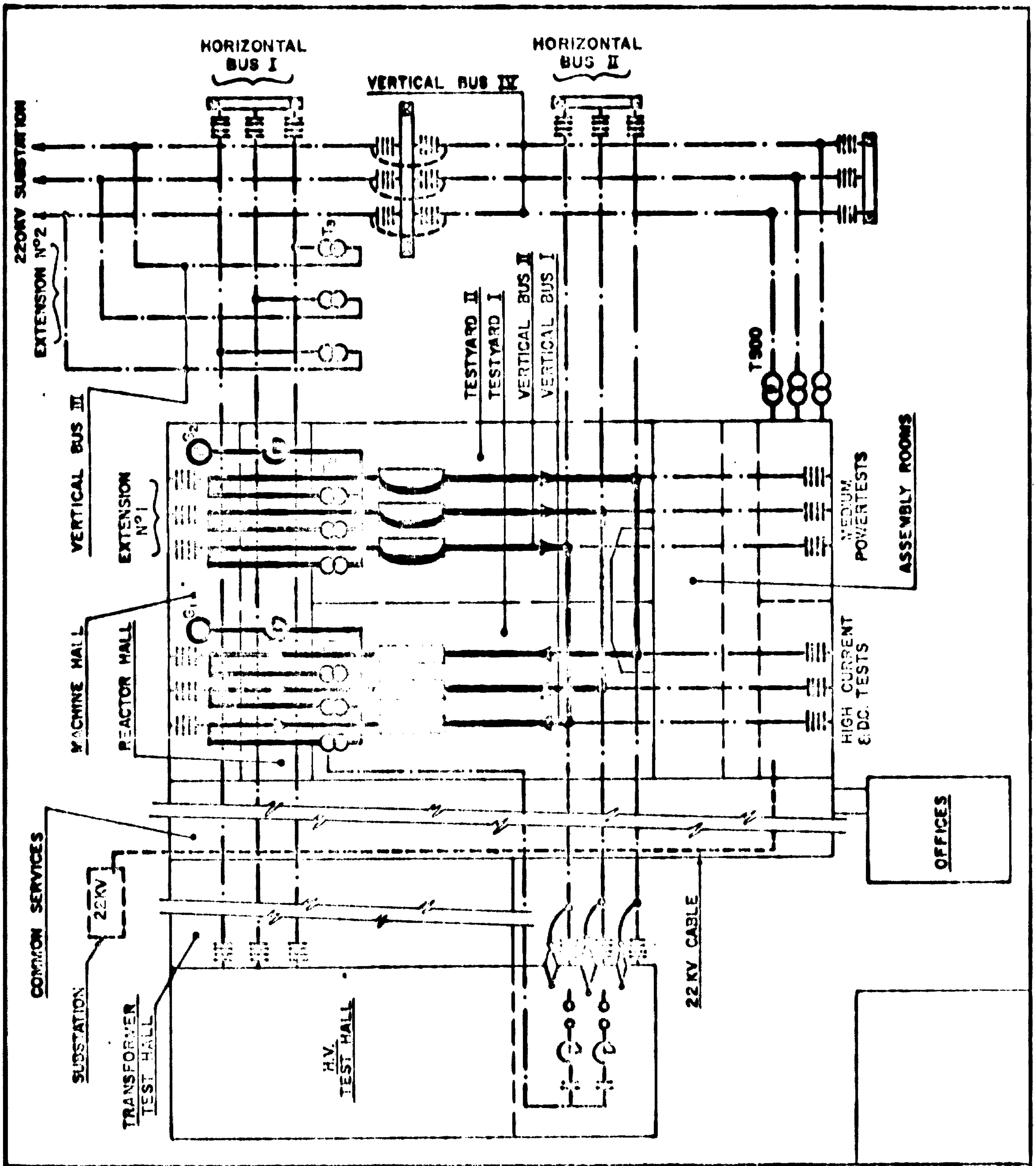

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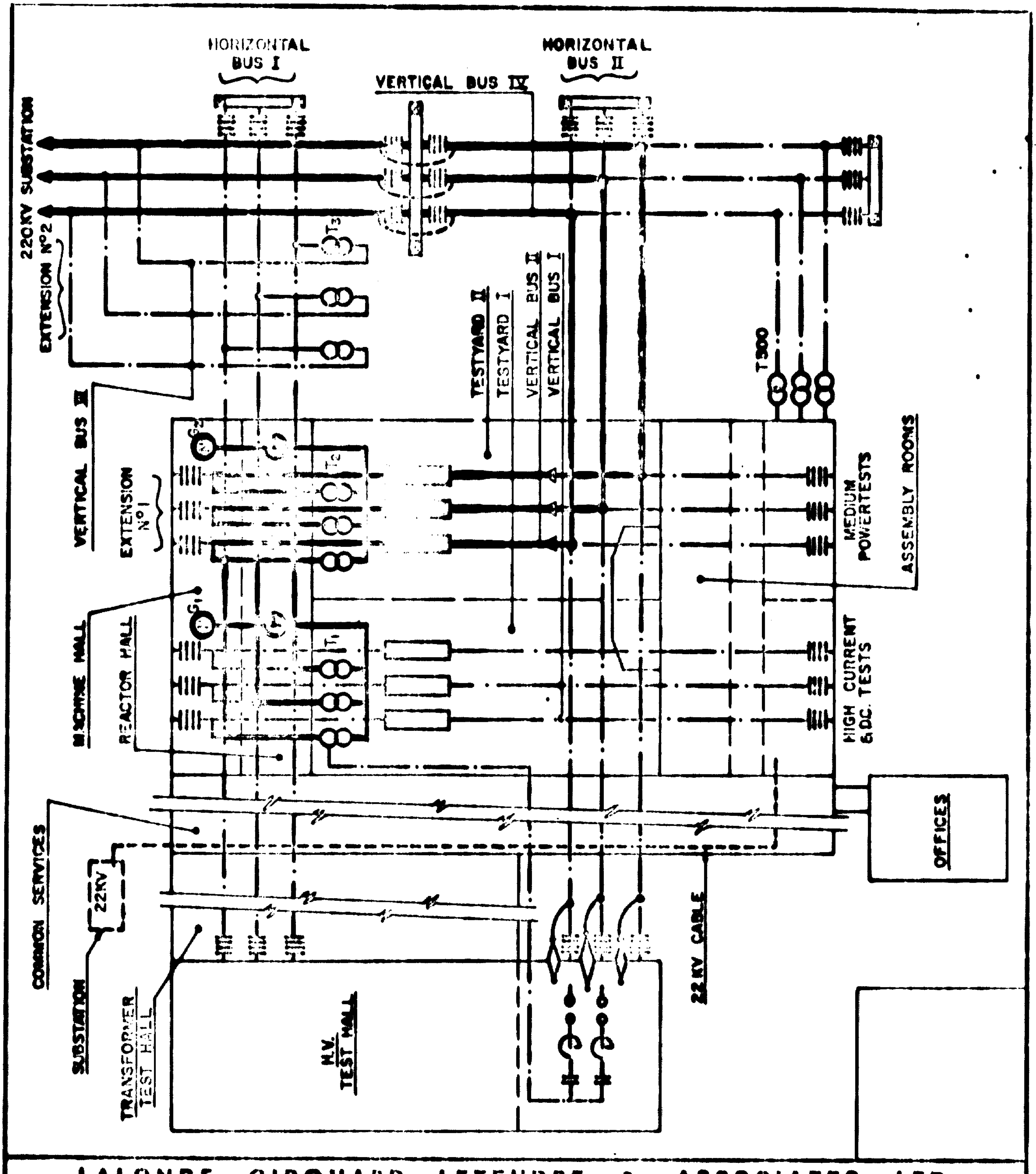

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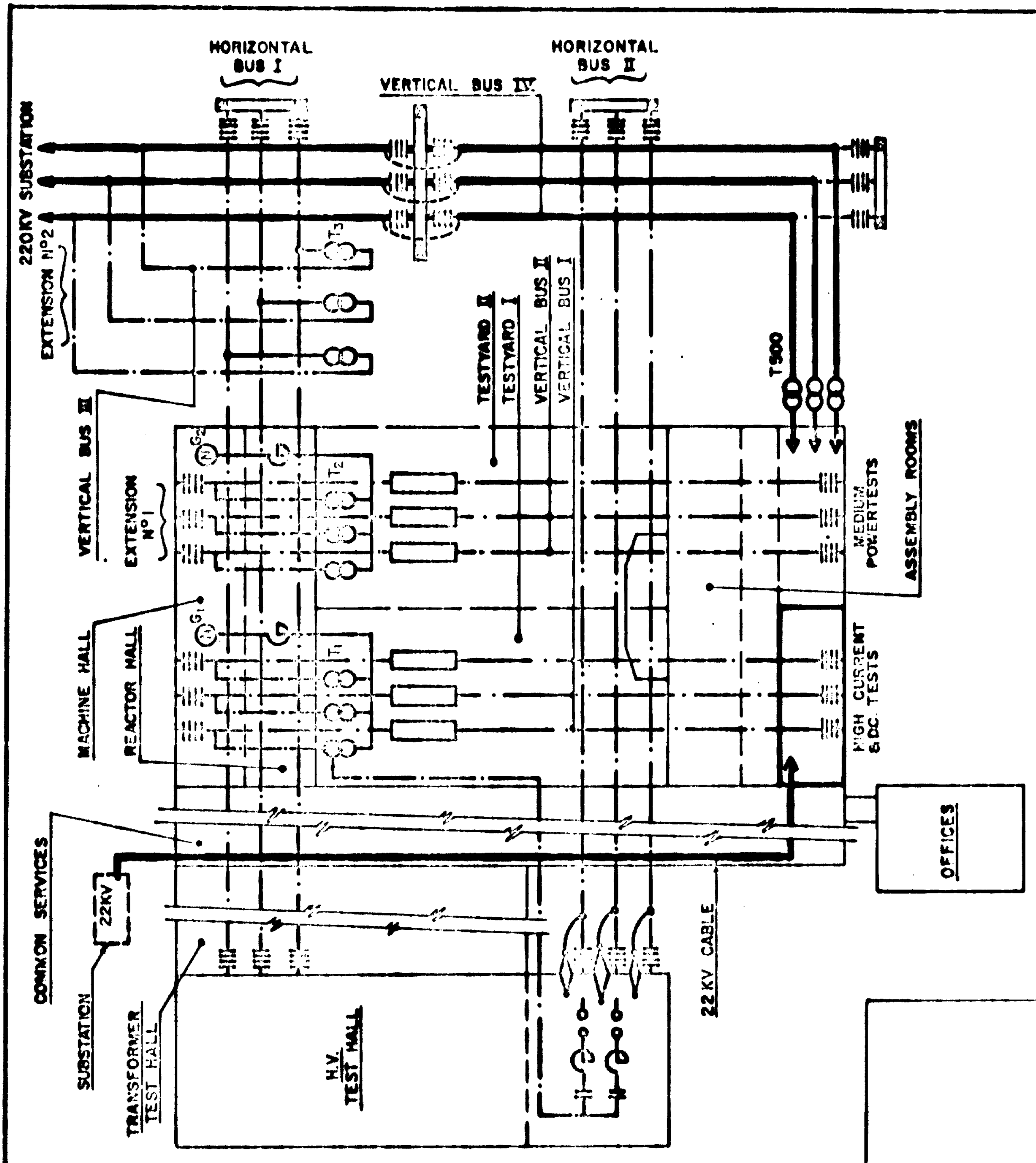

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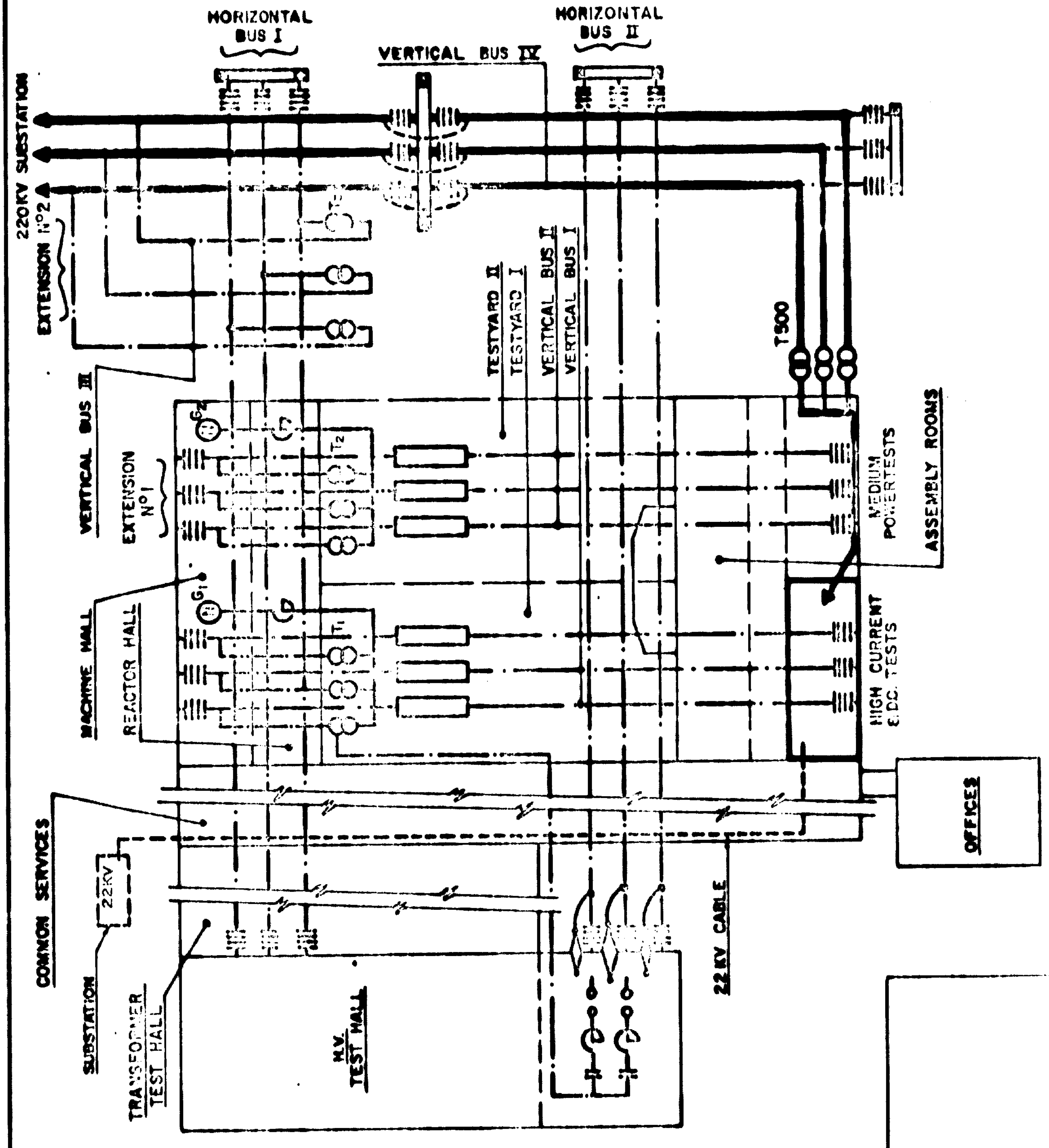

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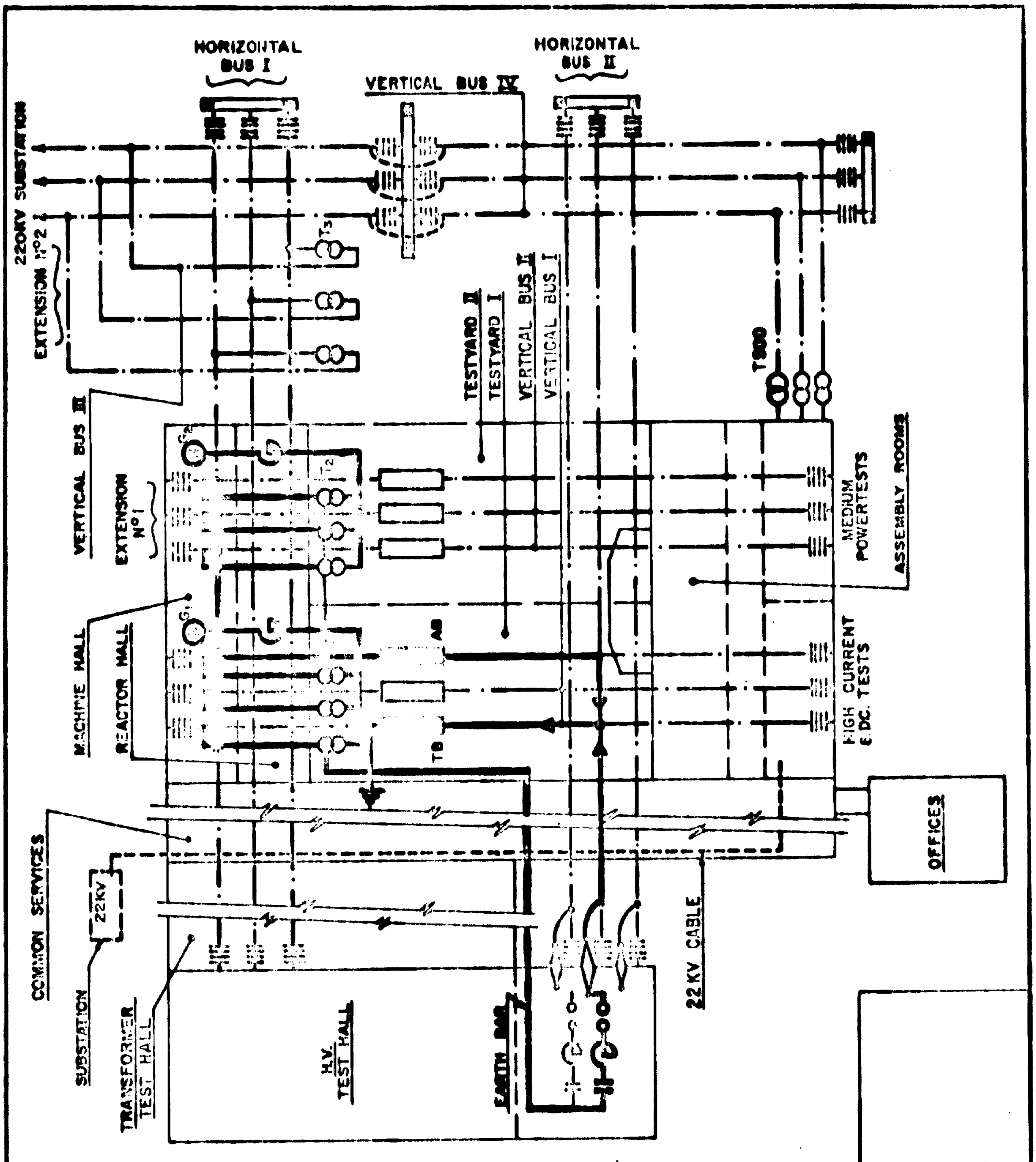

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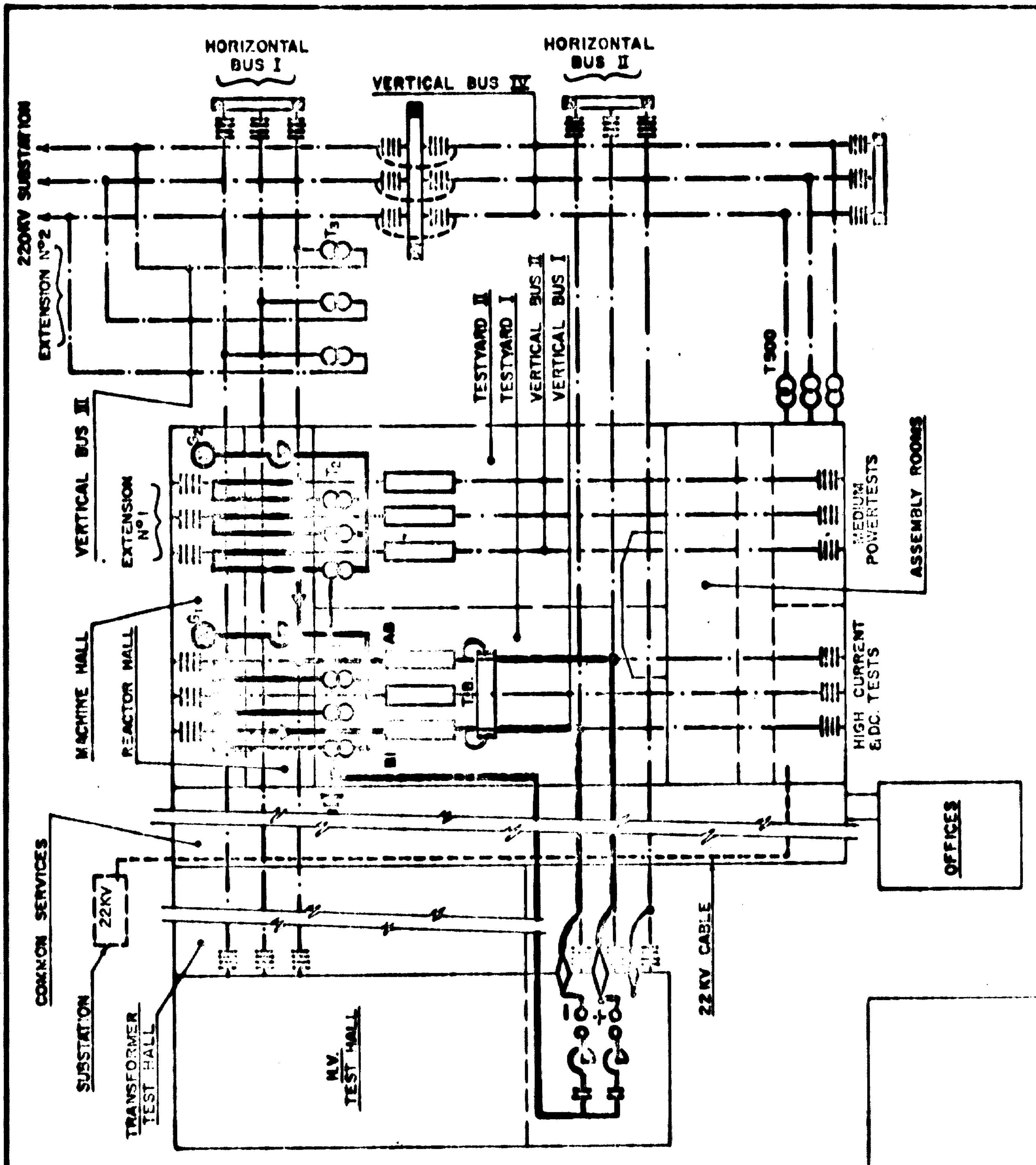

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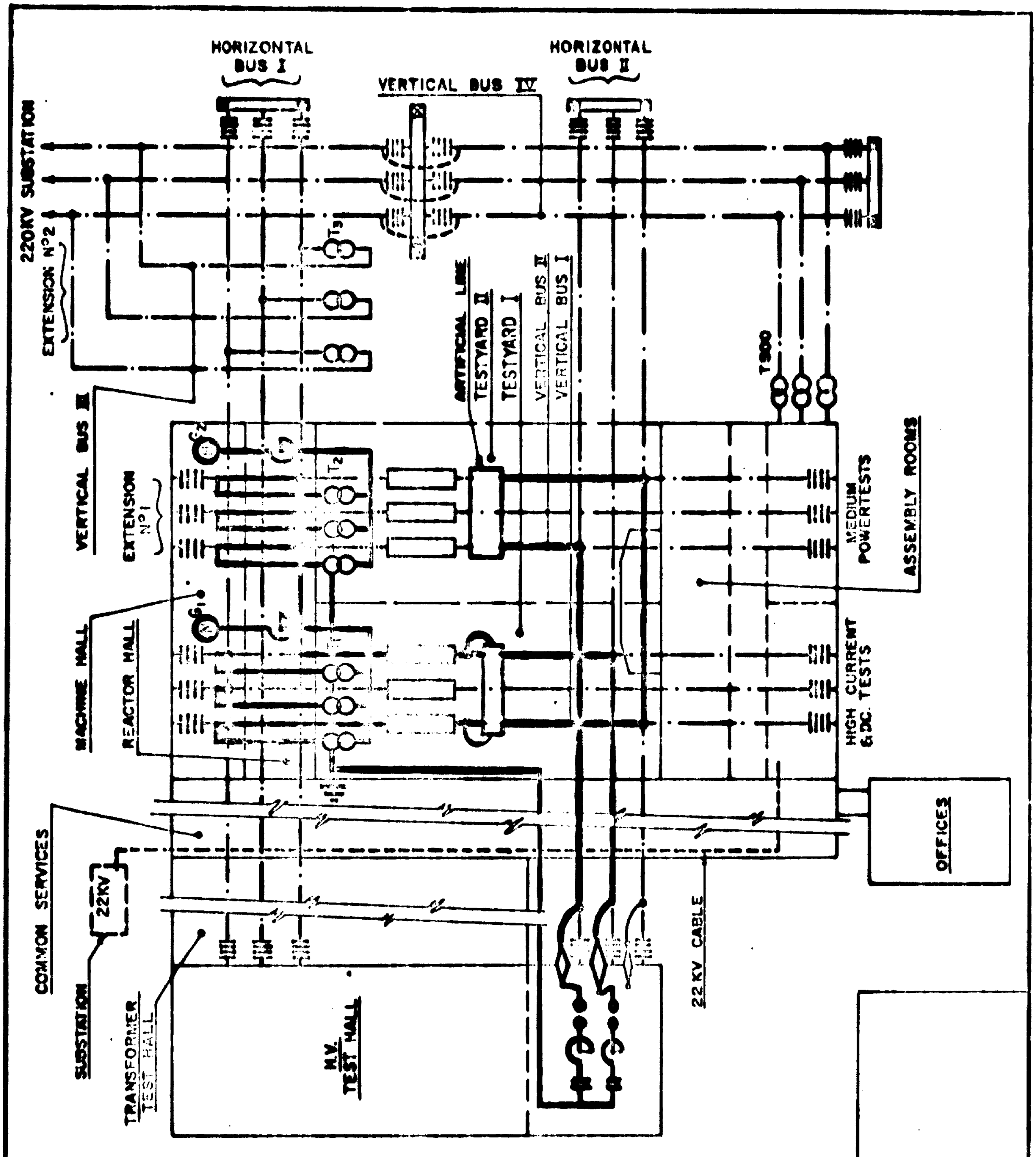

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DRAWN BY: CB		CHECKED BY:	
DESIGNED BY: V.Z			
APPROVED BY: A.D			
APPROVED BY: JPL			
CONTRACT N°: 412	FILE N°:	DATE: AUGUST 1972	
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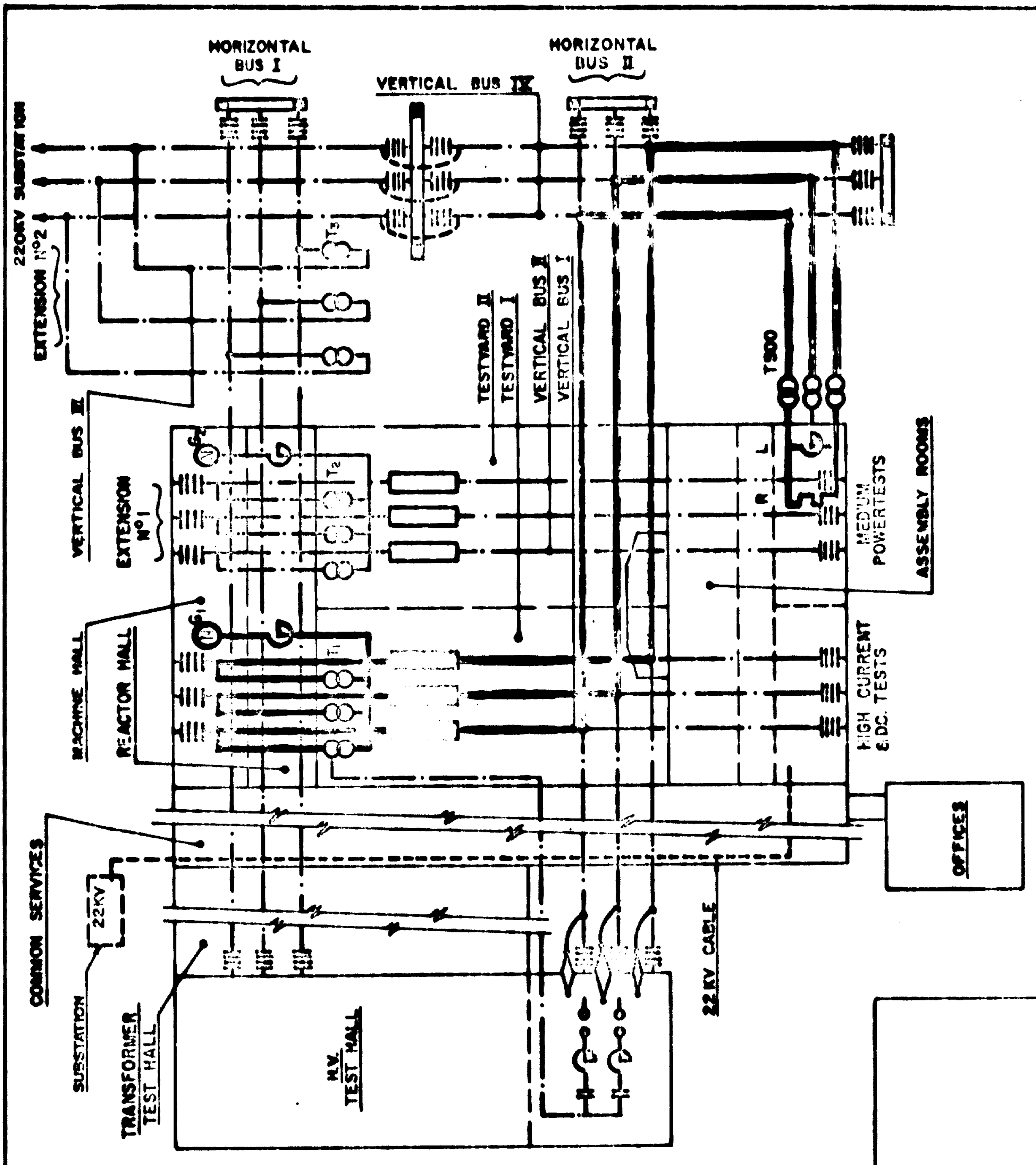

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ELECTRICAL INDUSTRY TESTING AND EXPERIMENTATION CENTRE MADRID, SPAIN	DRAWN BY: C.B	CHECKED BY:
	DESIGNED BY: V.Z	
	APPROVED BY: A.D	
	APPROVED BY: J.P.L	
	CONTRACT N°: 412 / FILE N°:	DATE: AUGUST 1972
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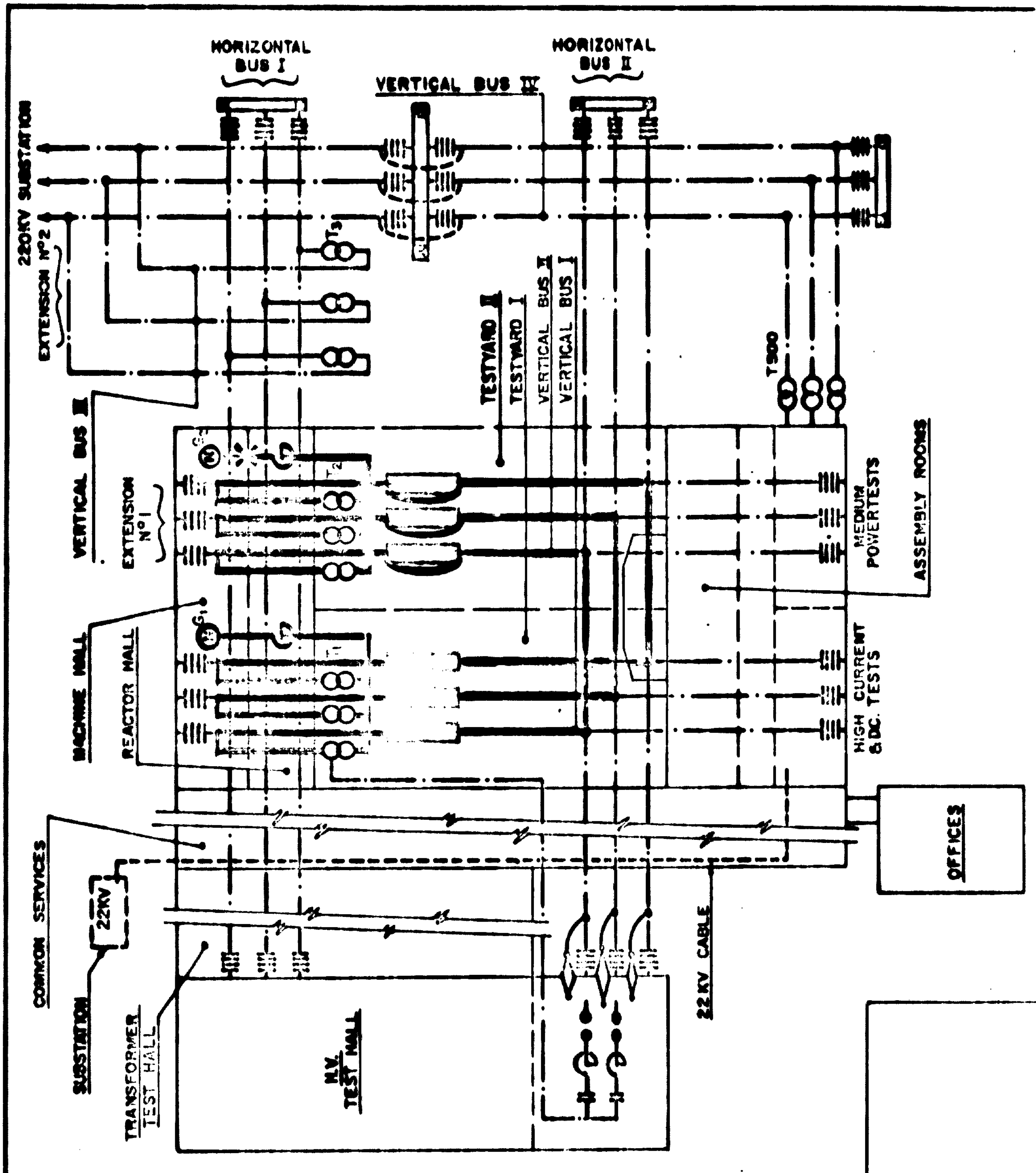

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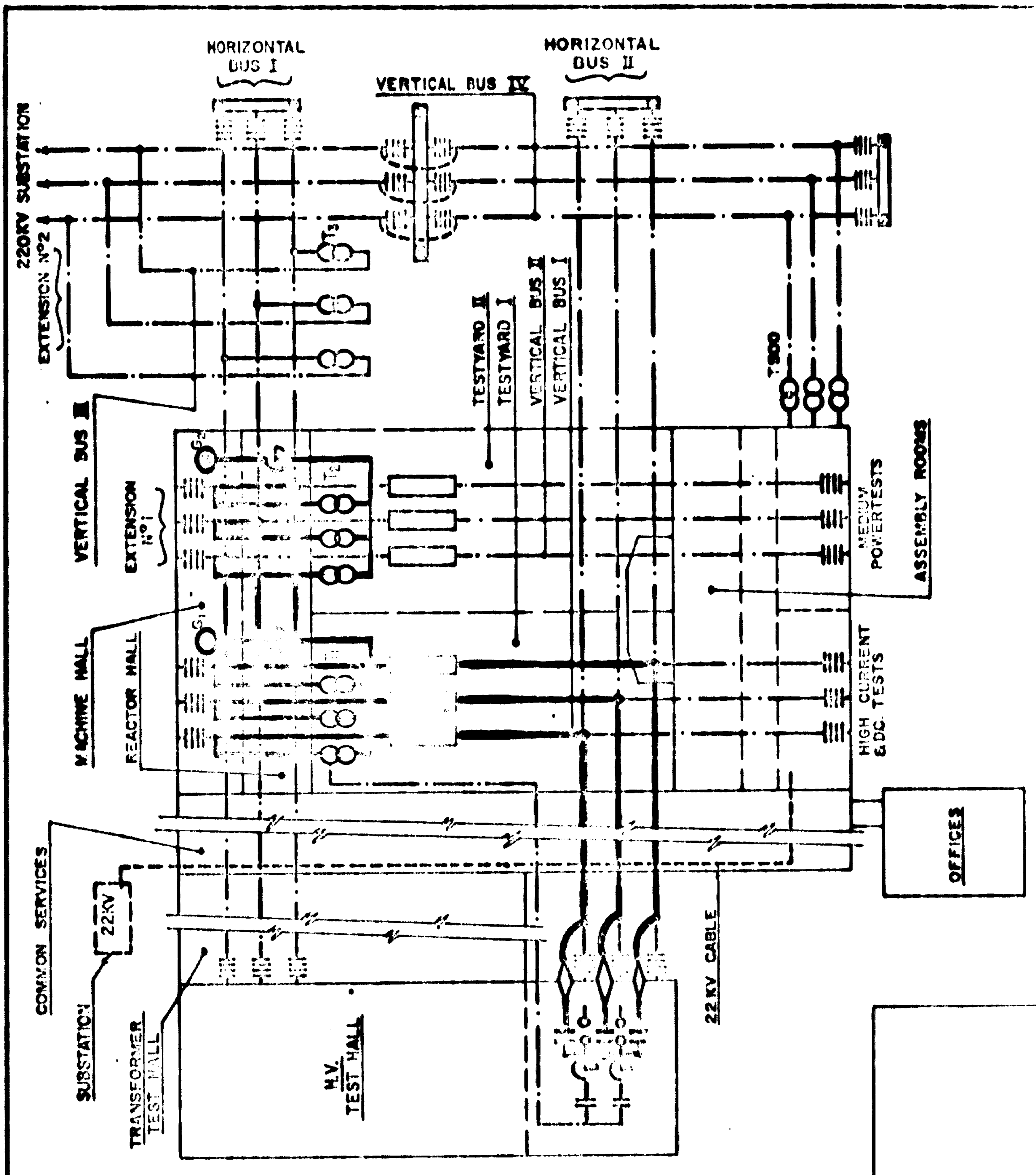

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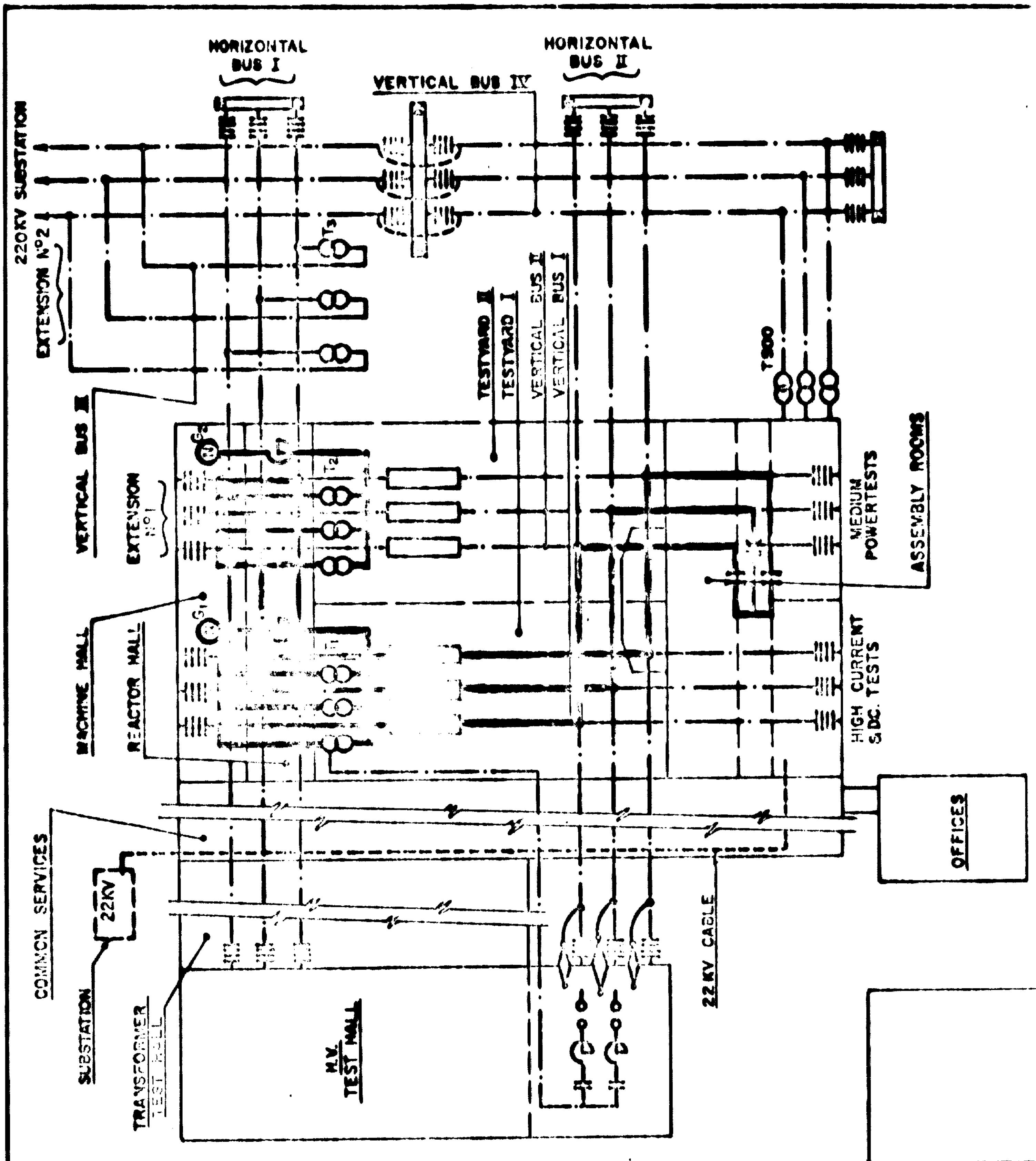

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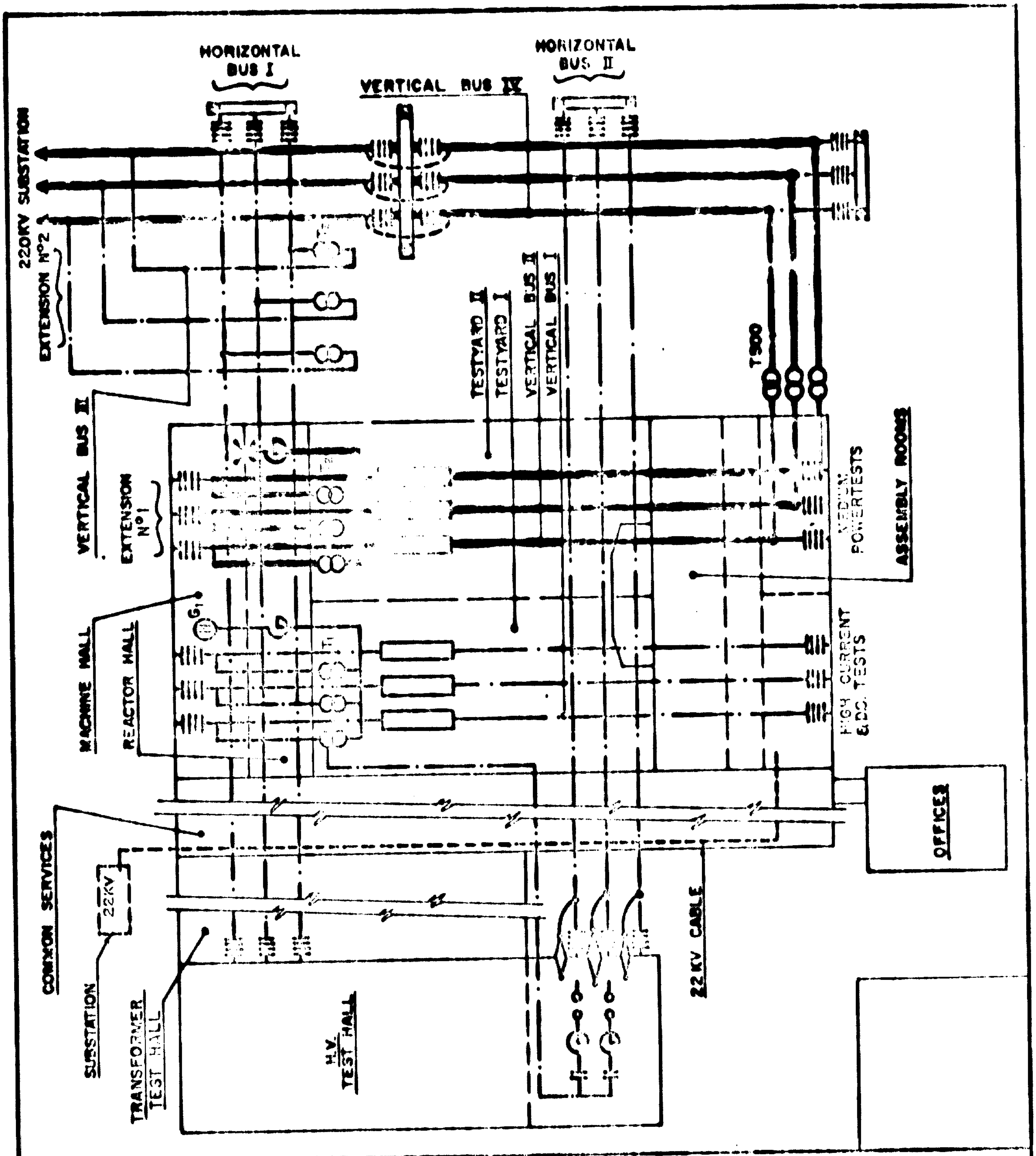

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Analysis of possible connections of the generator-transformer group

The following pages present a systematic analysis of possible connections of the generator-transformer group for the High Power Laboratory of the Electrical Industry Testing and Experimentation Centre.

It is concluded that the most economical solution giving satisfactory parameters will be based on the following points:

1. The generator will have no simple winding in each phase, connected in star permanently. No change-over switch is required for the generator.

2. A direct connection of the generator with the test cell (without passing through transformers) is not required at the beginning, but space and provisions will be made to enable the addition of such a test cell, when a second short-circuit generator is added.

3. The basic primary connection of the transformers for three-phase tests in delta. For single-phase tests the transformers will be in parallel, supplied from two phases of the generator, which remains in star.

ANALYSIS OF THE CONNECTIONS OF THE GENERATOR-TRANSFORMER GROUP FOR THE HIGH-POWER TEST STATION IN MADRID, SPAIN.

A. ASSUMPTIONS OF THE ANALYSIS:

1. It is assumed that a three-phase short-circuit generator will be used, having a rated voltage of 14 kV, rated short-circuit capacity of 2100 MVA, and phase reactance of 60 mΩ at 50 Hz.

These two parameters and others calculated on their bases refer to a time of 0,15 s after the beginning of the short-circuit.

2. The symmetrical short-circuit current (R.M.S.) at the same time is: $I_{sc} = \frac{2100.10^6}{\sqrt{3}.14.10^3} = 86$ kA

3. The total reactance of the test circuit per phase will be

$$X = \frac{14^2.10^6}{2100.10^6} = 0,094\ \Omega = 94\ m\Omega$$

4. The bus system connecting the generator terminals with the transformer will be made of bars having an equivalent diameter of 15 cm, placed in a plane at a distance 0,5 m (center to center). The mean distance is $l_m = 0,5 \times 1,26 = 0,76$ m, and the reactance at 50 Hz

$$X_{50} = 62.8\ (0,25 + \ln \frac{76}{7.5}) = 160\ \frac{\mu\Omega}{m}$$

for the estimated length of the connection of 35 m, $X_B = 160.10^{-6} \times 35 = 5,6$ mΩ $\doteq$ 6 mΩ

5. The highest reactance of the transformer group per phase will be:

$$X_{TMax} = 94 - 60 - 6 = 28\ m\Omega$$

B. CRITERIA OF THE ANALYSIS

1. Available capacity of the test circuit for 3 phase and single-phase tests.

   The capacity will be limited basically by:

   a) Generator's stator current,

   b) Generator's rotor current,

   c) Generator's voltage,

   d) Permissible current of other circuit elements such as bus bar system, back-up circuit breaker, making switch and transformers,

   e) Impedance of the circuit.

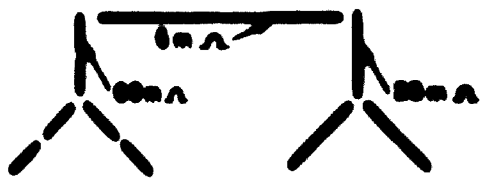
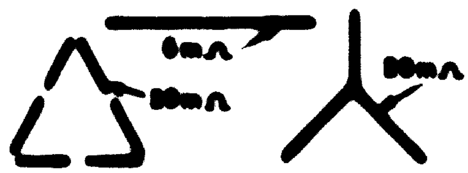
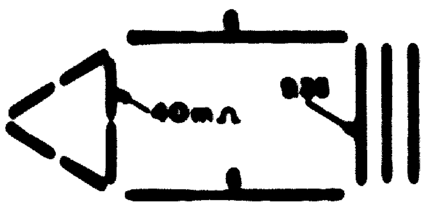
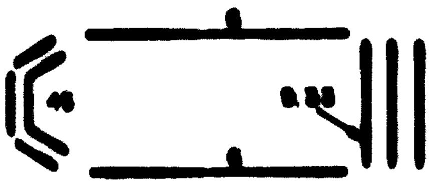
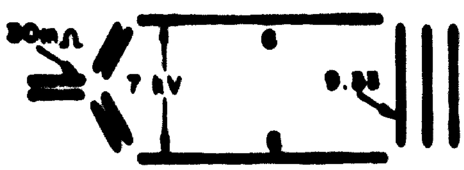
2. Test voltage range.

3. Complexity of the commutation and its cost.

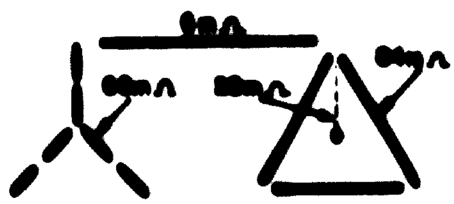
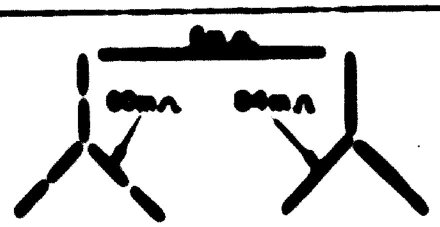
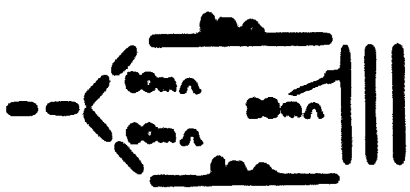
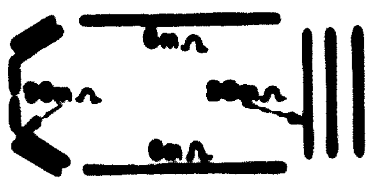
The aim of the analysis is to get highest possible capacities in those ranges of voltages and currents where they are needed with the most simple and economical arrangement.

The test capacities must be limited by generator's parameters only.

C. REVUE OF GENERATOR-TRANSFORMER GROUP CONNECTIONS AND ITS PARAMETERS

No.	Diagram & reactances per phase in mΩ Generator Bus Transformer	Voltage kV	total reactance mΩ	current per phase kA	capacity MVA
1		14.	94	86	2100
2	 Capacity limited by the reactance of transformers.	8.09	54	86	1200
3		8.09	61.33	128	1030
4	 Capacity limited by reactance of generator.	8.09	66.33	122	985
5	 Overexcitation by 15,6% overexcitation, by reactance of generator.	8.09	51.33	158	1270

Capacity limited, in spite of overexcitation, by reactance of generator.

No.	Diagram & reactances per phase in mΩ Generator Bus transformer	Voltage kV	total reactance mΩ	current per phase kA	capacity MVA
6		14	94	86	2100
7	 capacity limited by reactance of transformers.	14	130	54	1300
8	 Current limiting reactance of 3 mΩ to be included.	14	(160) 163	86	1200
9	 Overexcitation by 15,6% Current limiting reactance of 33 mΩ to be included.	14	(130) 163	86	1200

D. COMMENTS TO THE CONNECTIONS

1. The three-phase connections according to Nos 1 and 6 are equivalent as to the voltage and capacity. The fact, that in connection No. 6 the primary winding must be made for $\sqrt{3}$ times higher voltage and lower current will have probably negligible influence on the cost and mechanical rigidity.

2. The connection under No. 2 is the same as No. 1 except for the generator, which is connected in delta. Similar, connection No. 7 is the same as No. 6, except for the transformer which is connected in star.

Both connections, Nos 2 and 7, give on secondary of the transformers a voltage range, which is $\sqrt{3}$ lower compared to Nos 1 and 6. This solution is better than a simple underexcitation of the generator, which would give 700 MVA only in both cases.

Connection No. 7 is better than No. 2, giving a higher capacity. This is due to lower voltage drop in the bus bars.

3. Connections Nos 3 and 4 are eliminated because of lower capacities compared with Nos 5, 8 and 9, and for having no other advantages.

4. Connection No. 9 is eliminated, because, compared to connection No. 8 it gives no additional advantage. On the contrary its important drawbacks are necessity of overexcitation and necessity of much larger current limiting reactance.

5. The only two connections, for single-phase tests, remaining now are Nos 5 and 8.

The advantage of connection No. 5 is 3% more capacity. And this is its only advantage. On the other hand the advantages of No. 8 are the following.

a) The connection No. 8 goes with three-phase connection No. 6. It can be seen that in both connections the two sections of each phase are in series. It is then possible to eliminate the two winding sections, having just one winding in each phase. The generator will have 6 terminals instead of 12. Its cost will be reduced and its reliability increased.

b) If Nos 6 and 8 are selected as the two basic connections for three-phase and single-phase tests, no change-over is made on the generator at all. This makes it possible to eliminate the change-over switch completely. This would not be possible if Nos 1 and 6 were selected as basic connections. This means a further simplification and economy.

c) In case of the connections Nos 1 and 6 the bus bar system must be designed for 14 kV, because of connection No. 1 and for 158 kA, because of No. 5. On the contrary for combination of Nos 6 and 8 the parameters of the bus bar will be 14 kV, 86 kA. The mechanical forces in the latter case are 3,4 times less. The design will be easier and cheaper.

d) For connection No. 5 a 13.6% overexcitation must be used, which means an additional stress of the generator's rotor. This is not the case with connection No. 8.

In conclusion we believe that the 5% higher capacity connected with the connection No. 5 does not compensate many very important advantages of the connection No. 8.

This is why connections Nos 6 and 8, for three-phase and single-phase test are proposed for the operation of the generator-transformer group.

B. TESTING WITH THE GENERATOR ONLY

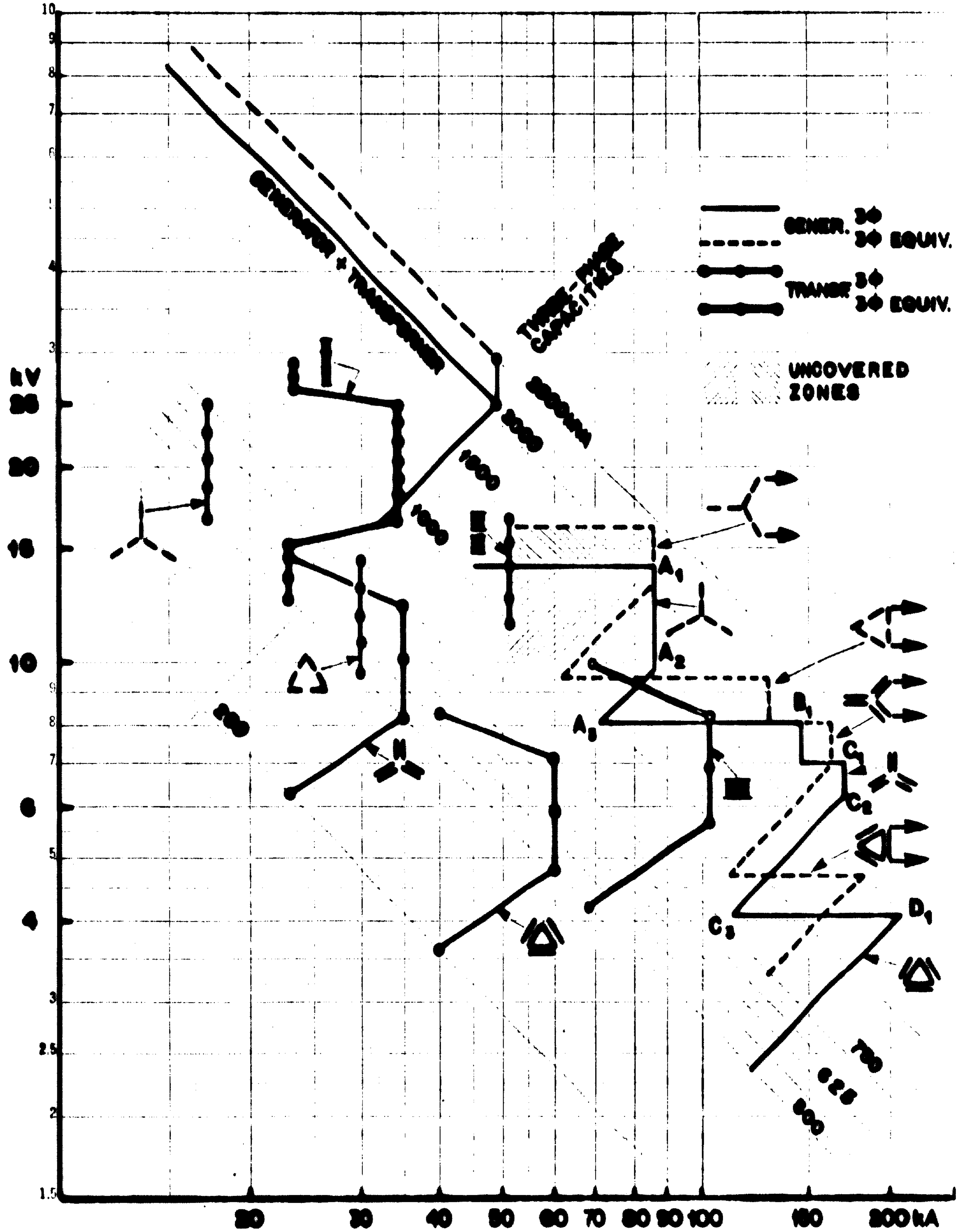
The question which we wish to answer in this part is:
Is it necessary to connect the generator into a special cell for tests with the machine only, and which connections will be used for these tests?

To answer this question we present the diagram in the next page. In this diagram we show the ranges of voltages, currents and test capacities covered by the generator in three-phase connections (full line) and in single-phase connection (broken line).

This will be compared to the ranges covered by other test facilities, namely by 500 MVA transformer group, supplied from 220 kV network and by the same generator, but across the transformers.

In this presentation, full logarithmic paper is used, with voltage on the vertical axes and current on the horizontal axes, the direct lines having positive 45° slope are the lines of the constant impedances, the lines having 45° negative slope being the lines of constant capacity in MVA.

In this diagram, the full line shows the testing capacity available at the test cell in three-phase connection. At points the A_1, B_1 and C_1 the full capacity of the machine is available in series-star,



kV
kA
GENER. 3Φ
3Φ EQUIV.
TRANSF. 3Φ
3Φ EQUIV.
UNCOVERED ZONES
GENERATOR × TRANSFORMER
THREE-PHASE CAPACITIES
3000MVA
2000
1500
1000
A1
A2
A3
B1
C1
C2
C3
D1
750
625
500
10
9
8
7
6
5
4
3
25
20
15
2.5
2
1.5
20
30
40
50
60
70
80
90
100
150
200

series-delta and parallel-star connections respectively. At these points the test current must be limited by additional protection reactance, otherwise the permissible current of the machine would be exceeded. Point D_1 shows the maximum current accessible in parallel-delta connection. In this specific connection the reactance of the bus bars itself is big enough to protect the generator, so that the full power is not excessible.

Looking more closely to the currents and voltages available and comparing these parameters with what will be requested for tests, we may say that:

1. The region $A_1 - A_2 - A_3$, with the generator in series-star connection seems very important. If this testing possibility is available, three-phase tests could be made up to a current of 86 kA at voltages between 9.8 and 14 kV and single-phase with the same current and equivalent voltages up to 16 kV. If, on the other hand, this possibility does not exist, only 52 kA single-phase or 35 kA three-phase (instead of 86 kA) is available in this voltage range from 500 MVA transformers.

It is estimated, that for a few years to come this limitation will be acceptable, but when the second short-circuit generator is added a very big area of generator circuit breakers will be covered by two machines in parallel.

In conclusion, our proposal is not to build the testing facility for direct tests from the generator only, but to leave the door open in order to be able to build one or two cells for such tests at the moment of the addition of the second machine. It is eventually possible to make the construction of the cells at the first stage, without however, installing immediately the whole electrical equipment for such tests.

2. The region of currents and voltages covered by remaining connections of the generator, that means the region limited by the full line B_1 – C_1 - C_2 - C_3 and D_1 seems to be of little importance. The currents of 104 kA are available from the 500 MVA transformers in single-phase connection at voltages between 5,6 and 8,2 kV. Higher currents are not requested in this zone.

It must be born in mind that, in the high-current test zone of the station, much higher currents will be available at voltages up to 1200 V single-phase for dynamic and thermal tests.

It is therefore suggested to eliminate all generator connections except series-star.

This restriction to our connection only falls in line with the recommendation outlined in section D and results in the same advantages as listed there.

F. CONCLUSION

General conclusions drawn from this analysis, taking into account the testing across the transformers as well as from the generator only are:

1. A short-circuit generator in simple star connection will be used.
2. No change-over switch of the winding is requested.
3. The withstand current of the bus bar system between the generator and transformer will be 86 kA R.M.S. and 260 kA peak.
4. One or two test cells for testing at generator voltage will be employed for the future but will not be equipped at the beginning.

APPENDIX 3

Choice of parameters for the short-circuit generator of the High Power Station

This Appendice No. 3 presents a short analysis of the short-circuit generator to be used as the power source for the High Power Station of the Electrical Industry Testing and Experimentation Centre.

The choice of parameters is based on this analysis taking into account the objectives of the project.

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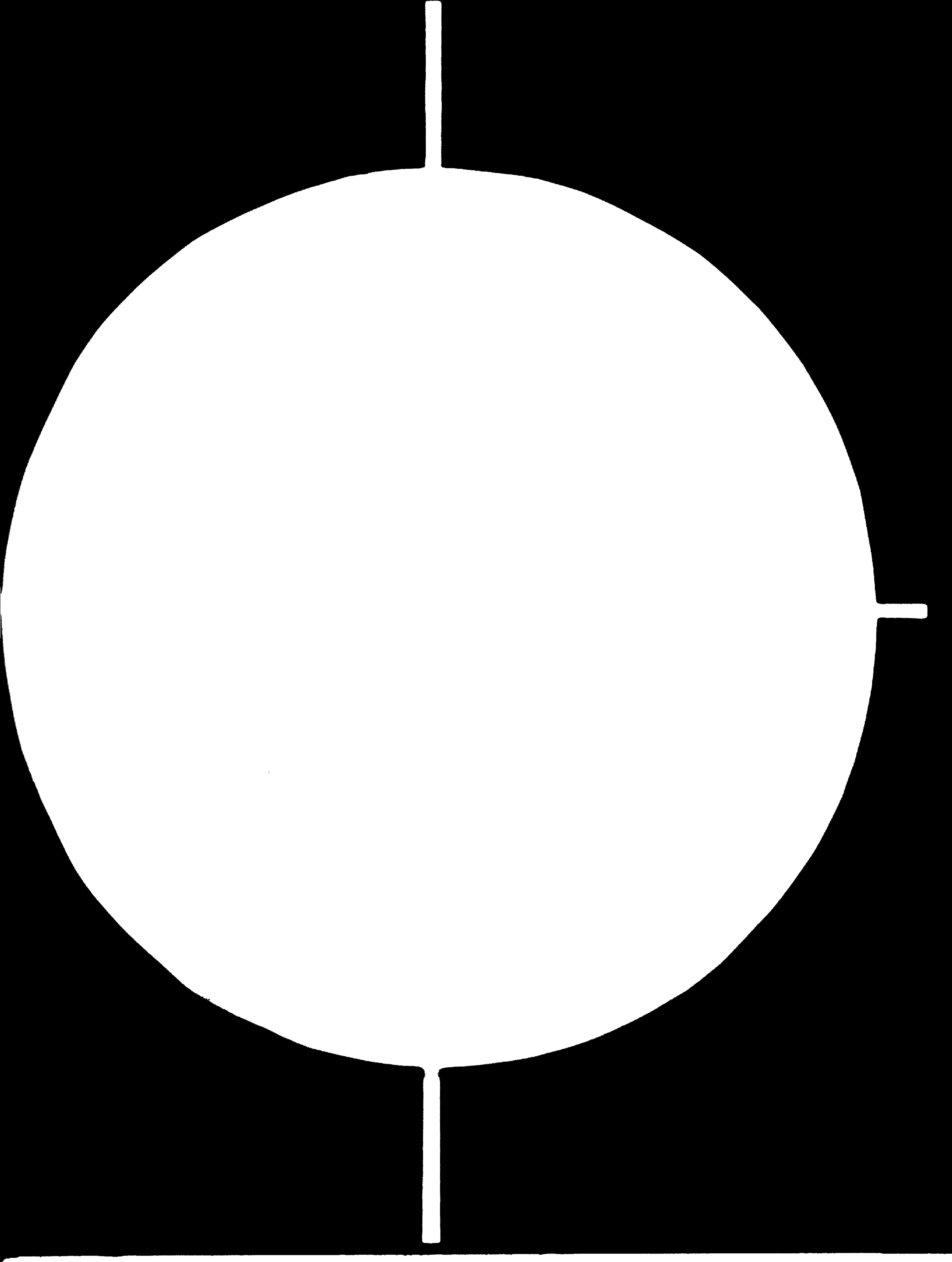

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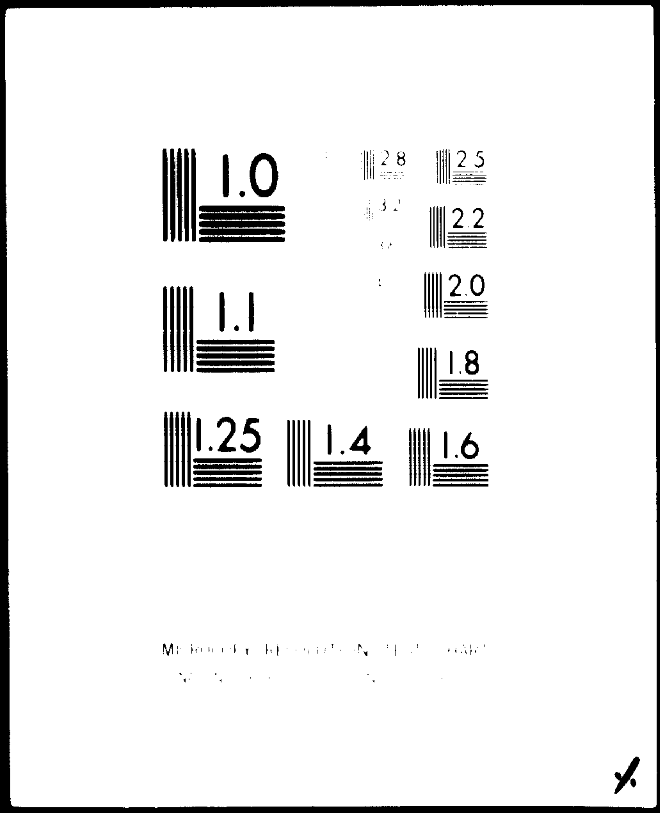

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	Damper winding	5
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Figure 1 EXCITATION SYSTEM WITH DC MACHINES 8

1. GENERAL

In the TEST AND EXPERIMENTATION CENTRE project in Madrid, Spain, an independent power source has been foreseen for feeding the High Power Station. The required power, around 4000-5000 MVA will be used both for direct testing and as a current source for synthetic testing. This power has to be supplied by alternators specially designed for developing large short circuits.

2. DEFINITION OF SHORT-CIRCUIT POWER

Since there is no universal definition of short-circuit power, the power flowing at the beginning of a short circuit is often used as a reference power. This definition is not satisfactory, however, for it does not give the power available in the test cell.

Our document on short-circuit generators is based on a definition of short-circuit power as the power available in the test cell, taking into account the impedance of transformers and bus bars over a period of 150-200 ms following the initiation of the short-circuit.

This power must be as steady as possible during short circuits to allow standard tests to be performed.

3. SHORT-CIRCUIT GENERATOR CHARACTERISTICS

To meet all the above requirements, these generators must be designed quite differently from standard generators. The following characteristics are required:

- To create large short-circuit currents, the short-circuit reactance must be reduced to a minimum. This implies a generous dimensioning of the magnetic circuit and a special rotor winding.

- A damper winding is added in the rotor to compensate for armature reaction. The winding is effective only at the very beginning of the short circuit but it does also tend to reduce the rate-of-rise of the recovery voltage. This consideration is valid for 3-phase short circuits. In the case of asymmetrical short circuits (single-phase or two-phase), which constitute the majority of tests, the damper winding helps to reduce the inverse magnetic field and, consequently, will provide a better shape for the short-circuit current and will reduce heating in the generator. In conclusion, the influence of the damper winding is questionable and while some manufacturers avoid it, most of them in fact use it.

- One of the most important requirements is to keep the short-circuit current steady but this is impossible using the damper winding. In order to compensate for the armature reaction, the excitation current needs to be increased 10 to 15 times compared with the rated current. A solution to the problem is to use an external source consisting of rotating machines or static rectifiers (diodes, thyristors etc...) and capable of supporting considerable overcharges during short circuits. The major difficulty involved is how to apply a very large direct current and cut it instantaneously.

4. CHOICE OF PARAMETERS FOR THE UNIDO PROJECT IN SPAIN

Short-circuit power

Power requirements have been based on the Centre's test program. Single-phase power (see section 2) should be 2500-3000 MVA to allow for the unit testing of 110-220-420 kV circuit breakers. Three-phase power in this case is 4200-5000 MVA. A study of existing generators reveals that a unit power (three-phase) of 2000-2200 MVA offers a better solution that is justified both technically and economically. The purchase of one generator is envisaged initially though provisions will be made for future extension.

Voltage

Since it is considered that the voltage of a generator with this short-circuit power needs to be higher, we have chosen 14 kV as the reference voltage with the possibility of 10% overexcitation above rated voltage. Power increases in proportion to the increase in voltage. The whole project is based on this voltage. The additional reactances, bus bars and transformers are estimated to be 30 mΩ, in accordance with the requirements of the specification.

Damper winding

We consider that manufacturers have all the information they need to evaluate the advantages and disadvantages of this winding and it is therefore for them to decide whether or not to use it.

Excitation system

The standard excitation system using rotating machines has provided satisfactory results, as can be seen from the example in Figure 1. The asynchronous motor (1) supplied by the system drives the dc generator (2). This generator supplies the dc motor (3) with a fluctuating voltage, which enables the speed of group 3-4 to be regulated. The ac generator (4) feeds the motor (5) with a variable frequency and this in turn drives the main generator (6). When the short circuit is produced, the dc generators (2) and (3) are short-circuited through the magnetizing coil of the main generator (6) and produce the required super-excitation. At the time of the short circuit, all the generators are driven by their rotating inertia.

The advantages of this system are as follows:

a) Reliable service due to long use and sophistication of the system.

b) Possibility of verying the generator frequency without further investment.

The disadventages are the following:

a) The presence of large generators creates problems in the system due to the large dc current (>20 kA) particularly during de-excitation.

b) The large machine time constants limit the possibilities of improving the system (controlling the dc current for example).

c) The cost of dc machines is very high. In the case of a 2100 MVA generator, the equipment would cost between $750,000 and $800,000 (excluding the generator). The cost can be reduced substantially if diodes are used for excitation but this solution involves technical disadvantages particularly with regard to instantaneous breaking of the current when de-excitation takes place.

In light of these disadvantages, it was decided to use the thyristor system (see the proposed diagram in drawing 1005).

The driving motor is fed by the system in the case of service at 50 Hz; in the case of 60 Hz, it is driven by the generator (3). This generator is designed both for normal excitation and superexcitation controlled by the thyristor bridges. A this generator represents an independent source of power, it is possible to avoid harmonics in the supply system.

This system offers the following possibilities:-

- excitation before the short circuit occurs and automatic regulation of the voltage to the required level.
- rapid passage from rated excitation current to super-excitation current.
- control of the dc current by applying an electronic circuit to the gates of the thyristors.
- extremely rapid de-excitation due to the reversibility of the thyristors.

This excitation method is used widely in all modern standard generators; in the case of short-circuit generators, however, the overexcitation factor has to be further increased.

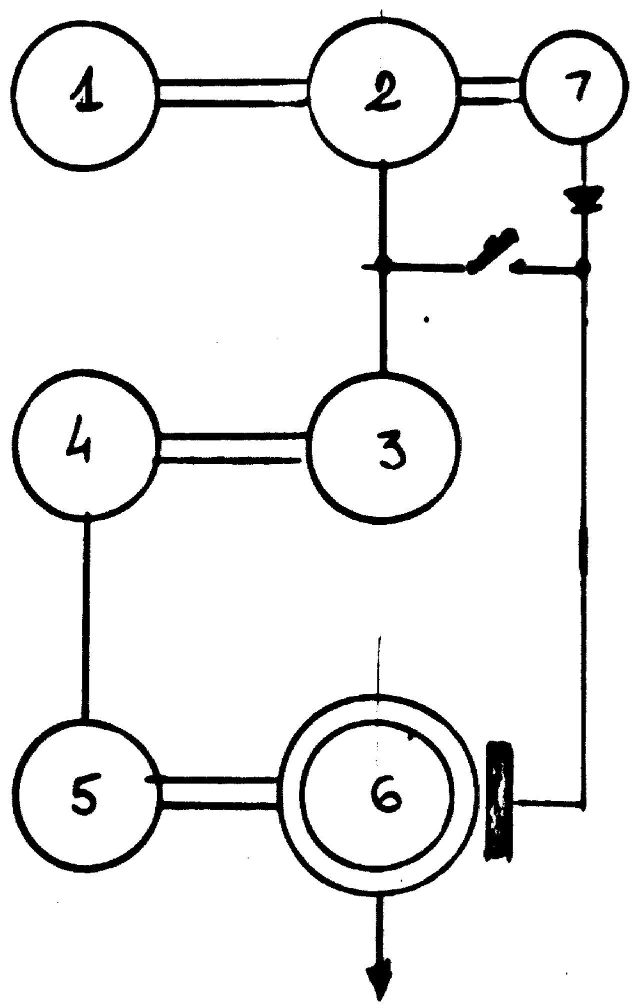
Cooling of the generator

The system of cooling choosen for this project is the open-circuit type. The decision in favor of this system was basedon the fact that the ambient humidity at the Centre is relatively low and cannot harmfully affect the machine's insulation.

EXCITATION SYSTEM

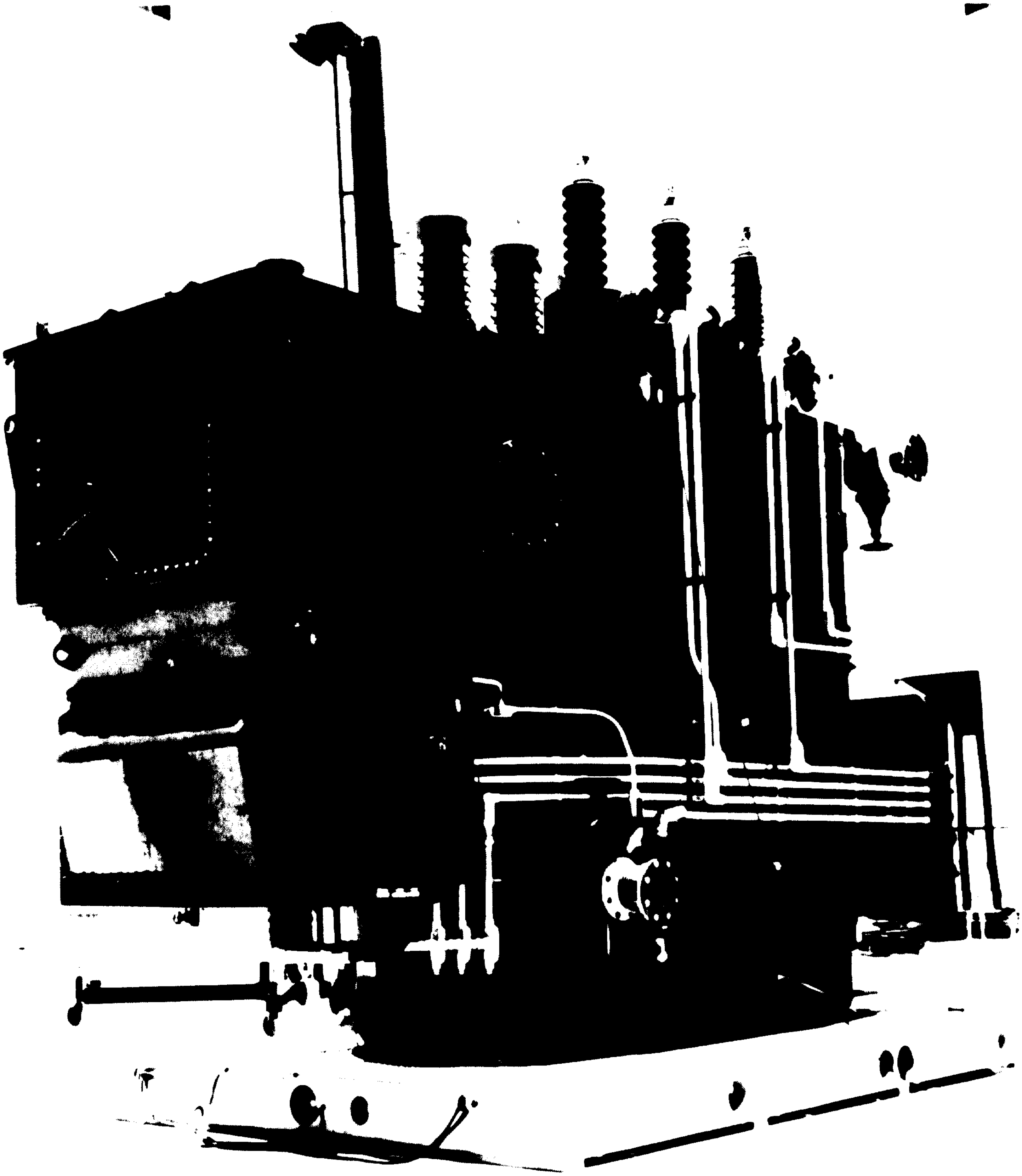
WITH DC MACHINES

Figure 1



1. asynchronous motor
2. dc generator
3. dc motor
4. ac variable - frequency generator
5. asynchronous motor
6. main dc generator
7. normal exciter set

PHOTOGRAPHIC REPRODUCTIONS



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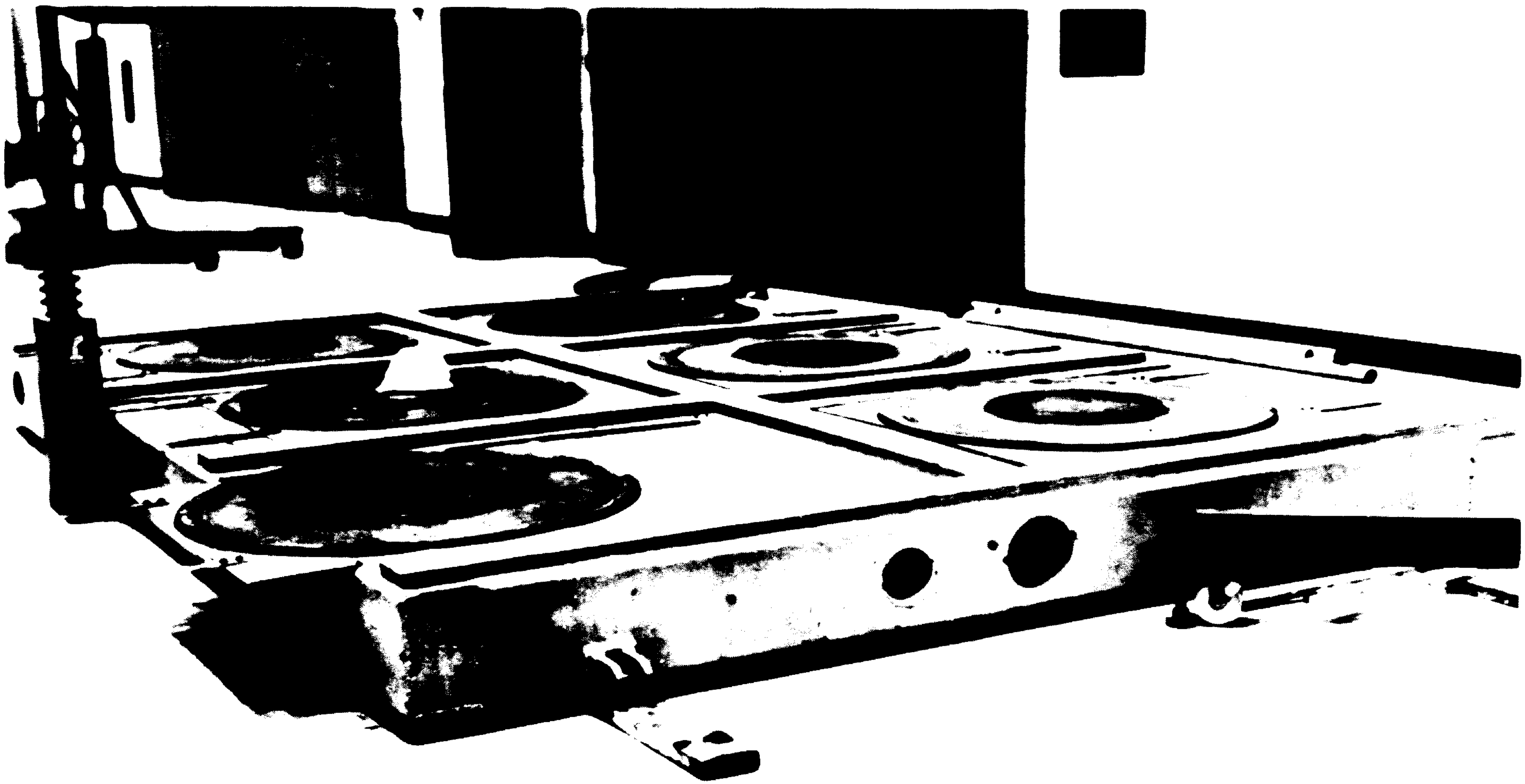

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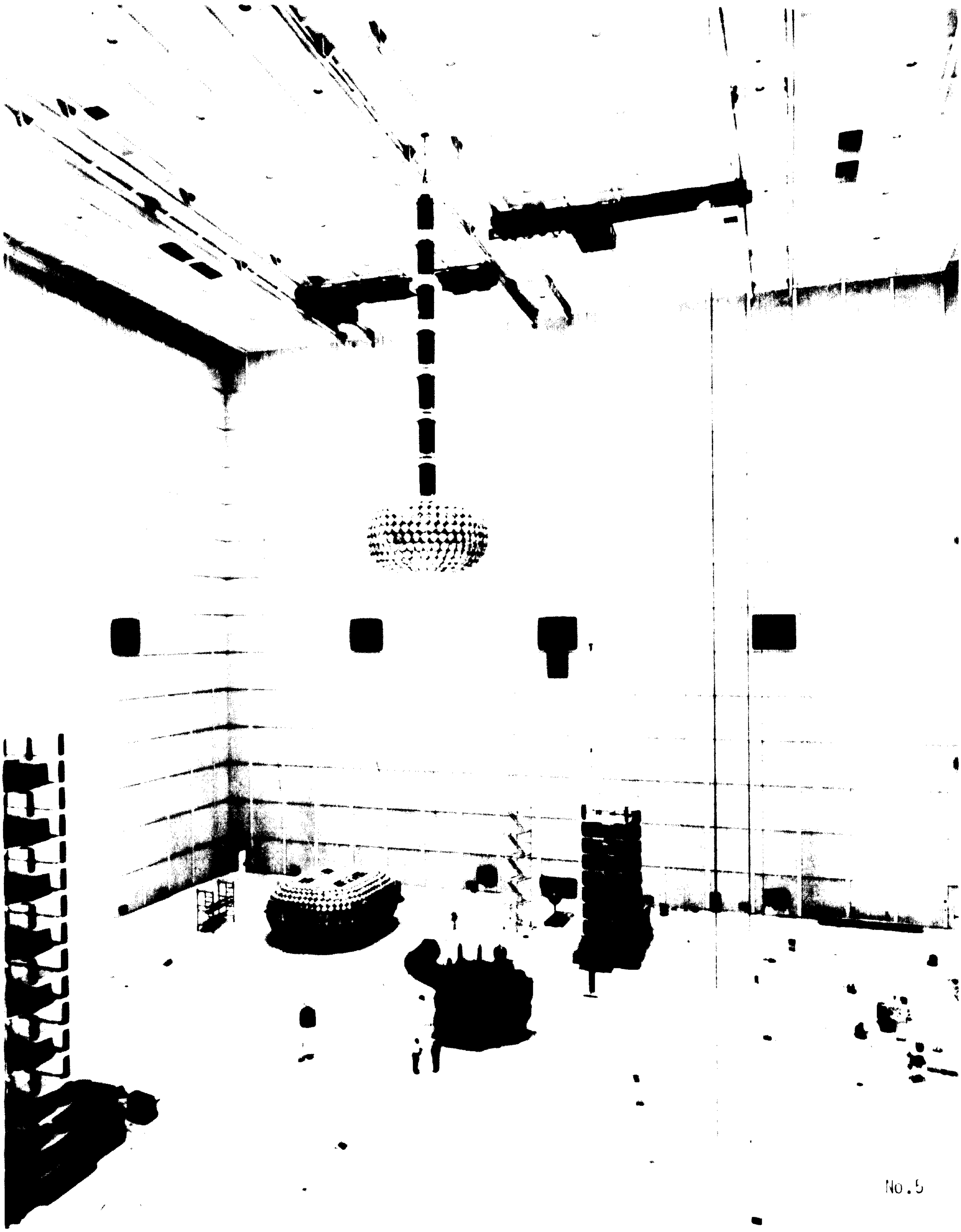

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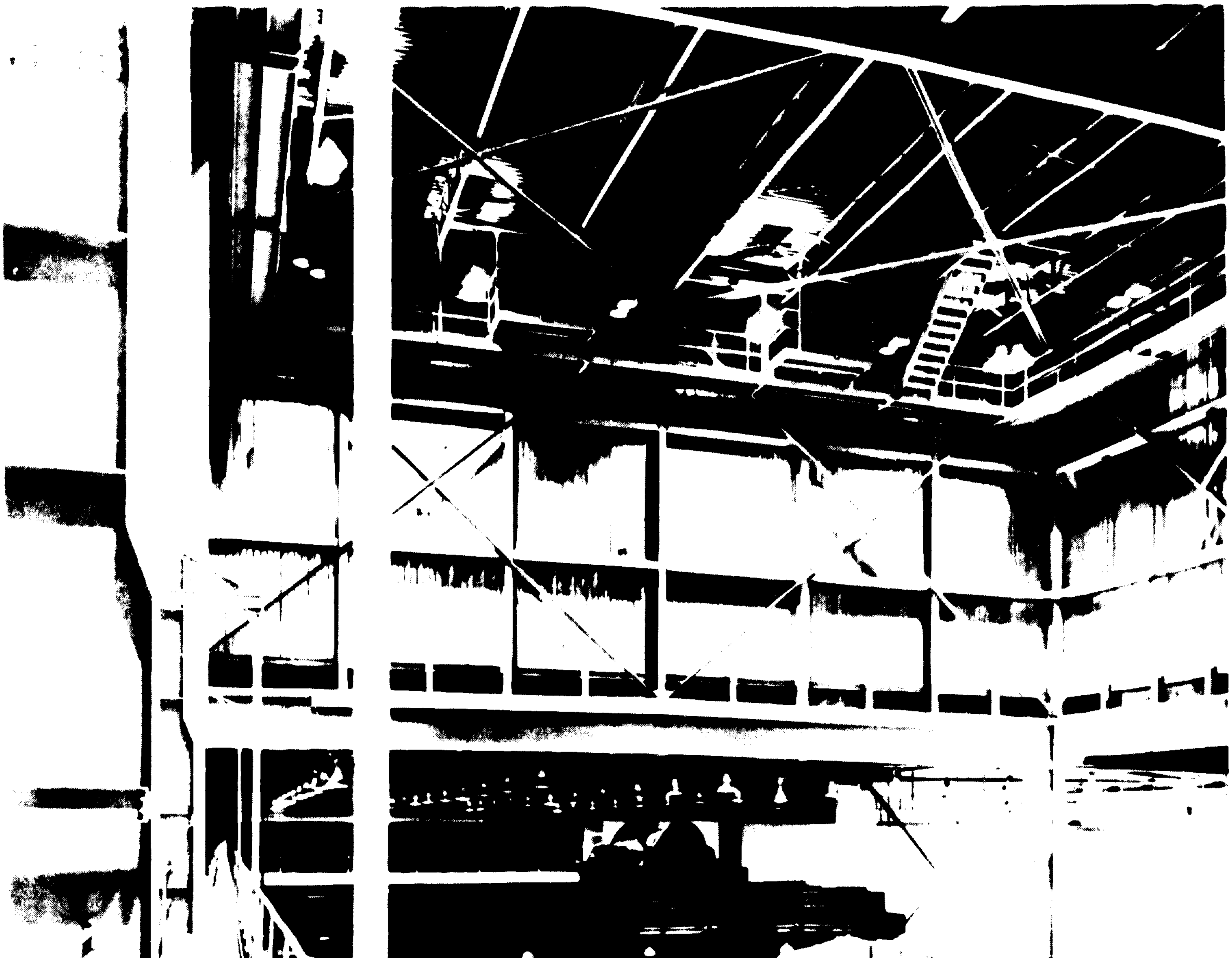
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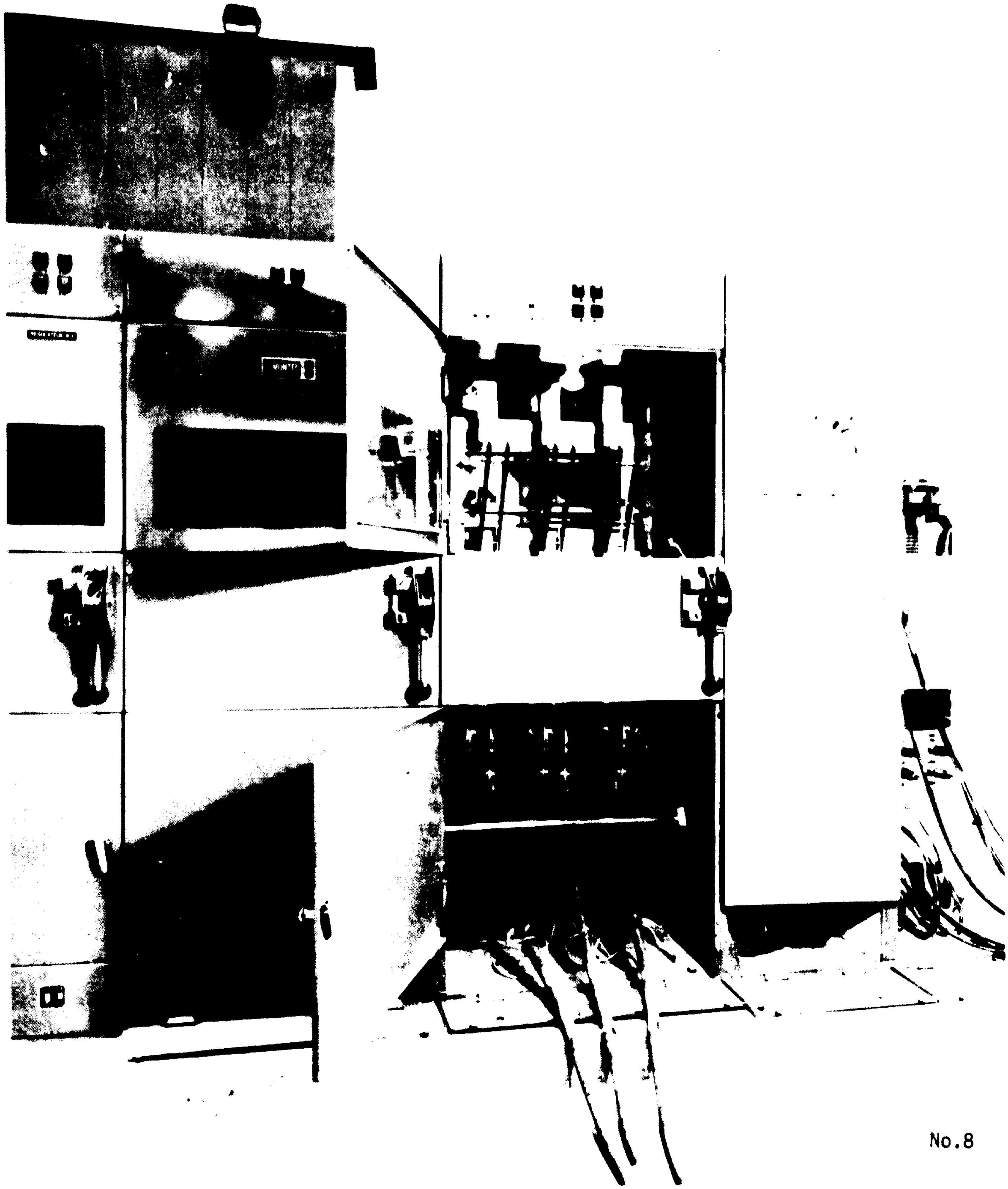

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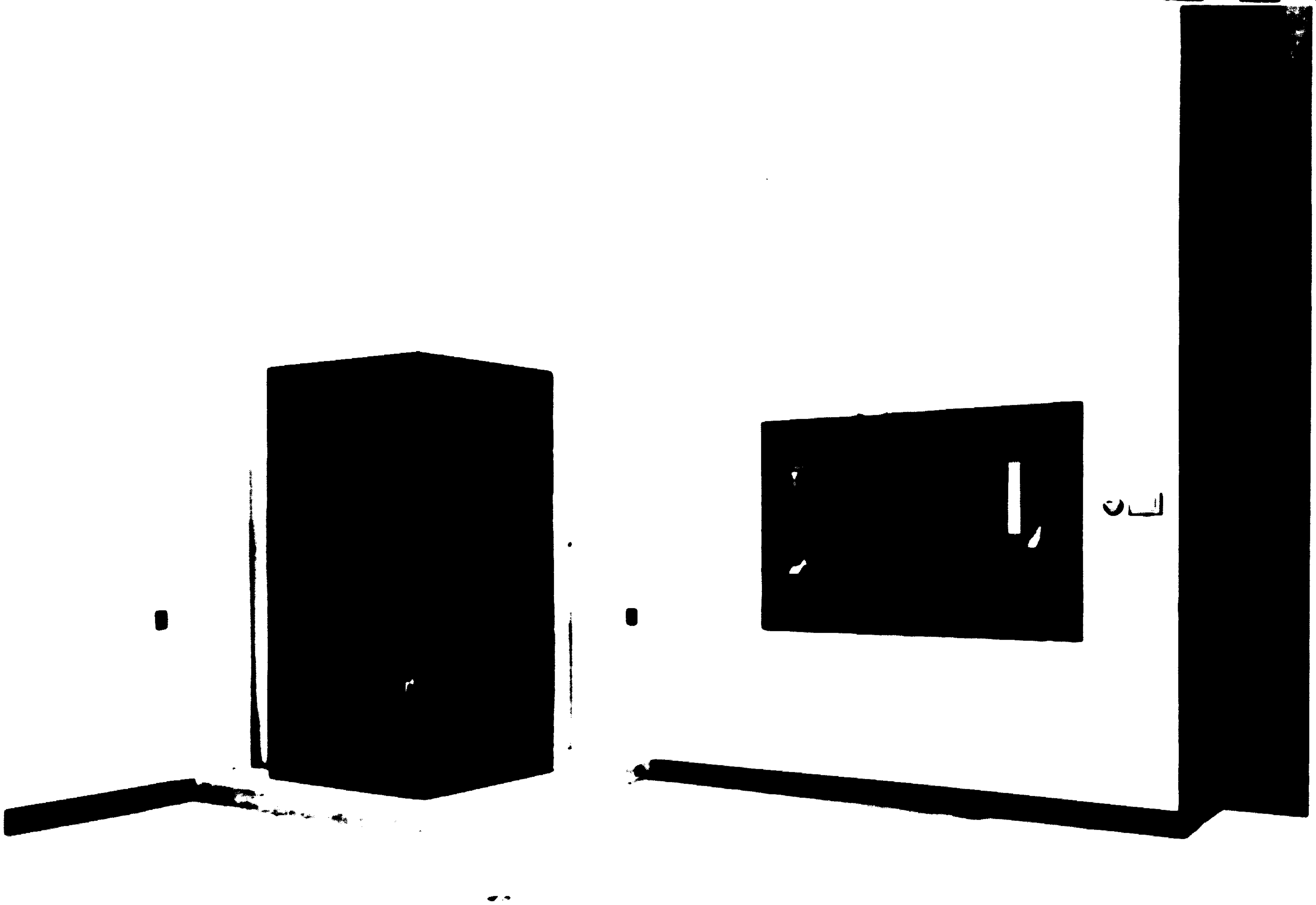

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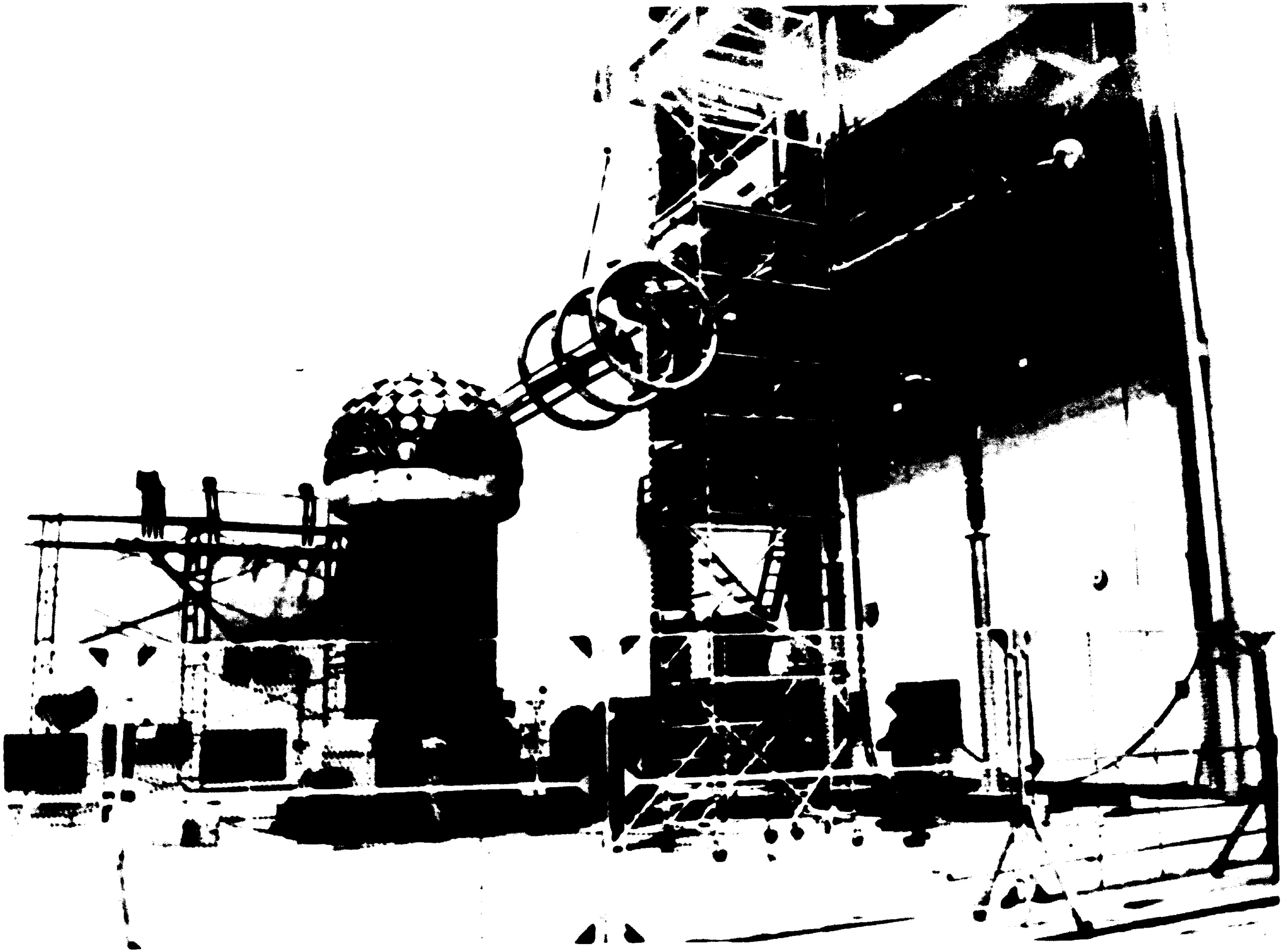

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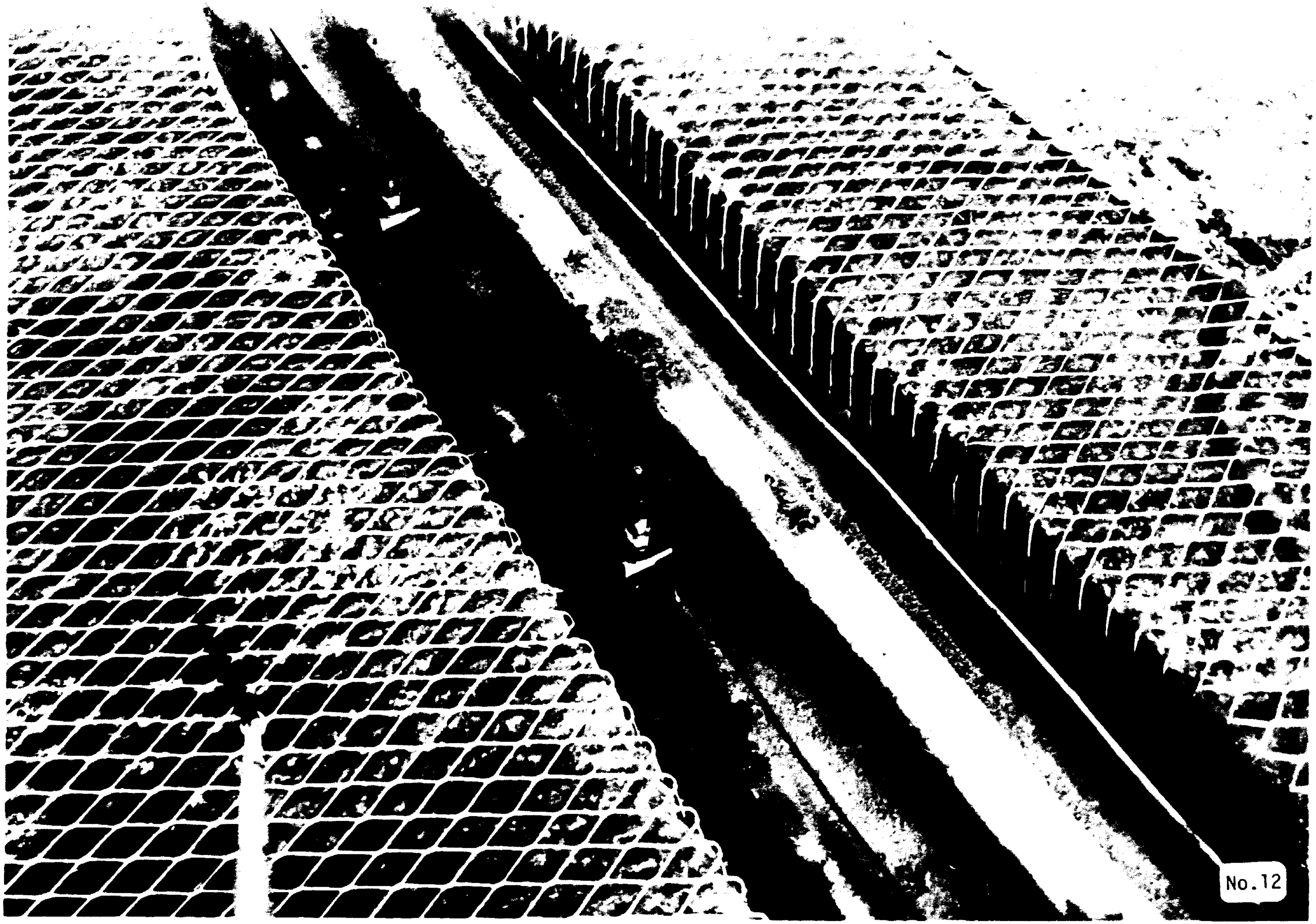
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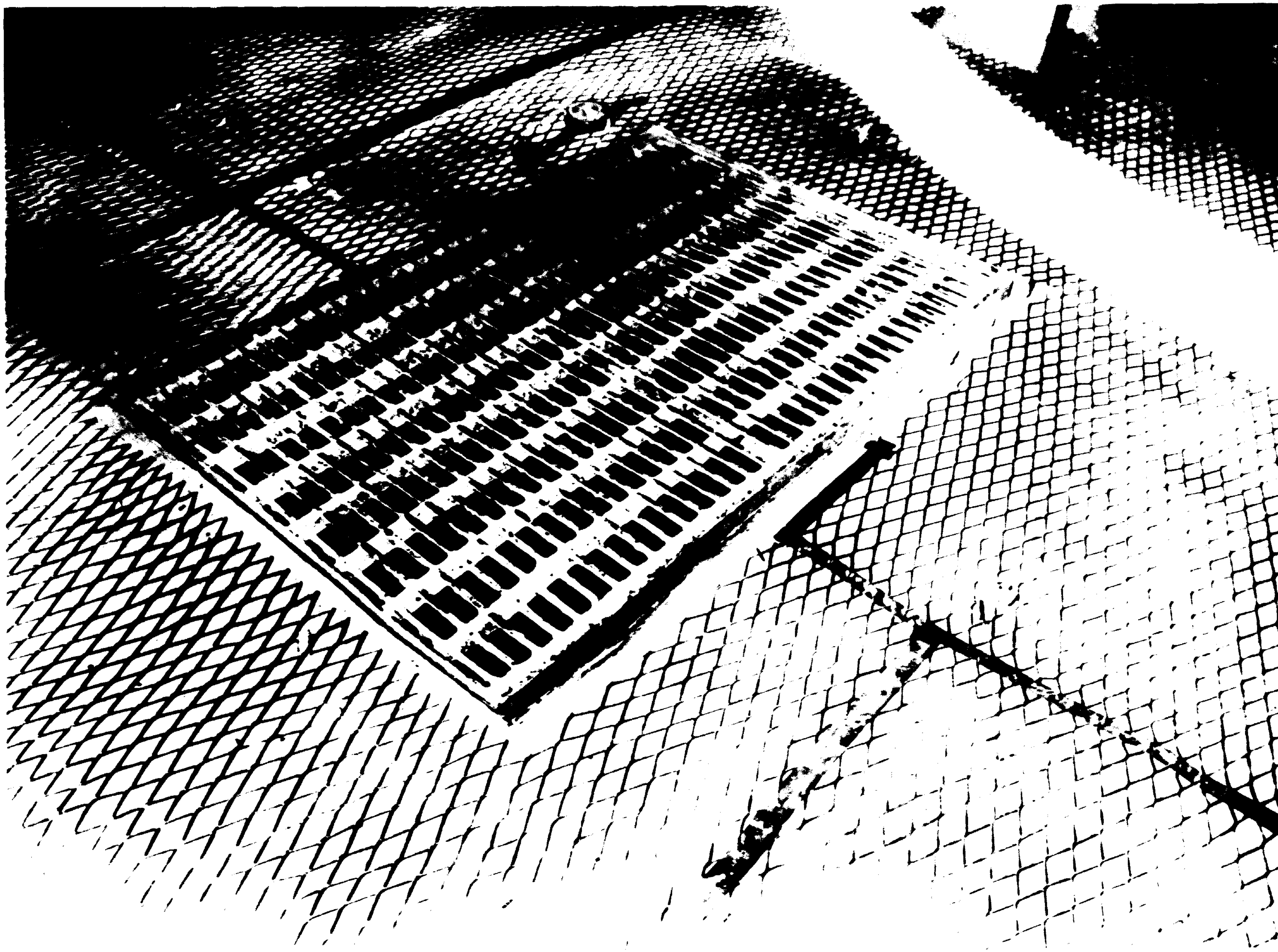

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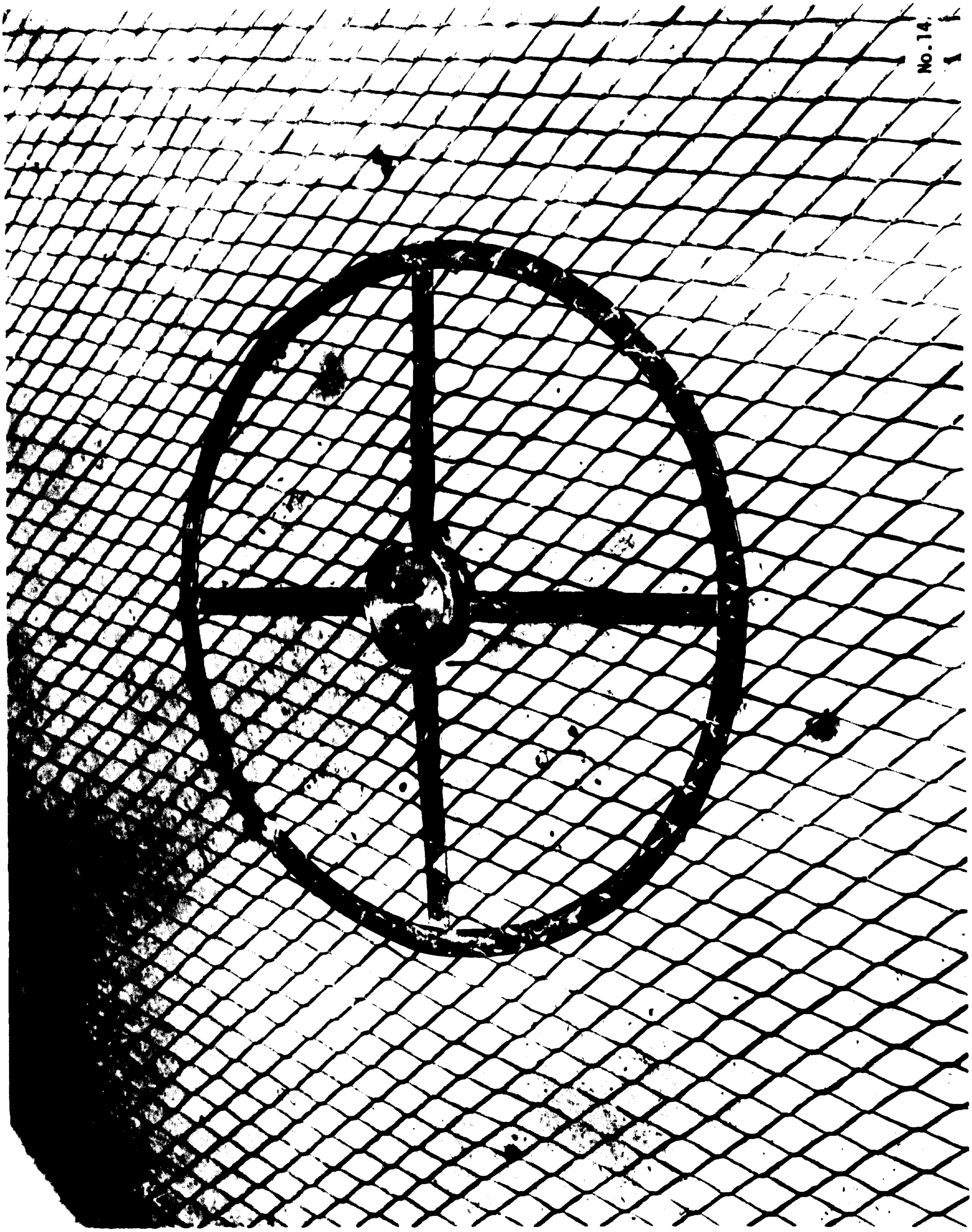
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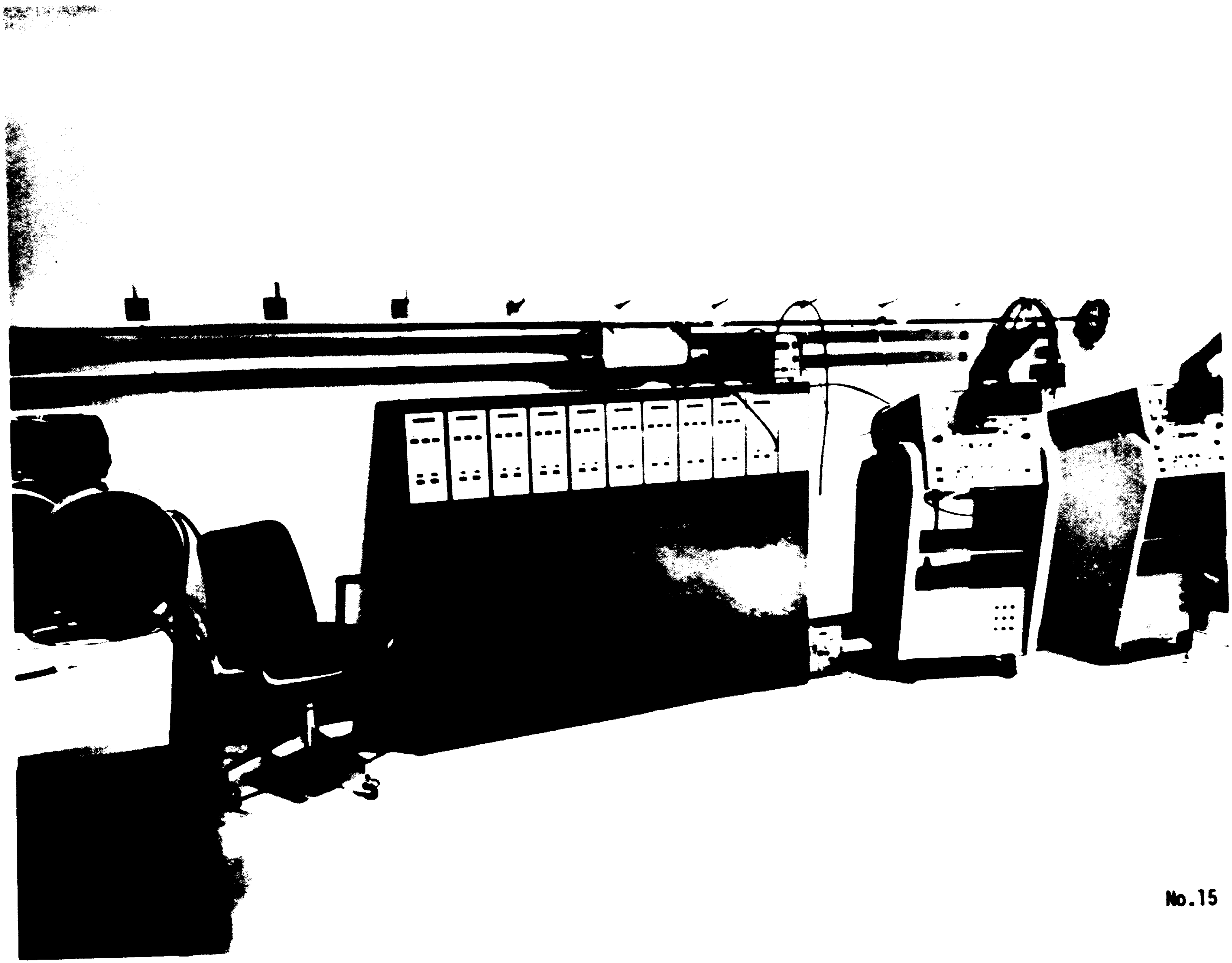

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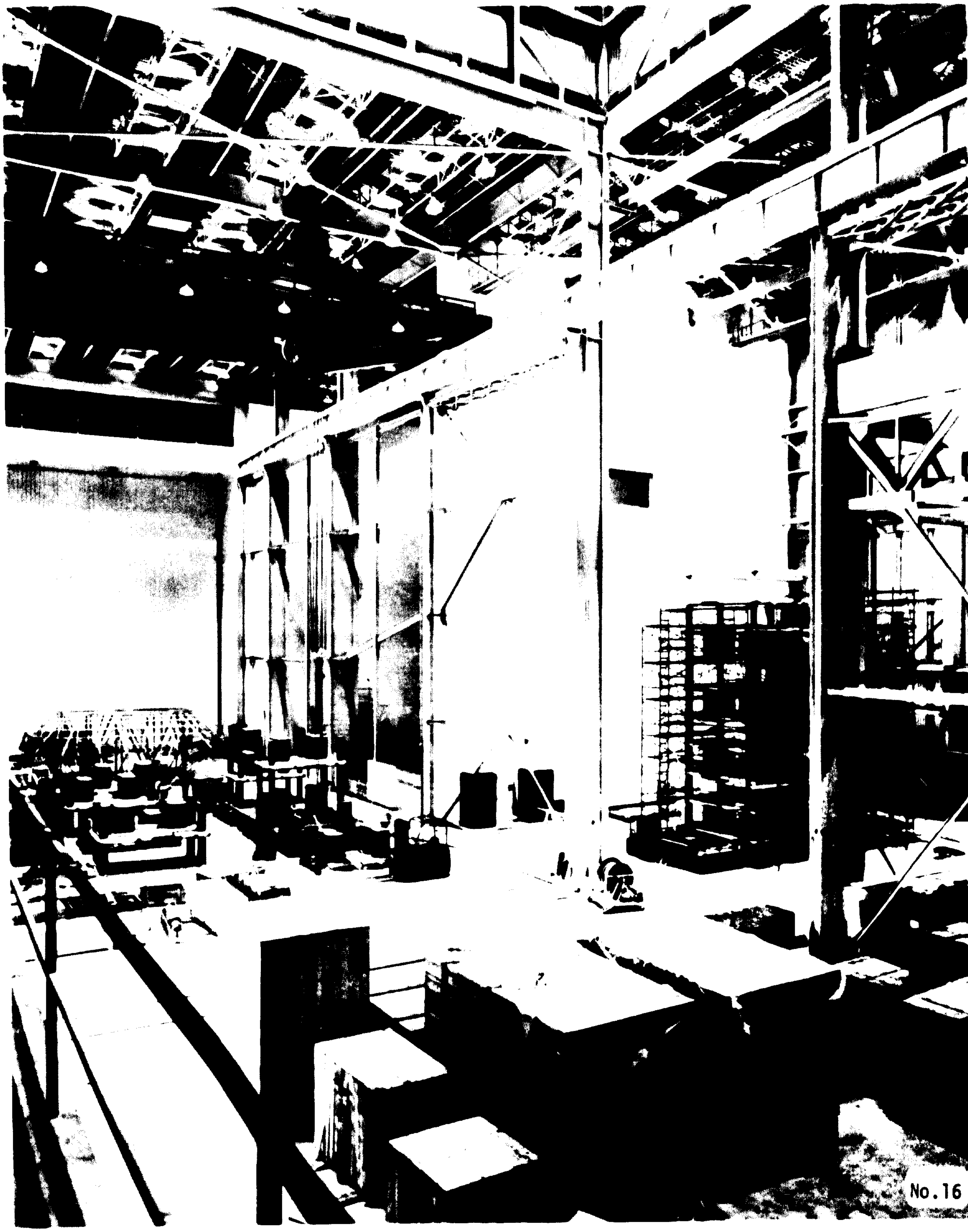
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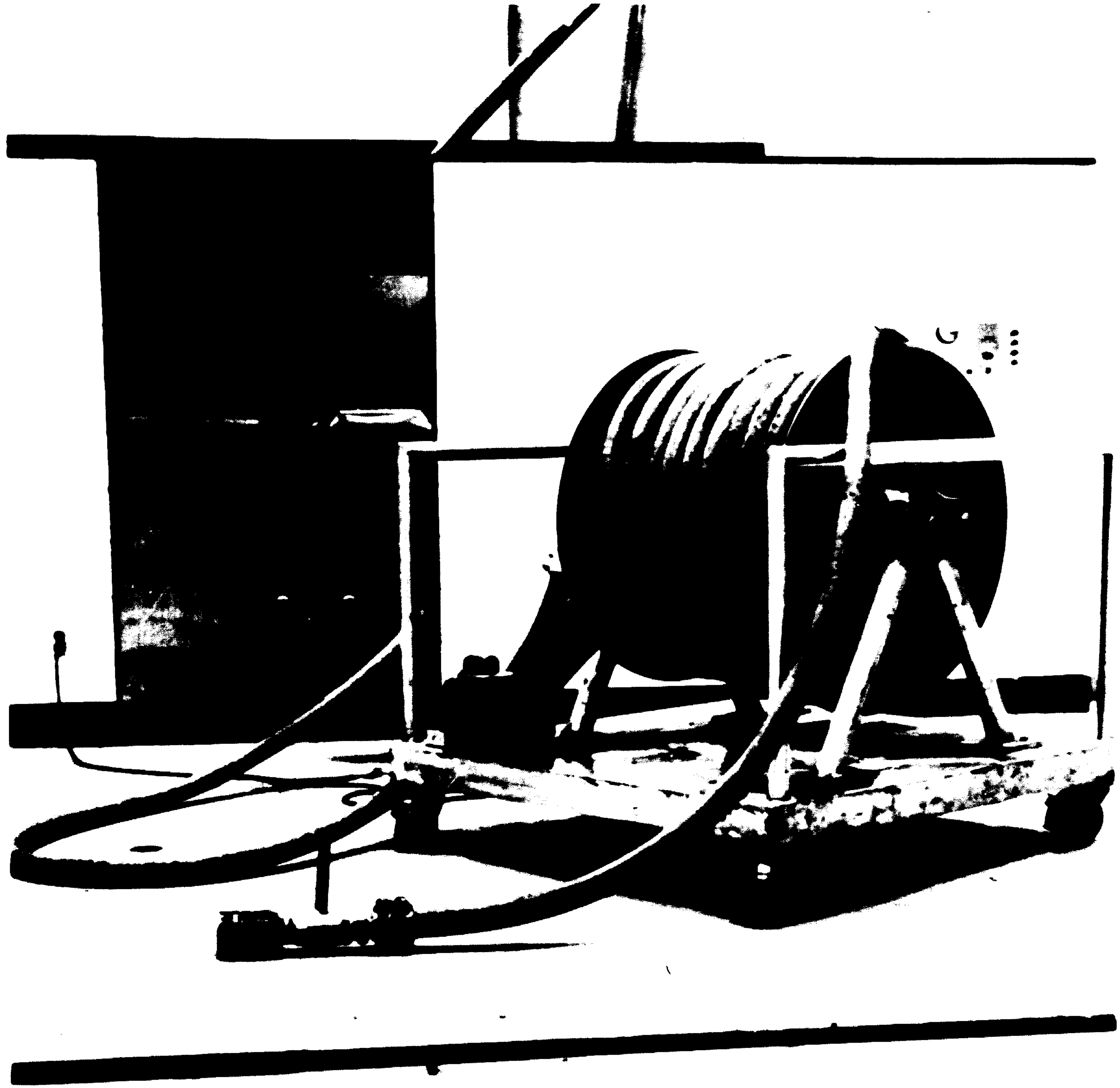

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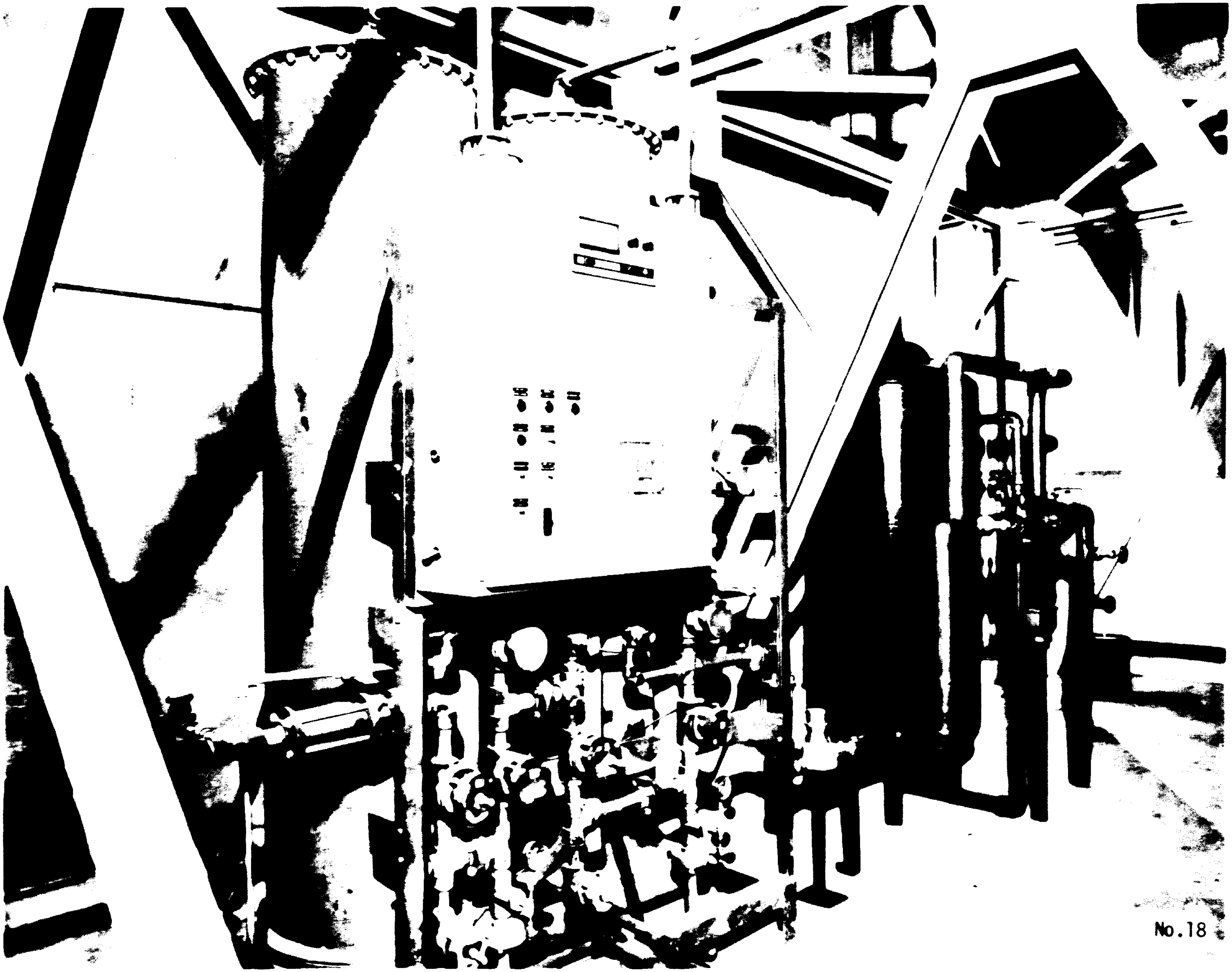
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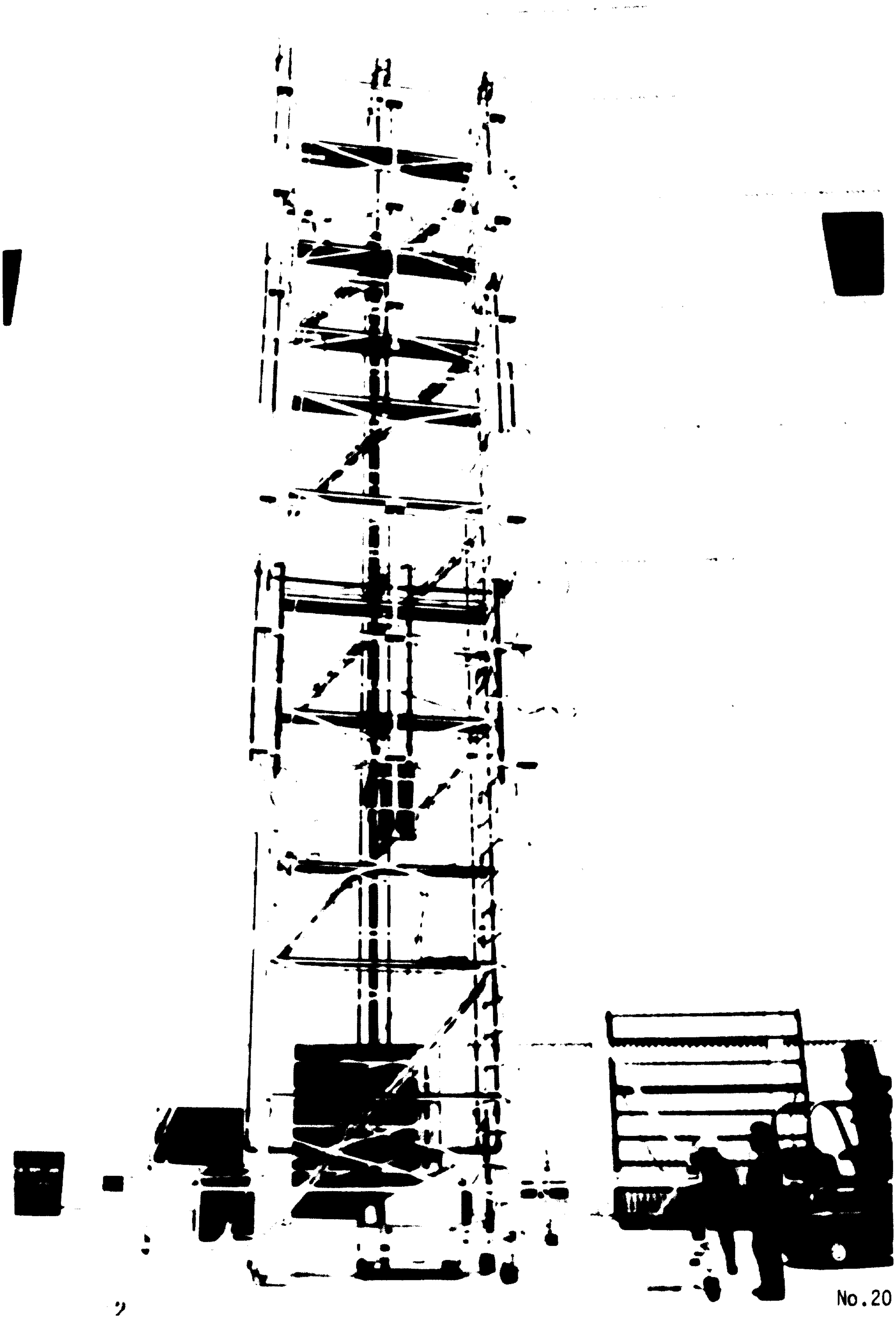

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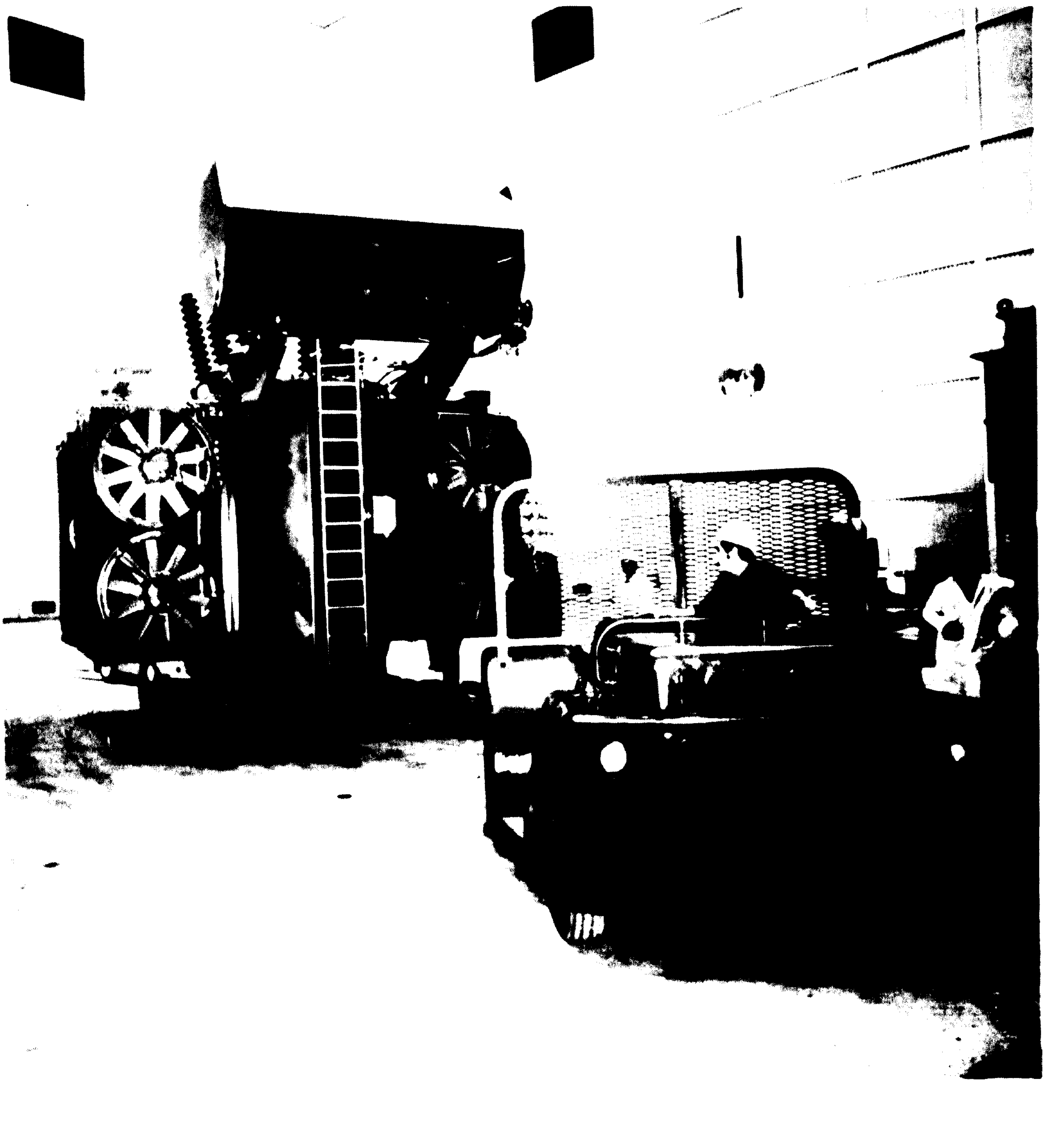
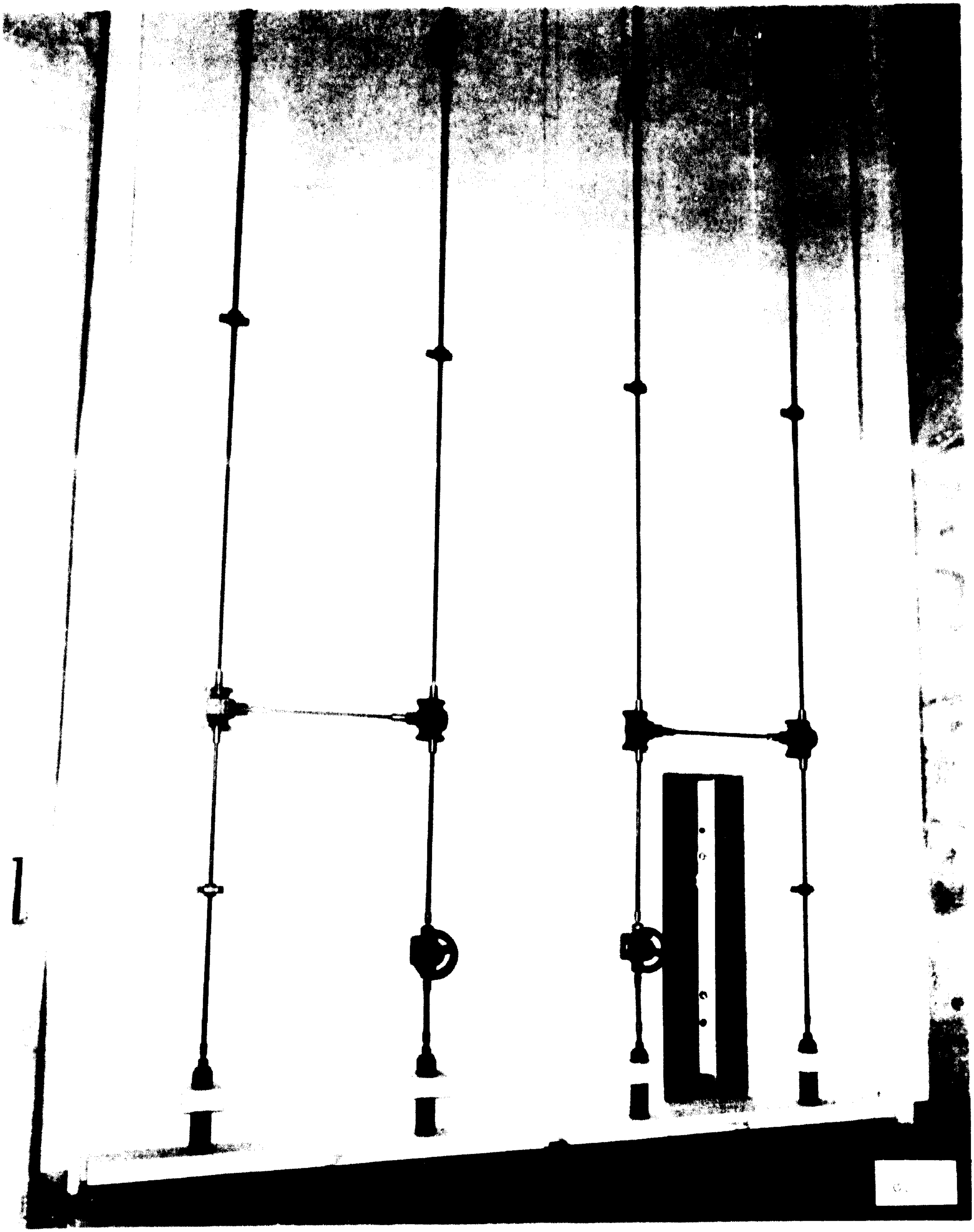


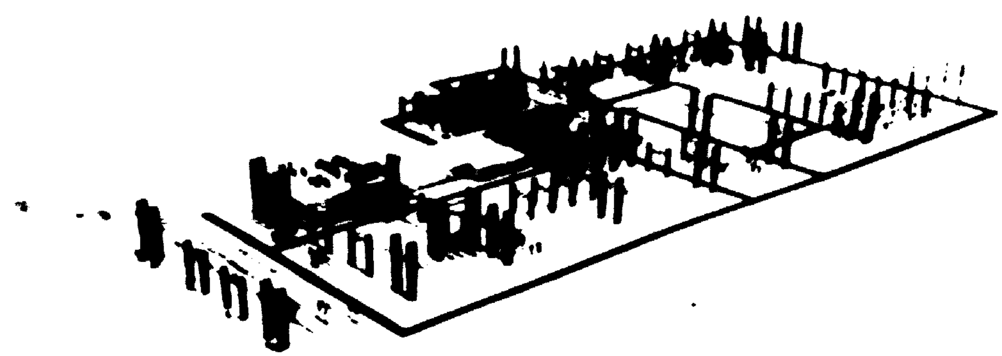


BUILDING REPORT

HIGH VOLTAGE AND HIGH POWER LABORATORIES

MADRID - SPAIN

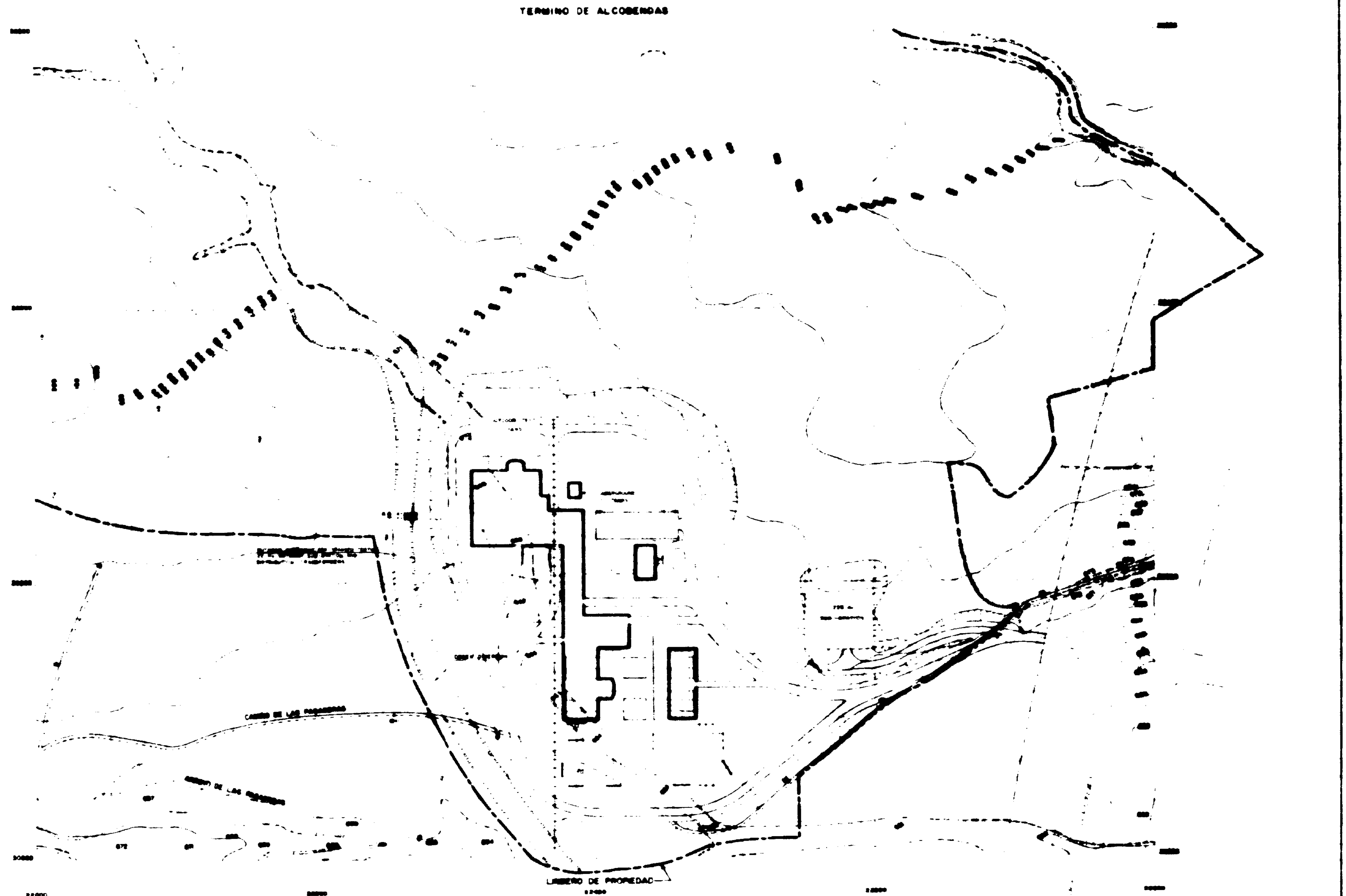
UNIDO CONTRACT 72/47



L'ALONDE GIROUARD LETENDRE & ASSOCIATES LTD

in association with

IREQ

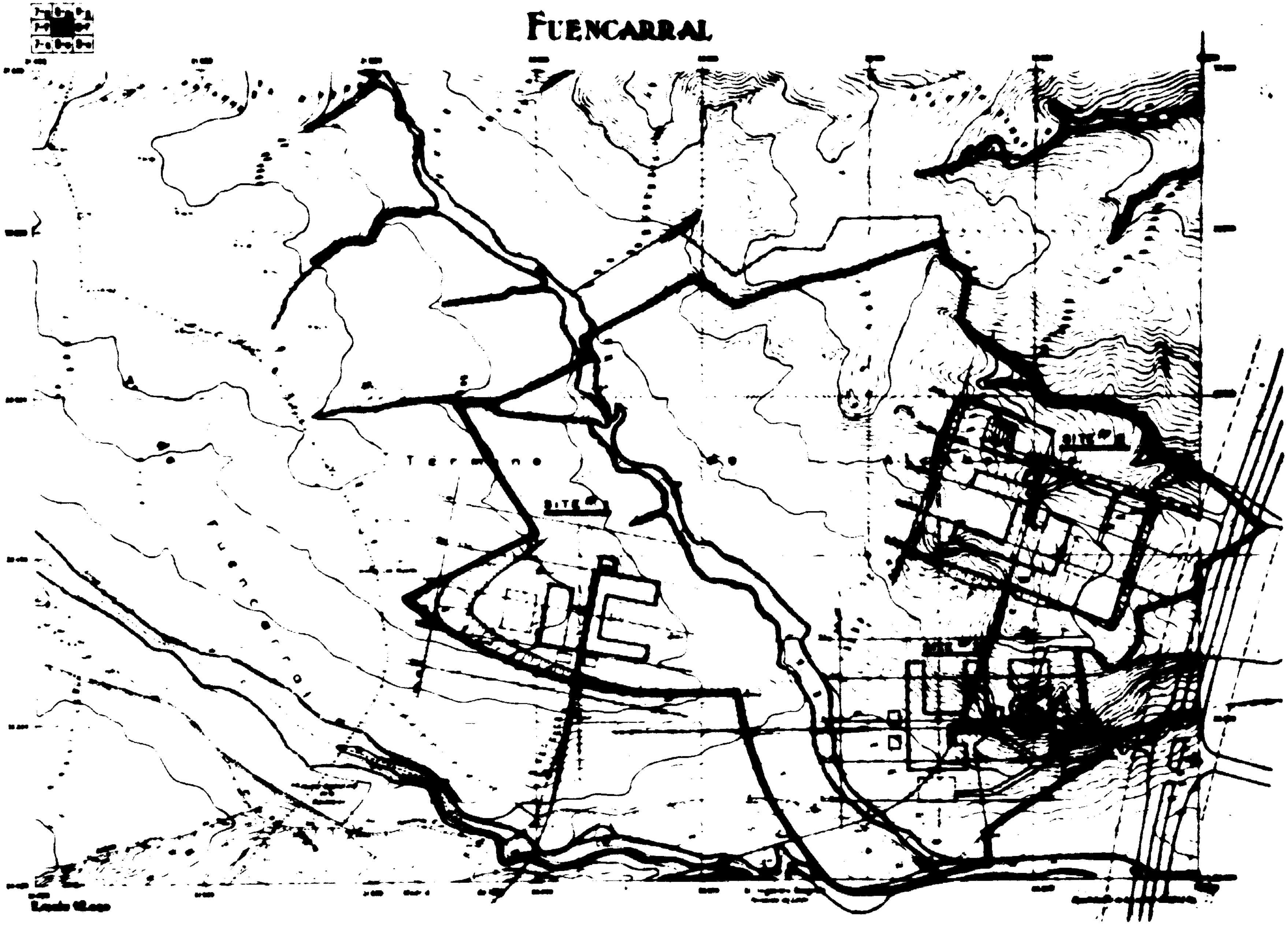


ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

SITE PLAN

412

001

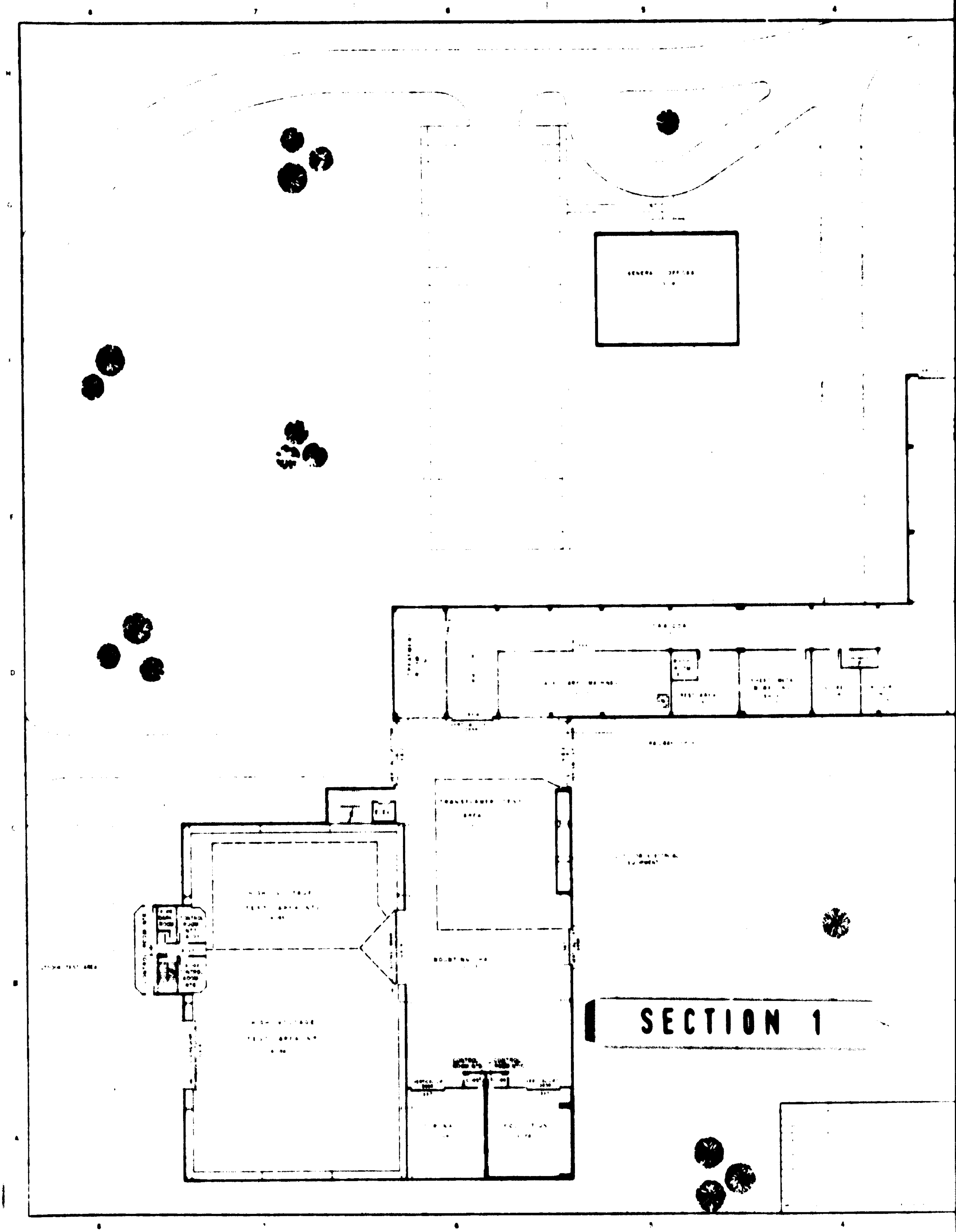


ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

STUDY OF POSSIBLE LABORATORIES LOCATION
ON TOPOGRAPHIC PLAN

412

002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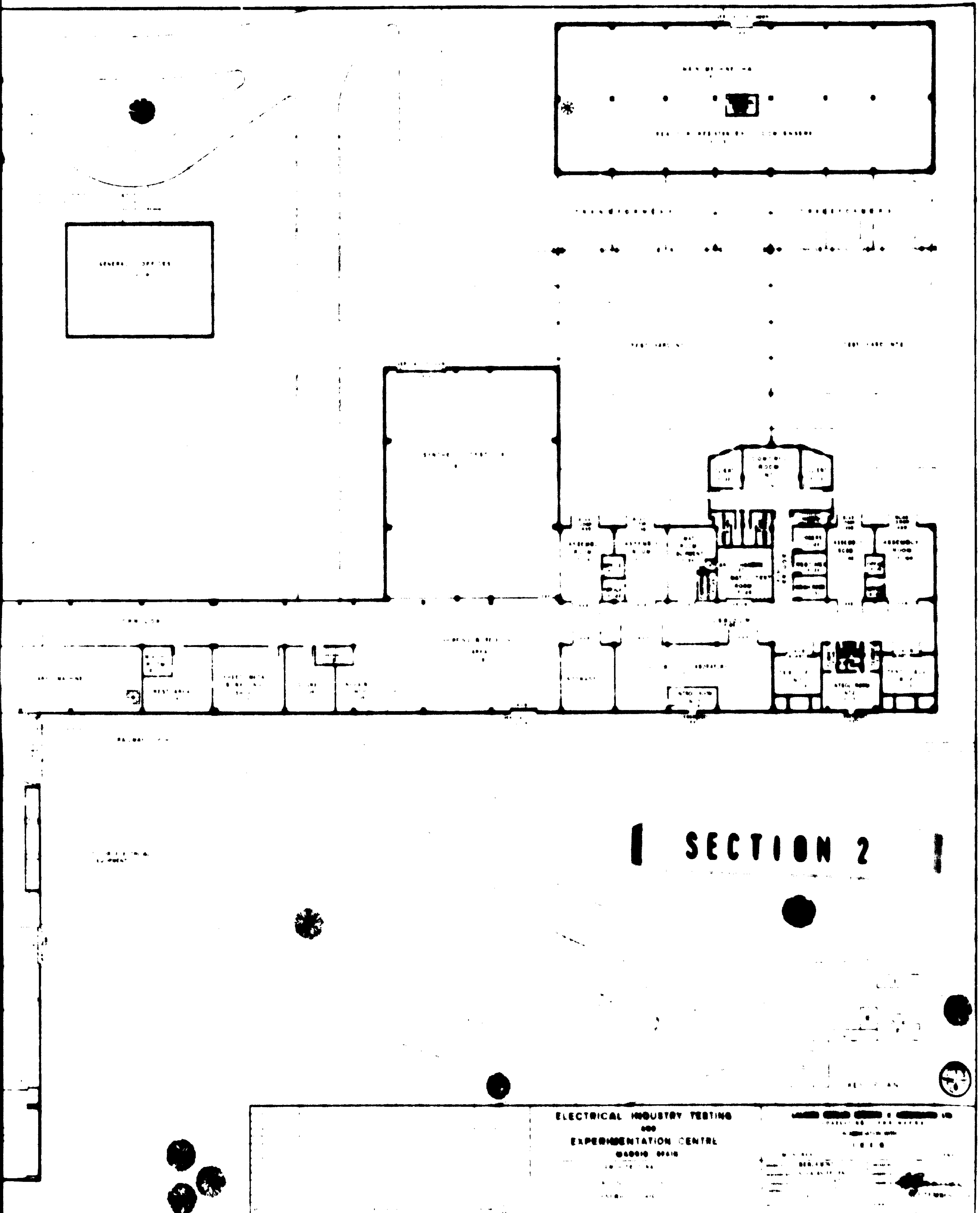
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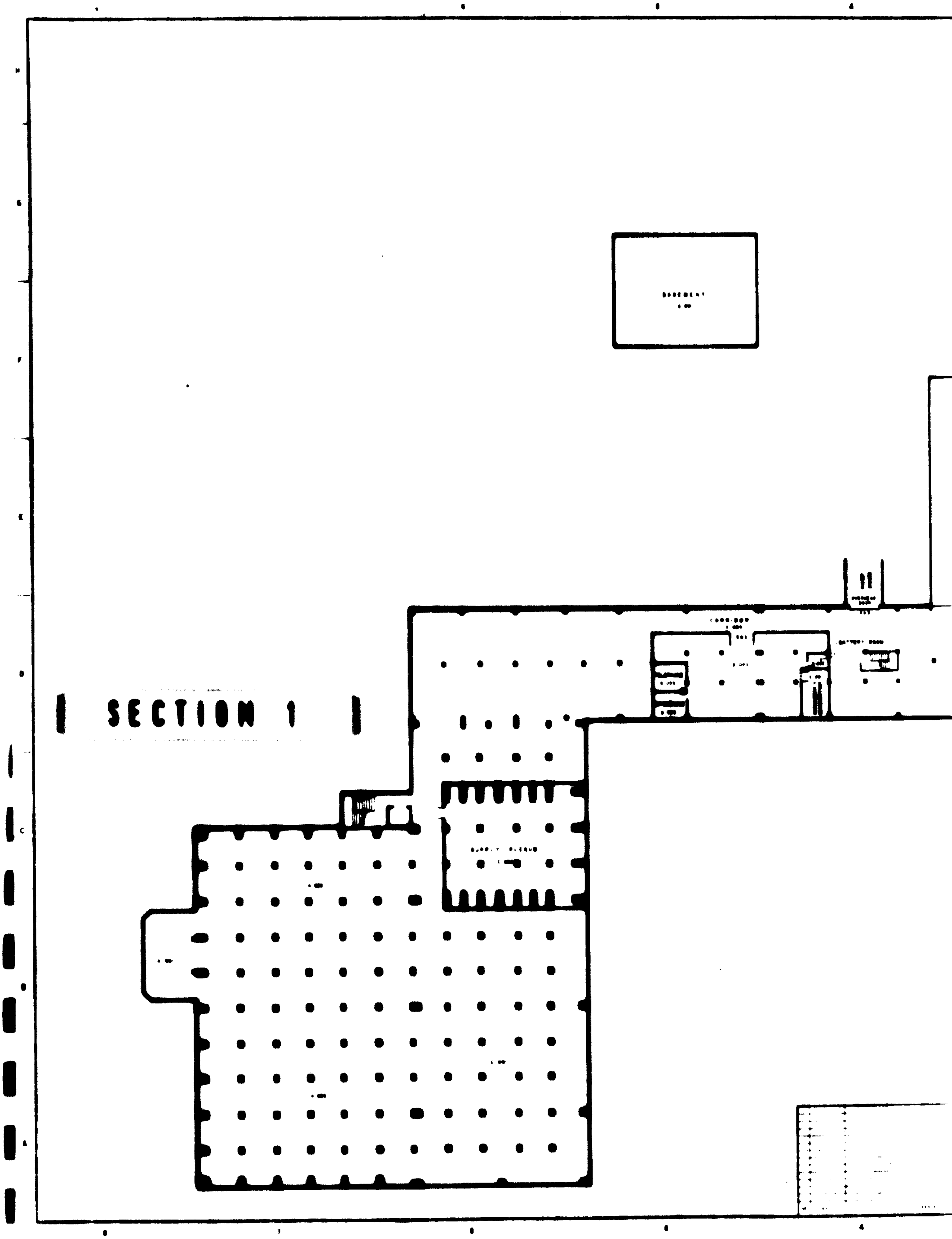
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN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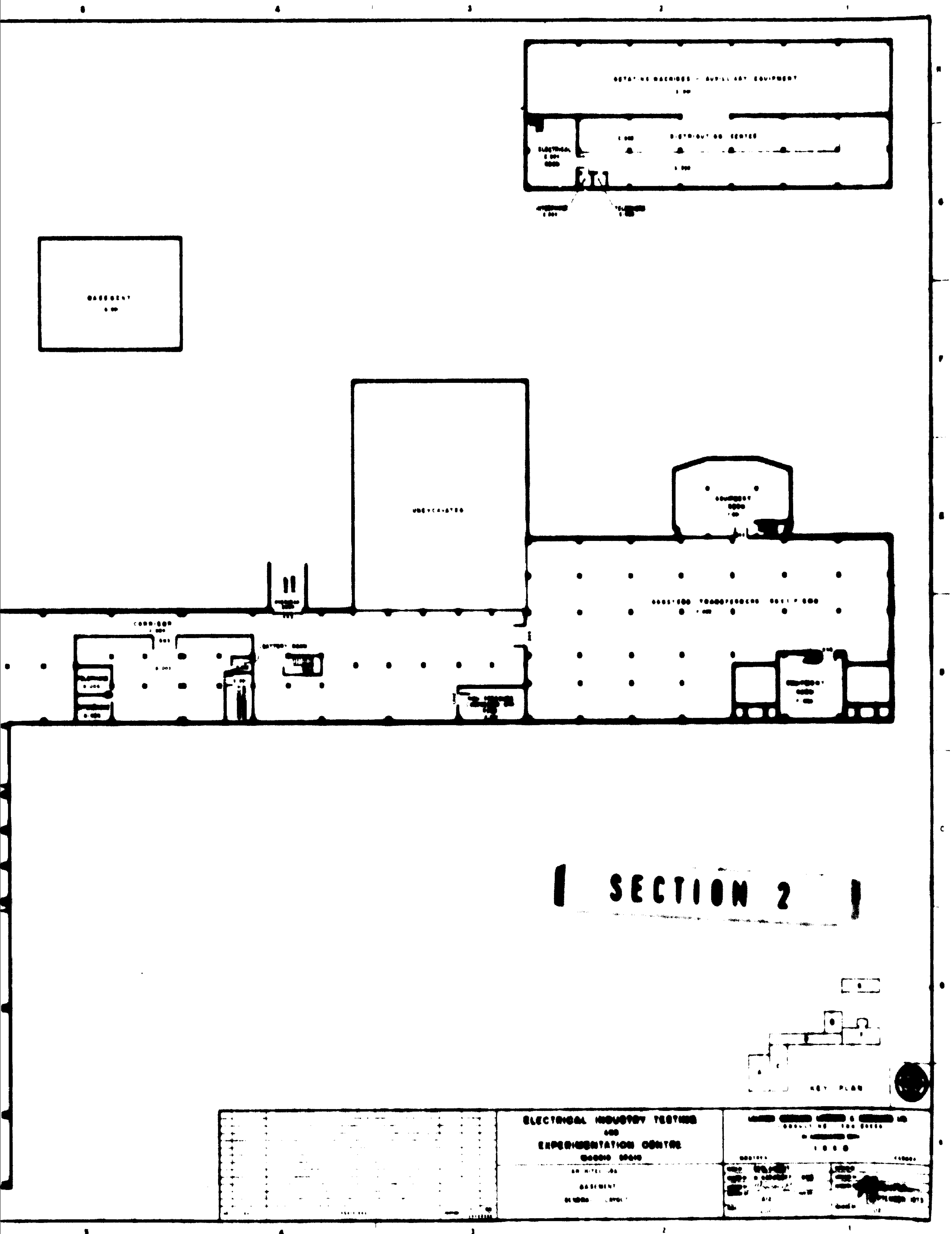
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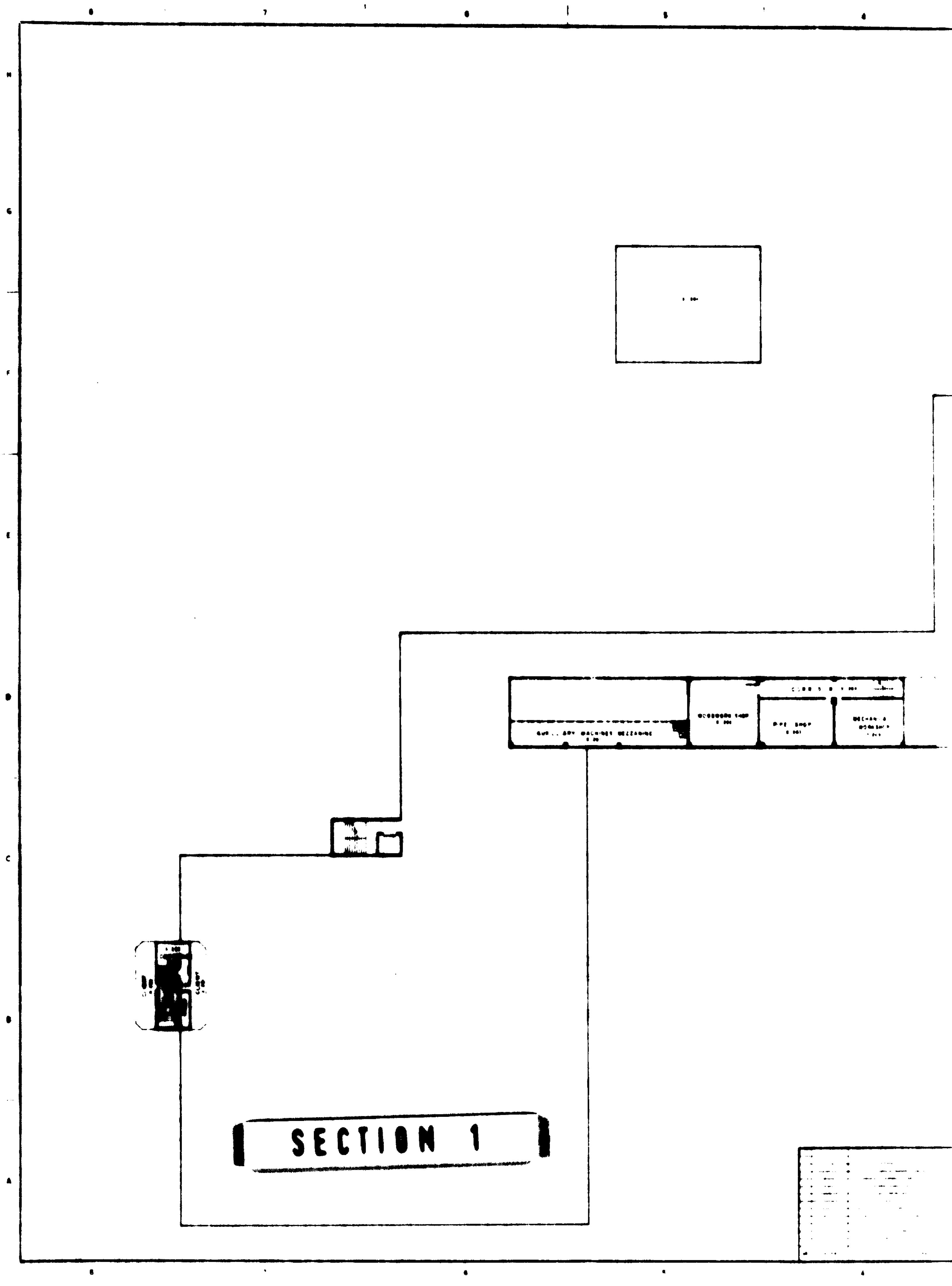
BASEMENT
UNEXCAVATED
KEY PLAN
ELECTRICAL INDUSTRY TESTING
EXPERIMENTATION CENTRE
BASEMENT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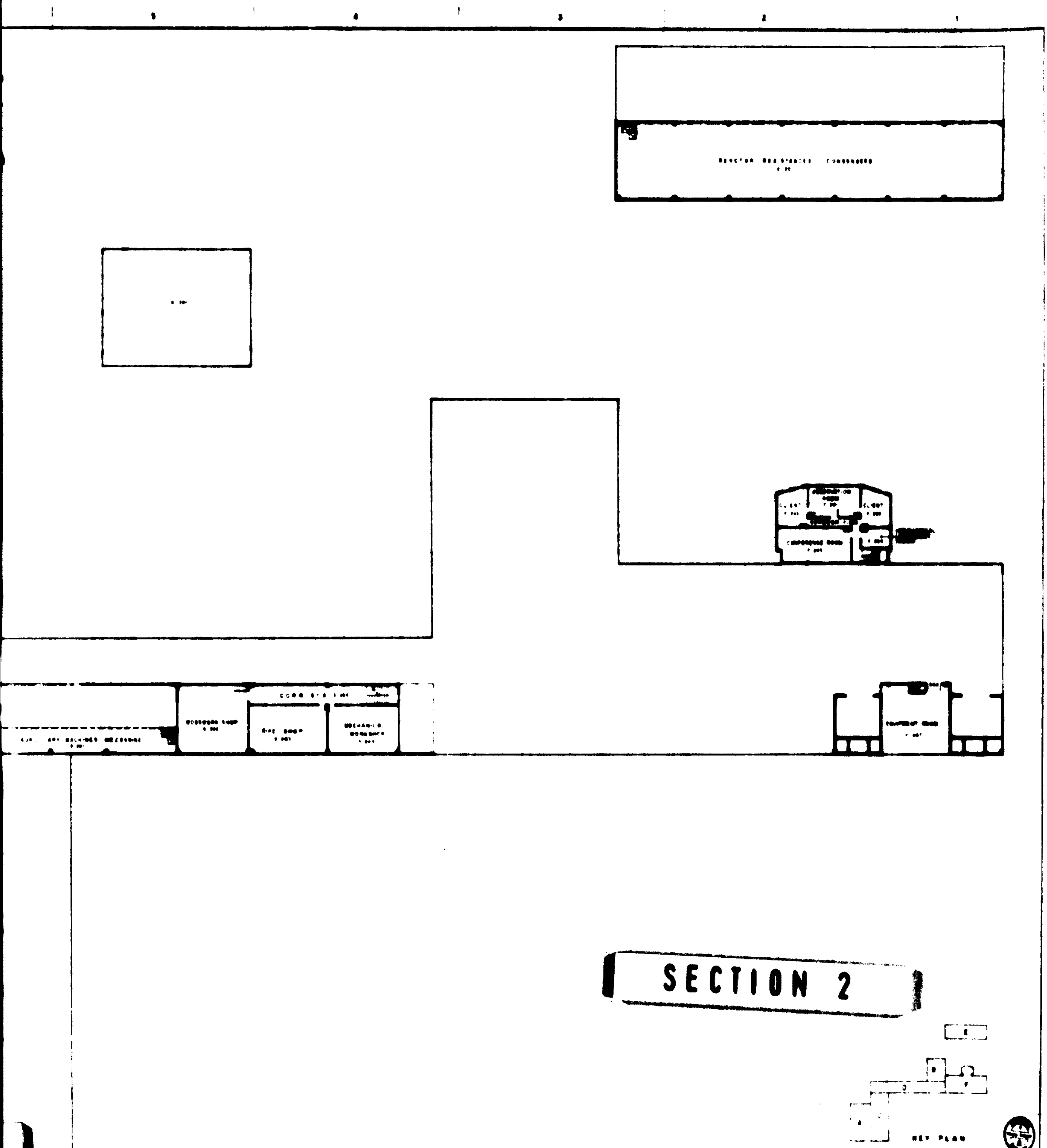


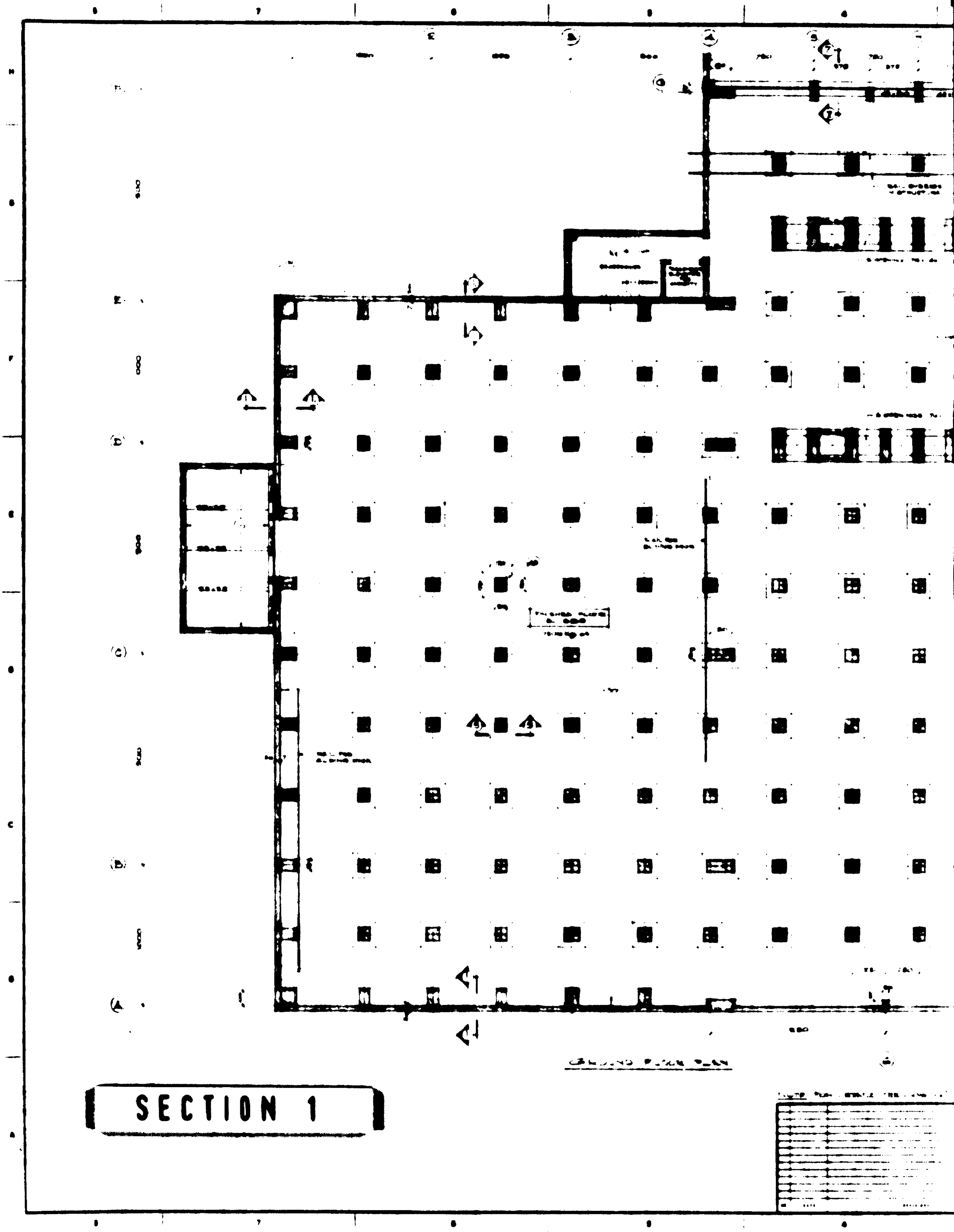
SECTION 2

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID, SPAIN

ARCHITECTURAL
FIRST FLOOR
GENERAL LAYOUT

MONTREAL CANADA

SEPTEMBER 1971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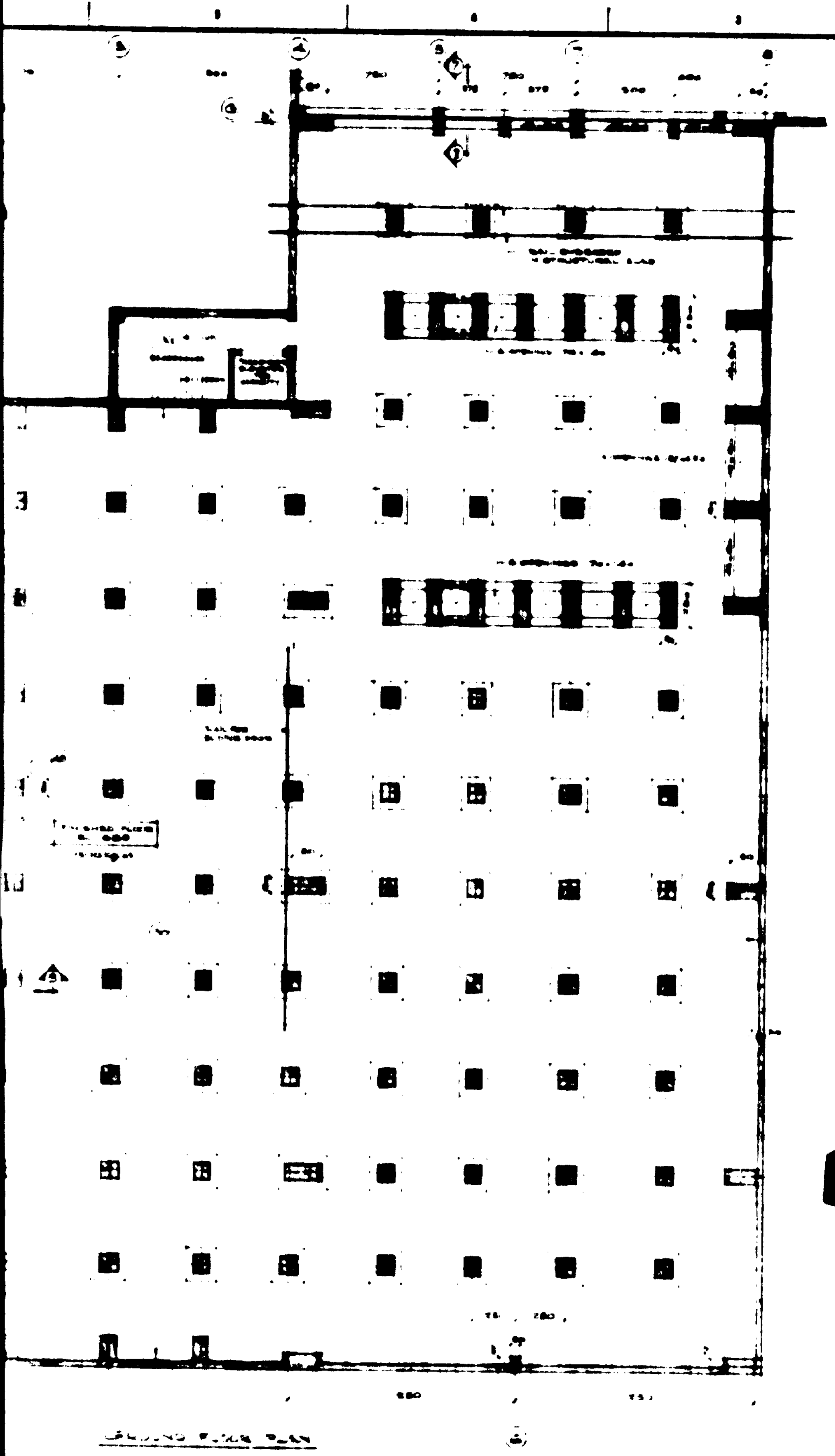

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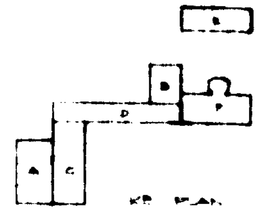
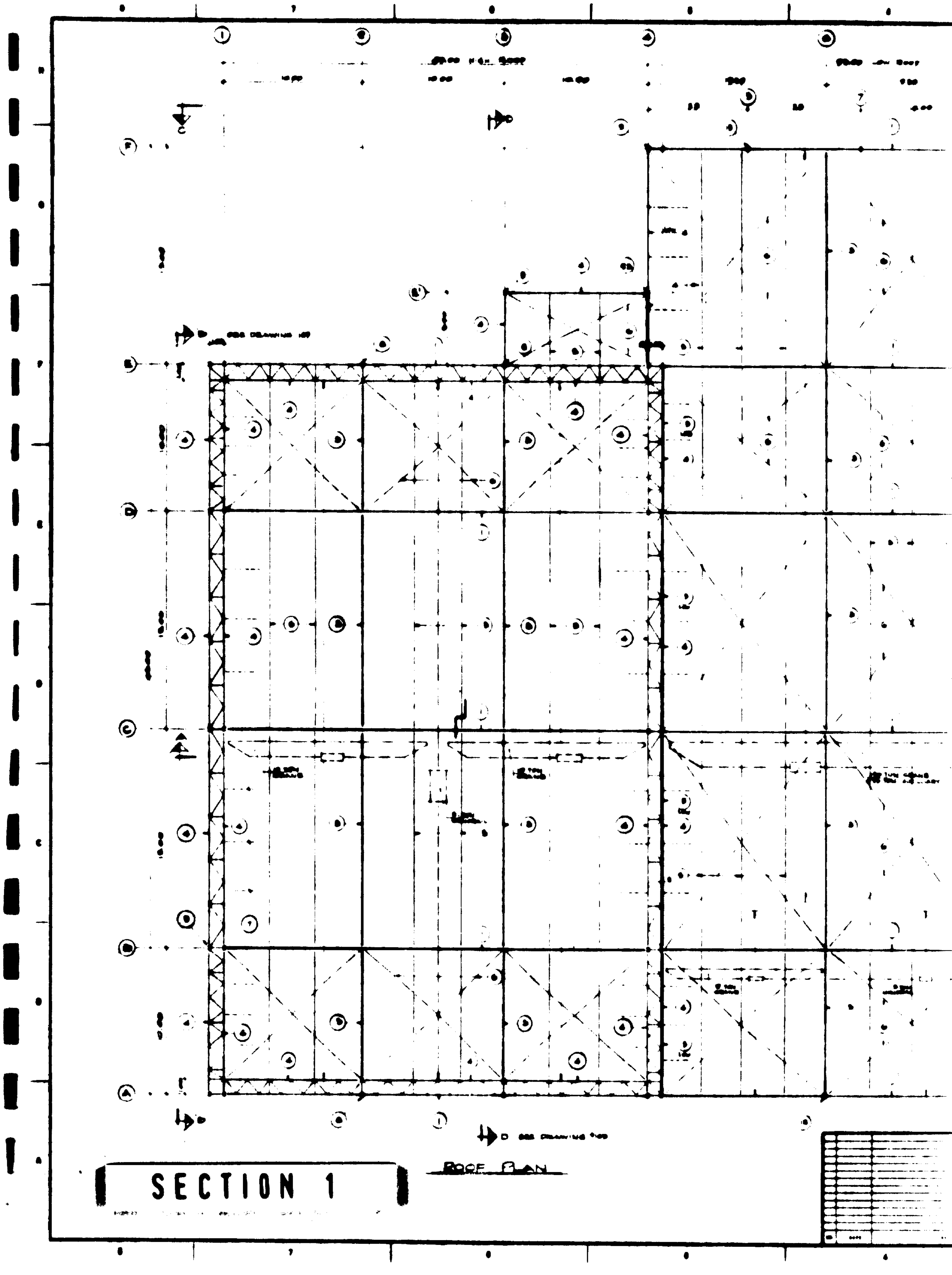


ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID, SPAIN

STRUCTURAL

"A" & "E" GROUND FLOOR

SEPTEMBER 1973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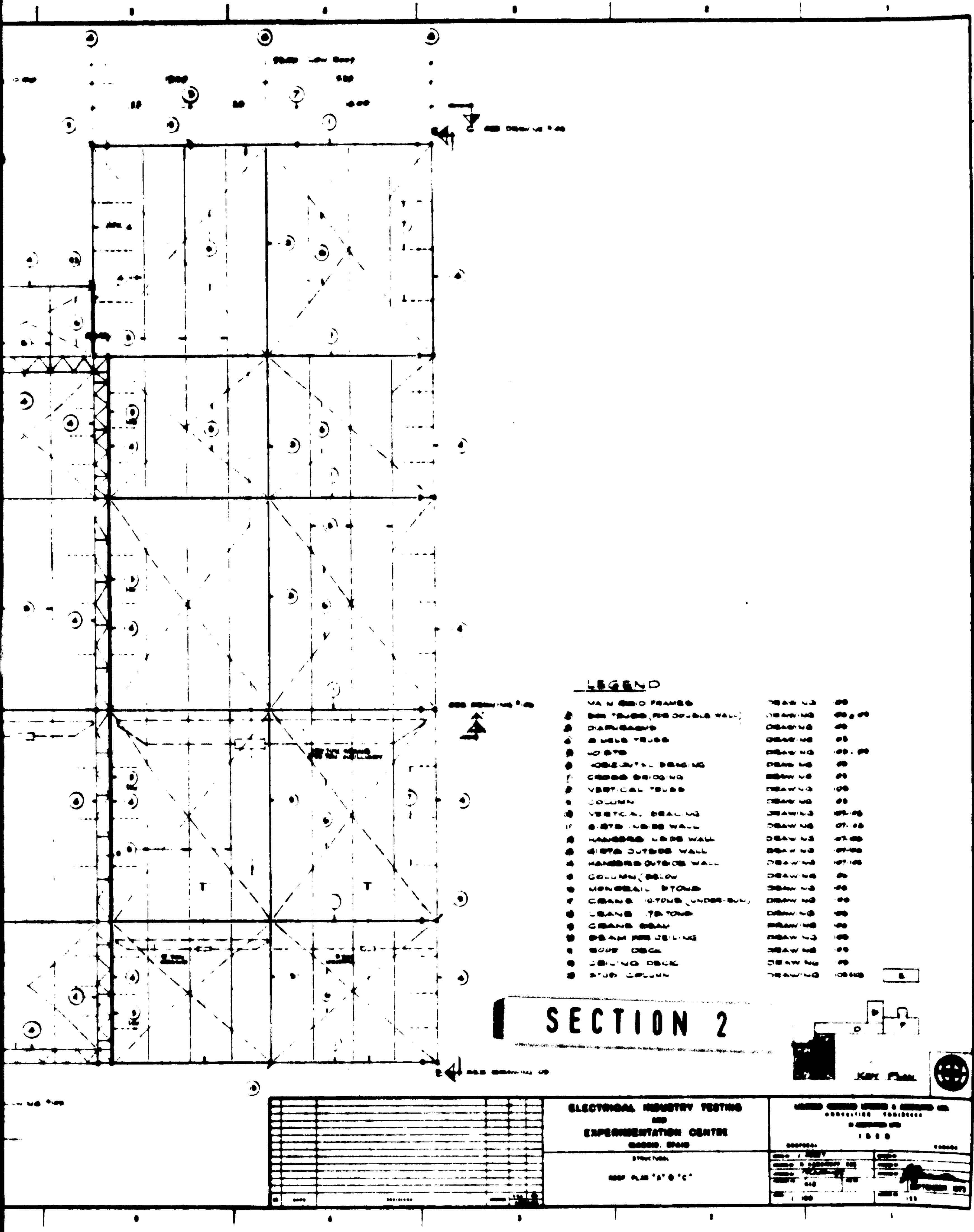
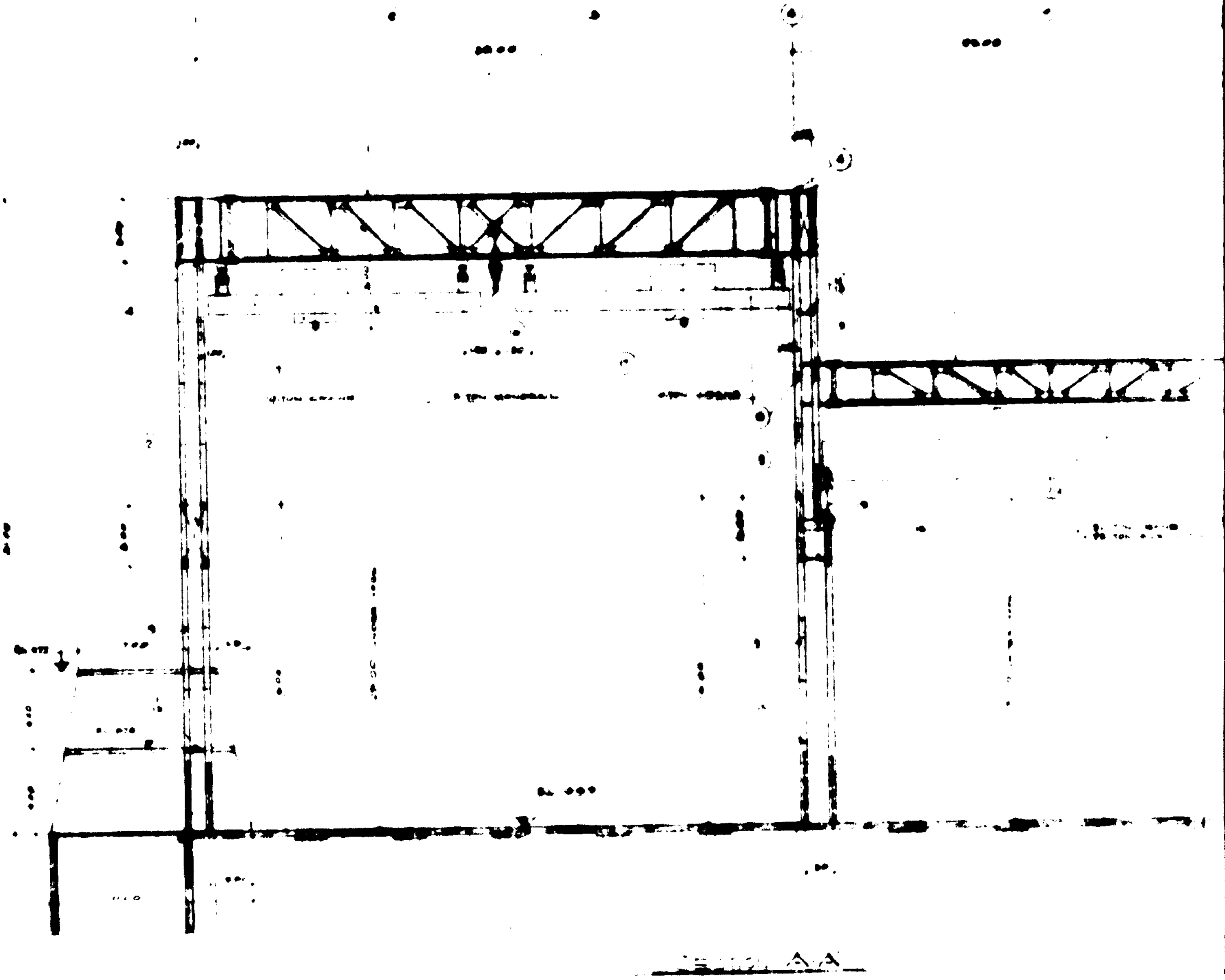
ROOF PLAN


LEGEND
COLUMN
SECTION 2
KEY PLAN
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID, SPAIN
STRUCTURAL
ROOF PLAN "A" & "C"



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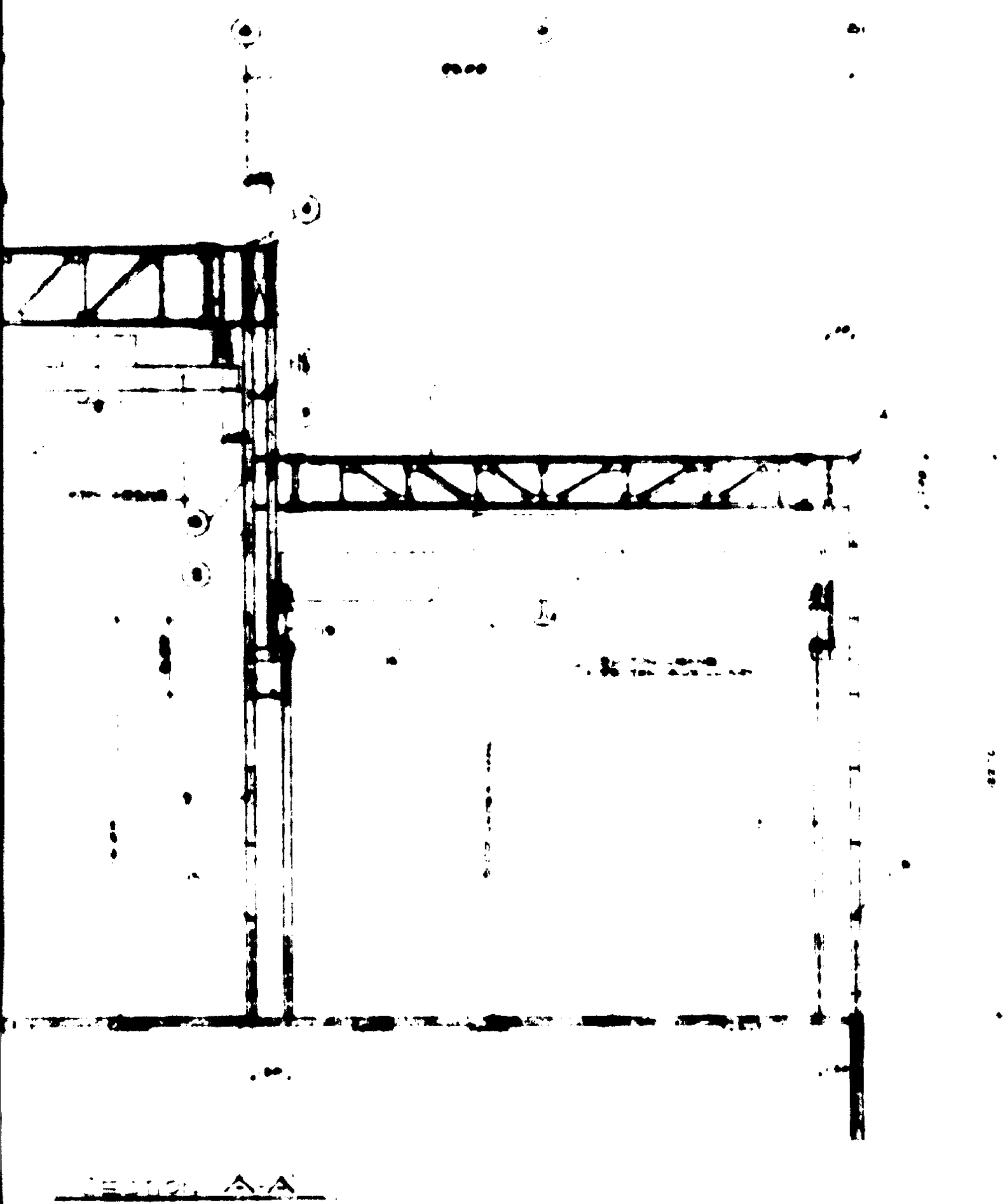


SECTION 2

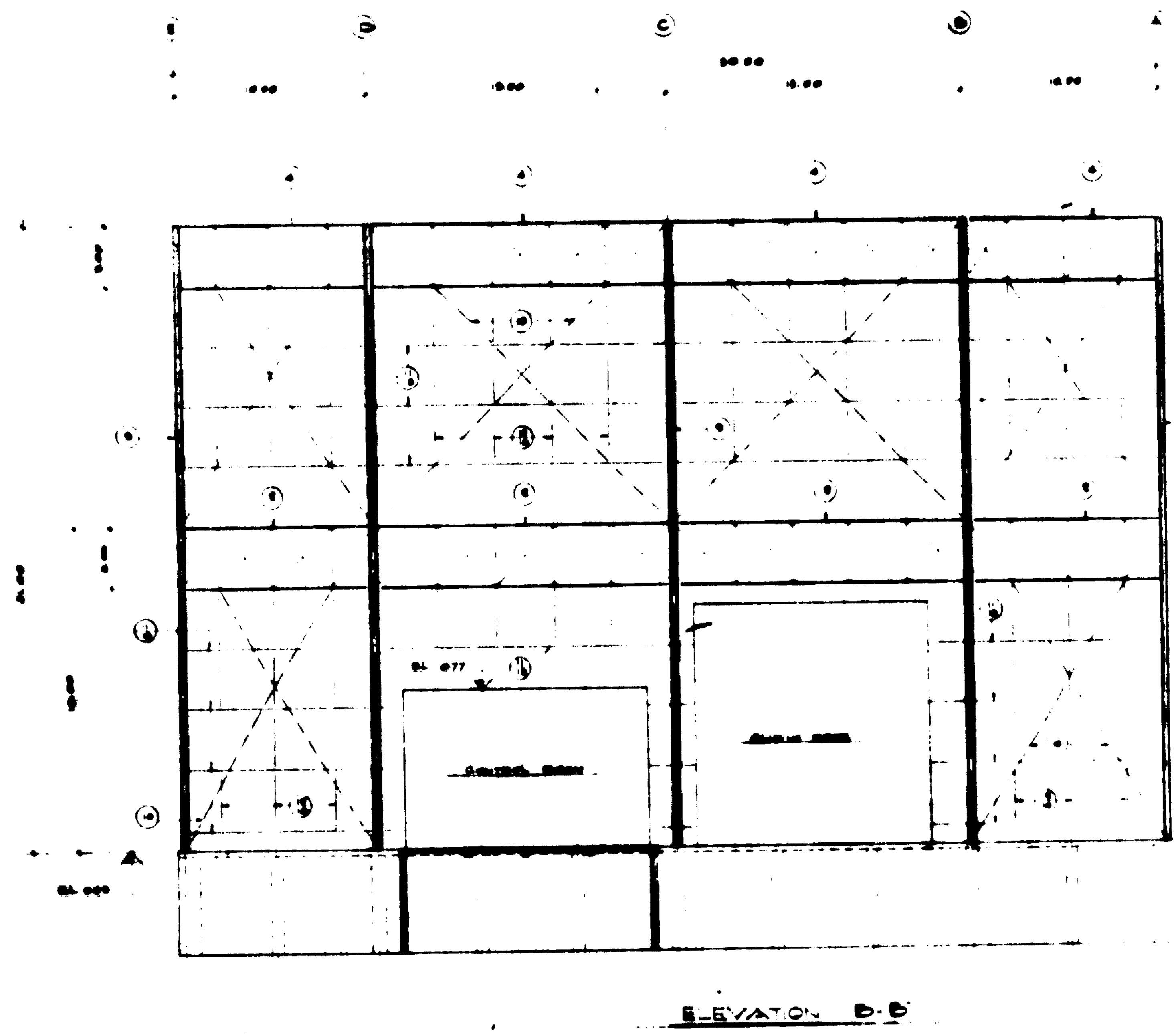
ELECTRICAL INDUSTRY TESTING

AND

EXPERIMENTATION CENTRE

STRUCTURAL

SECTION - A A



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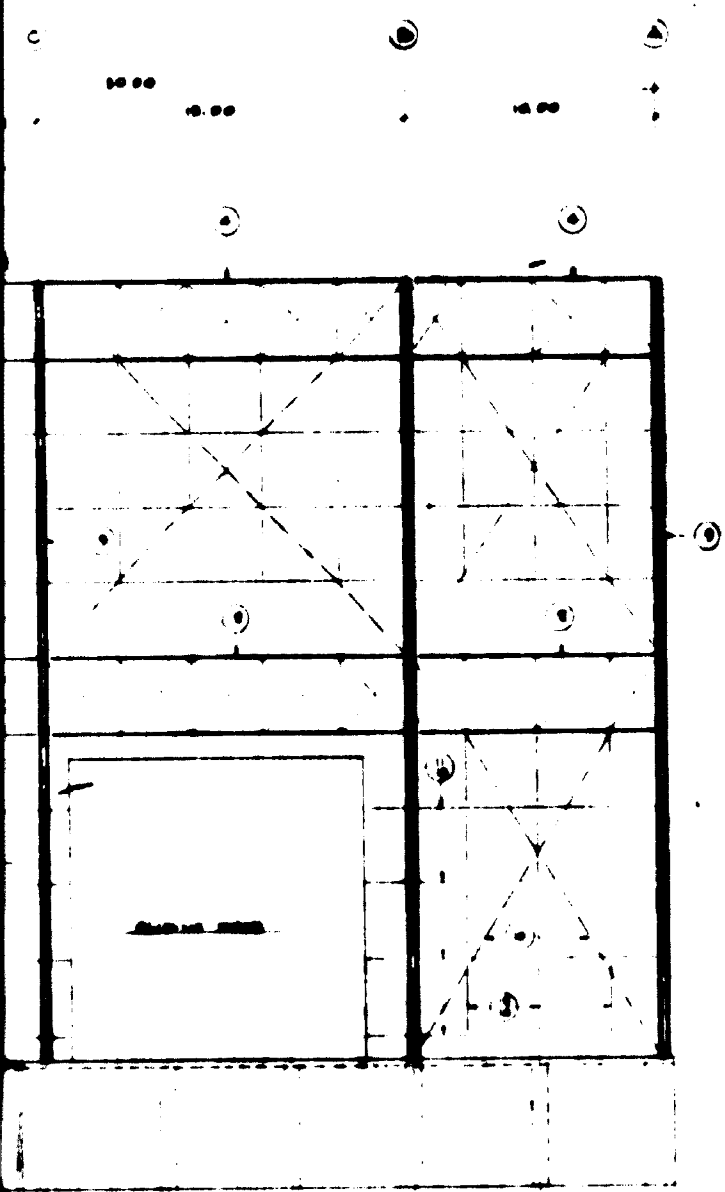
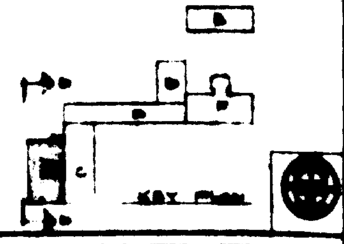


ELEVATION B-B

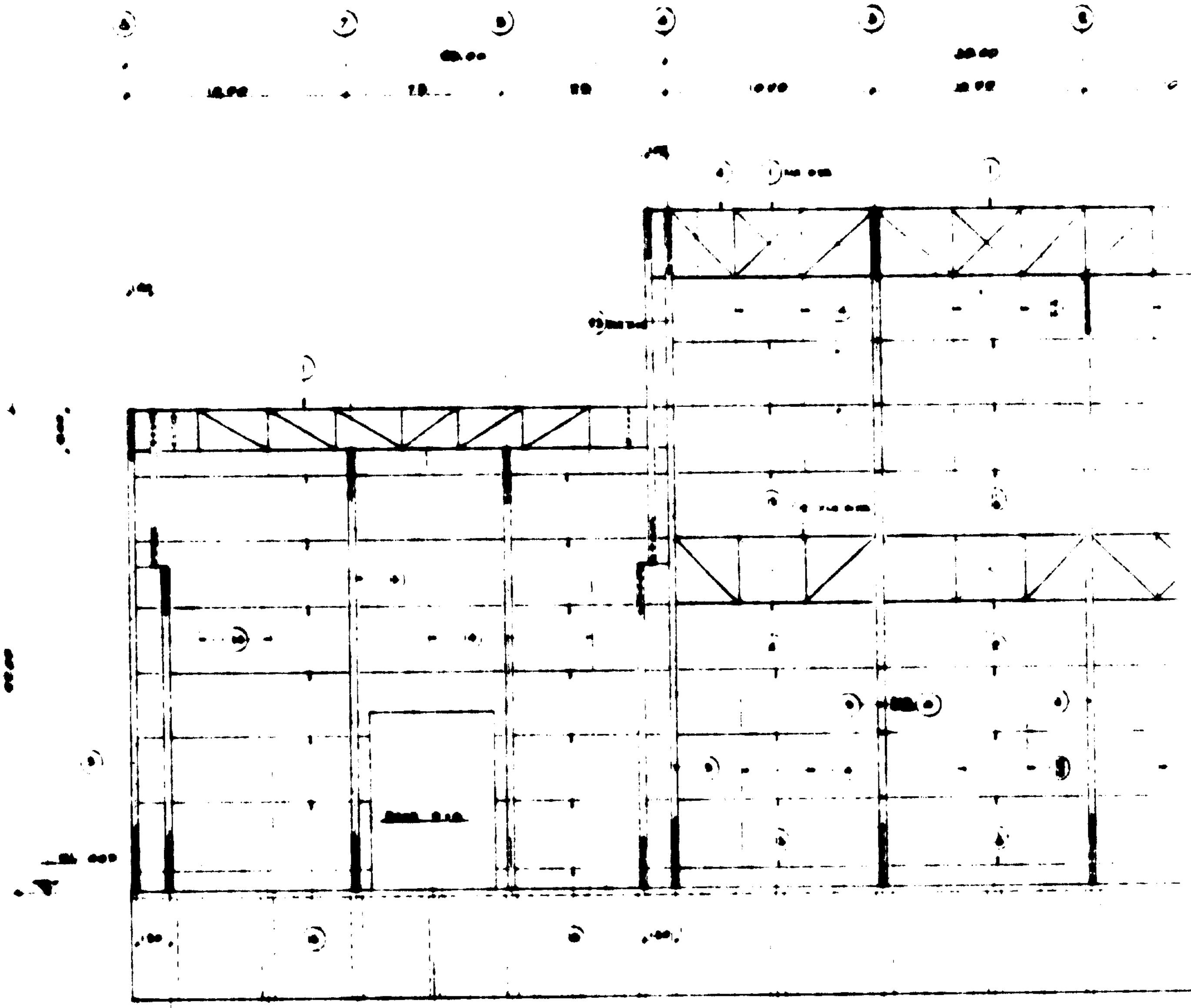
SECTION 2



ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE

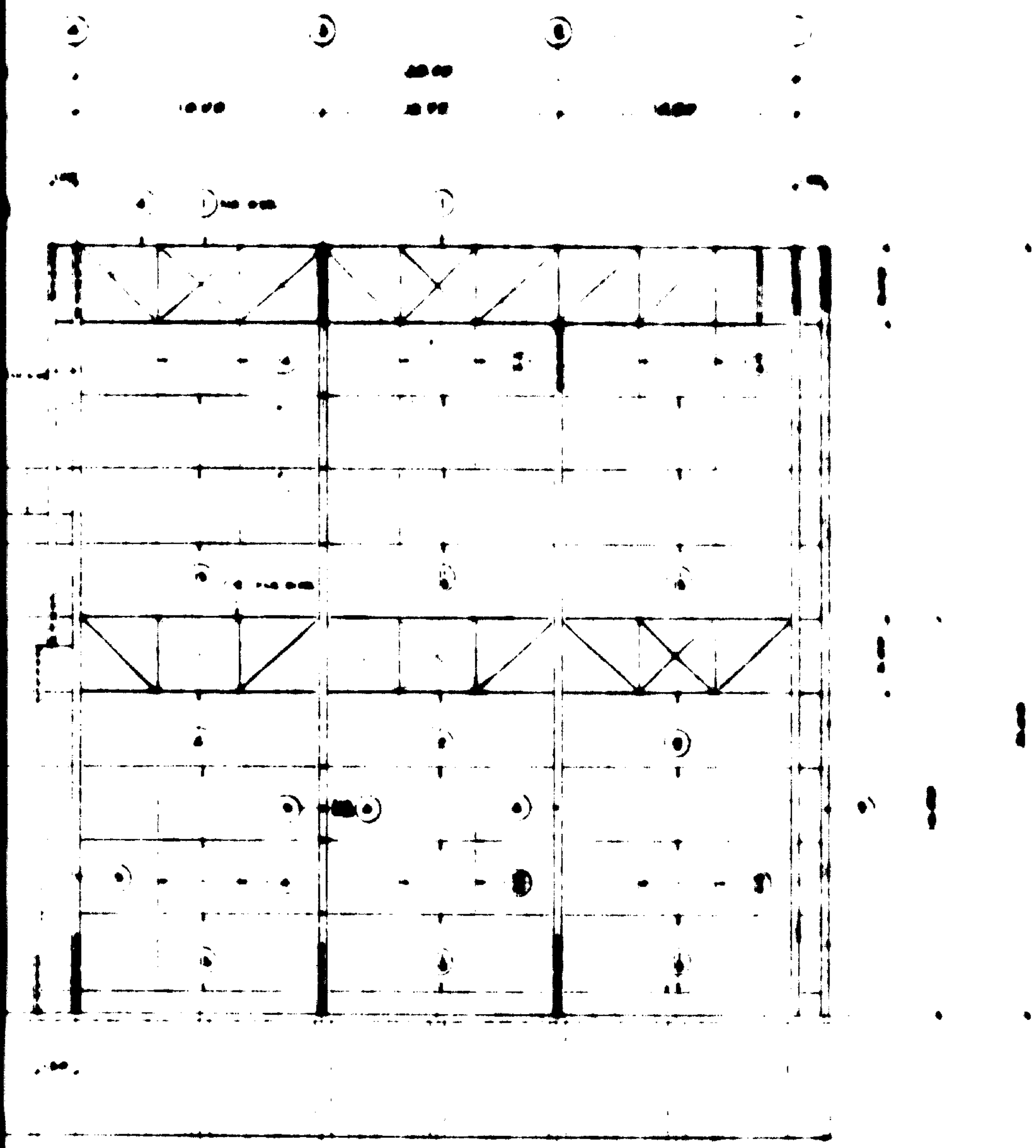
STRUCTURAL

ELEVATION "B-B"
"C"



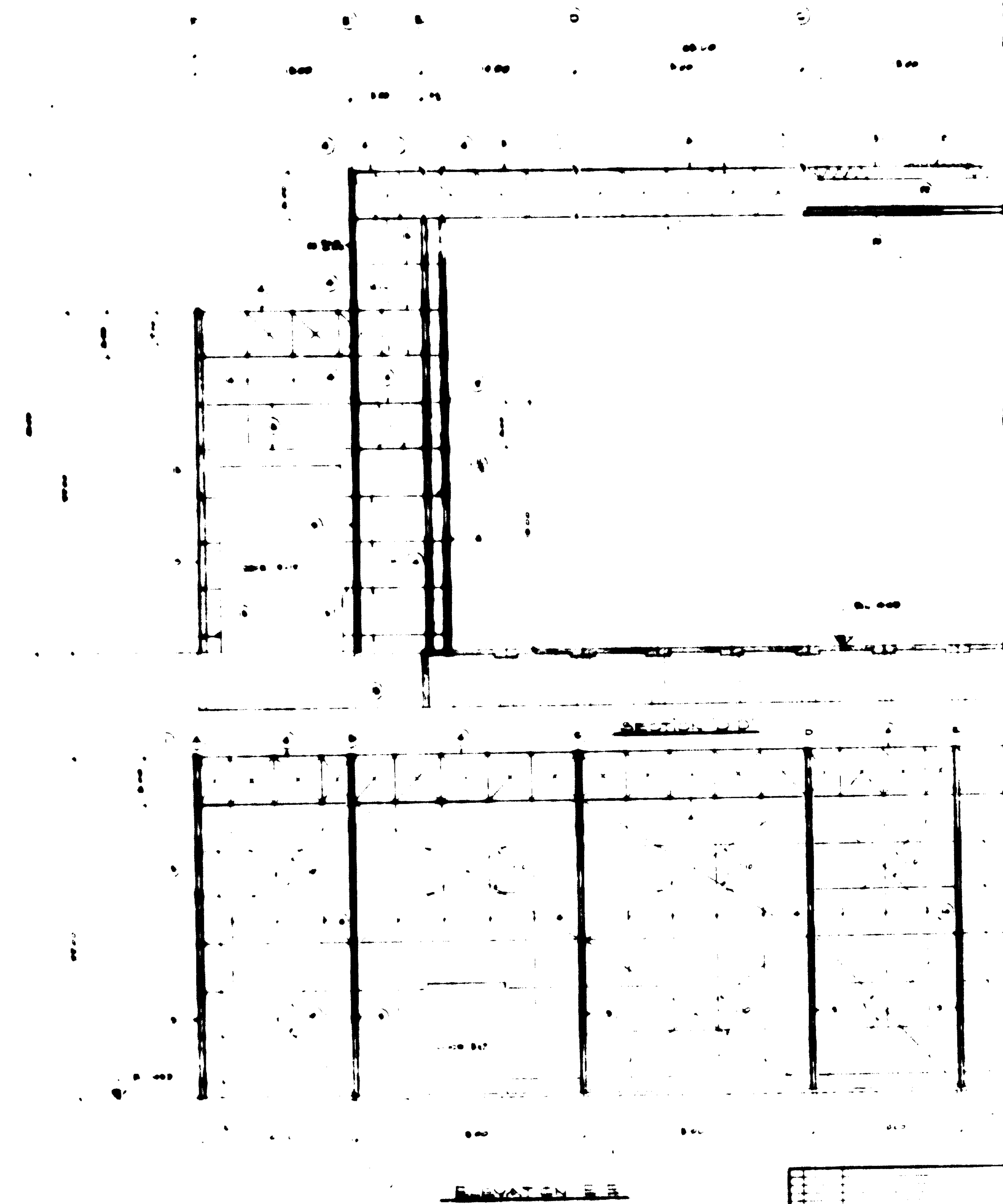
ELEVATION 'C-C'

SECTION 1



LATION 'C-C'

SECTION 2



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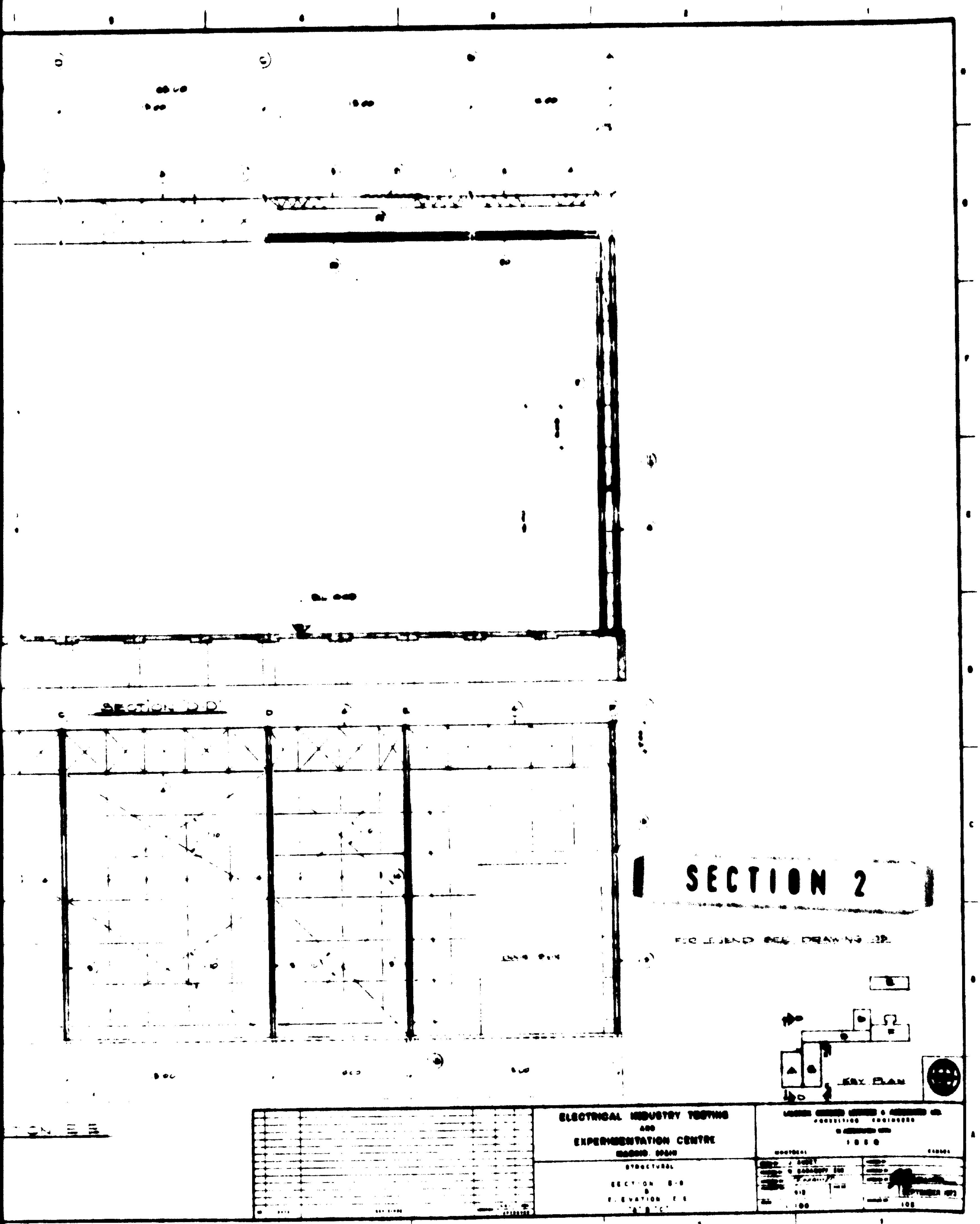
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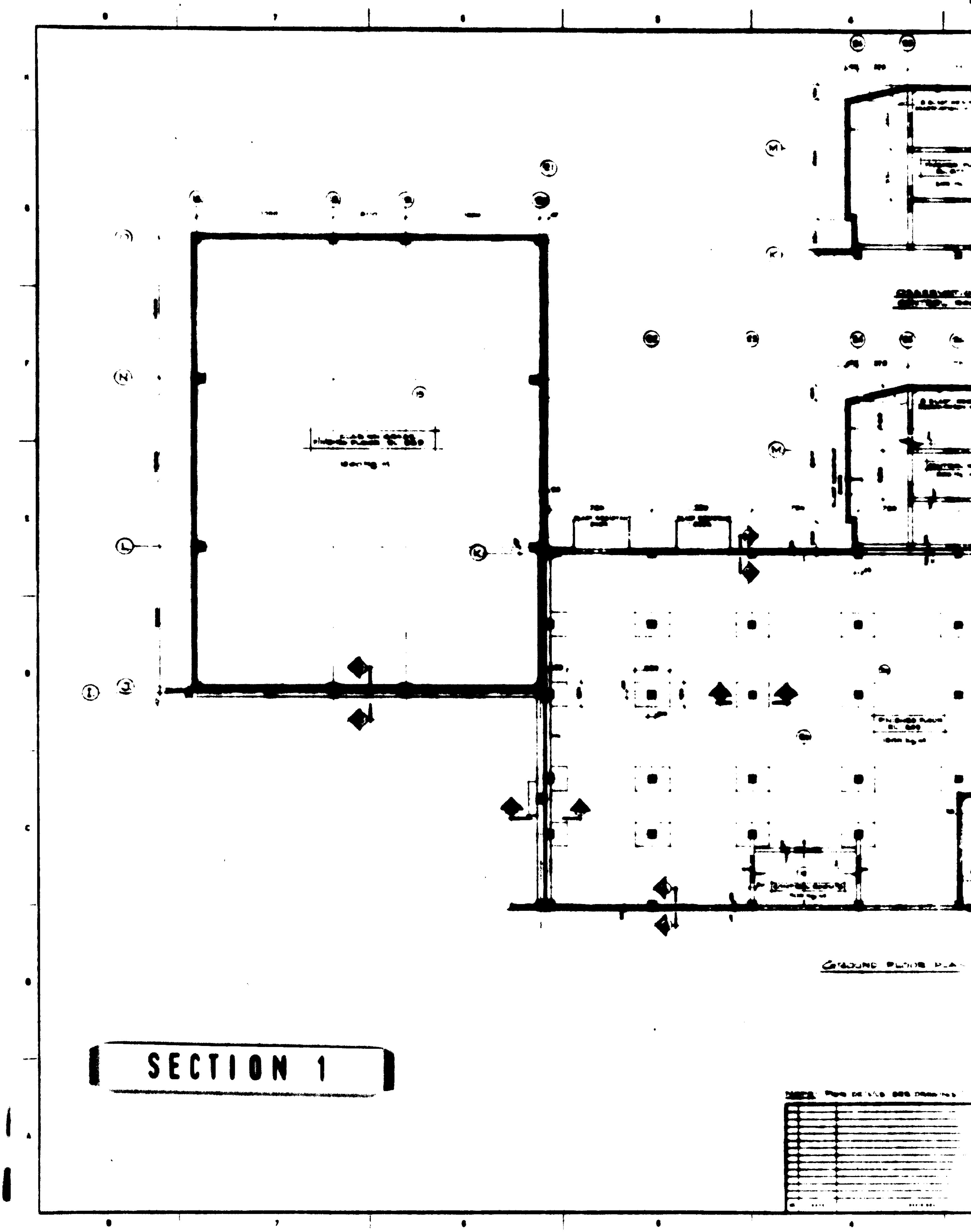
SECTION 2
KEY PLAN
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
STRUCTURAL
SECTION D-D
&
ELEVATION E-E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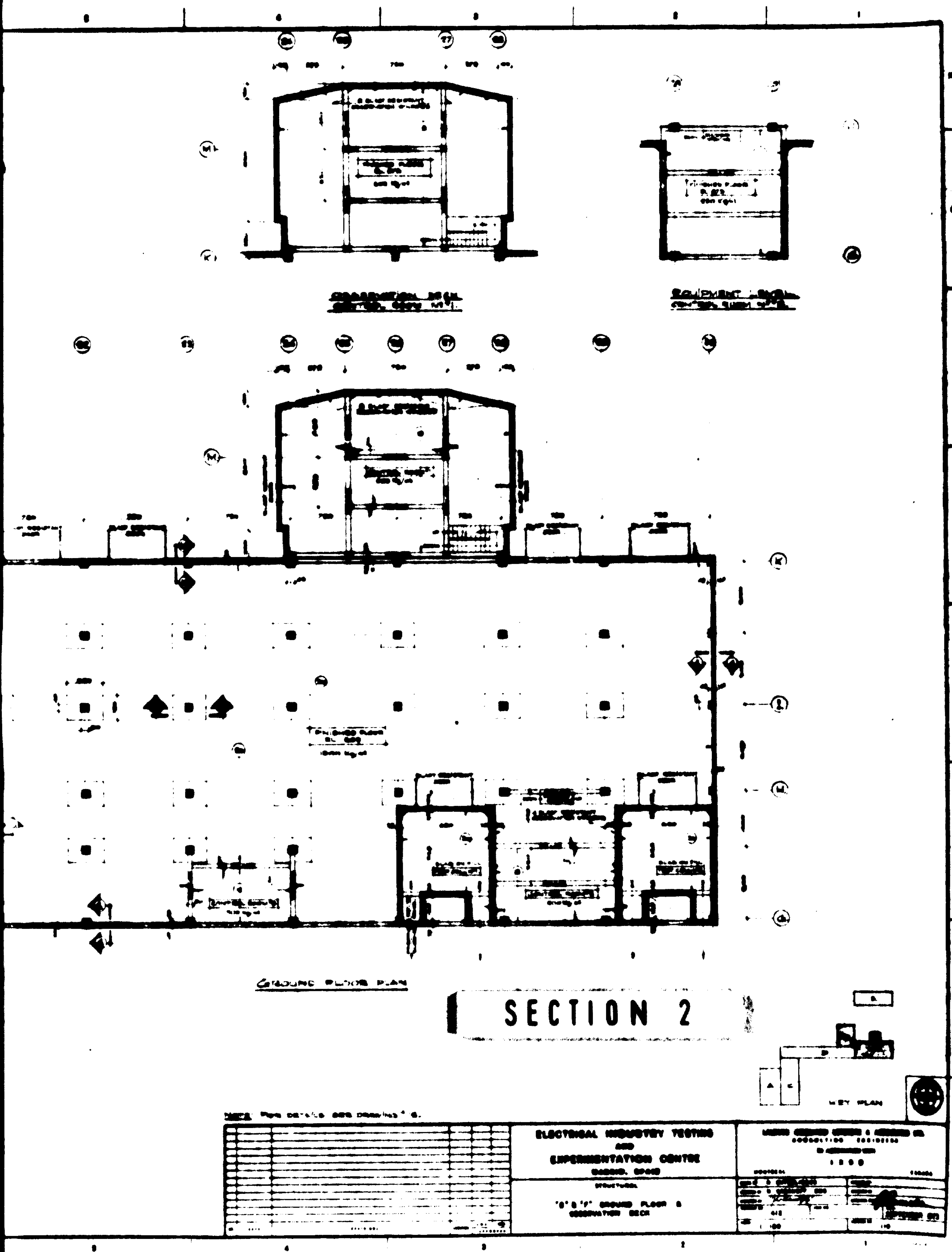
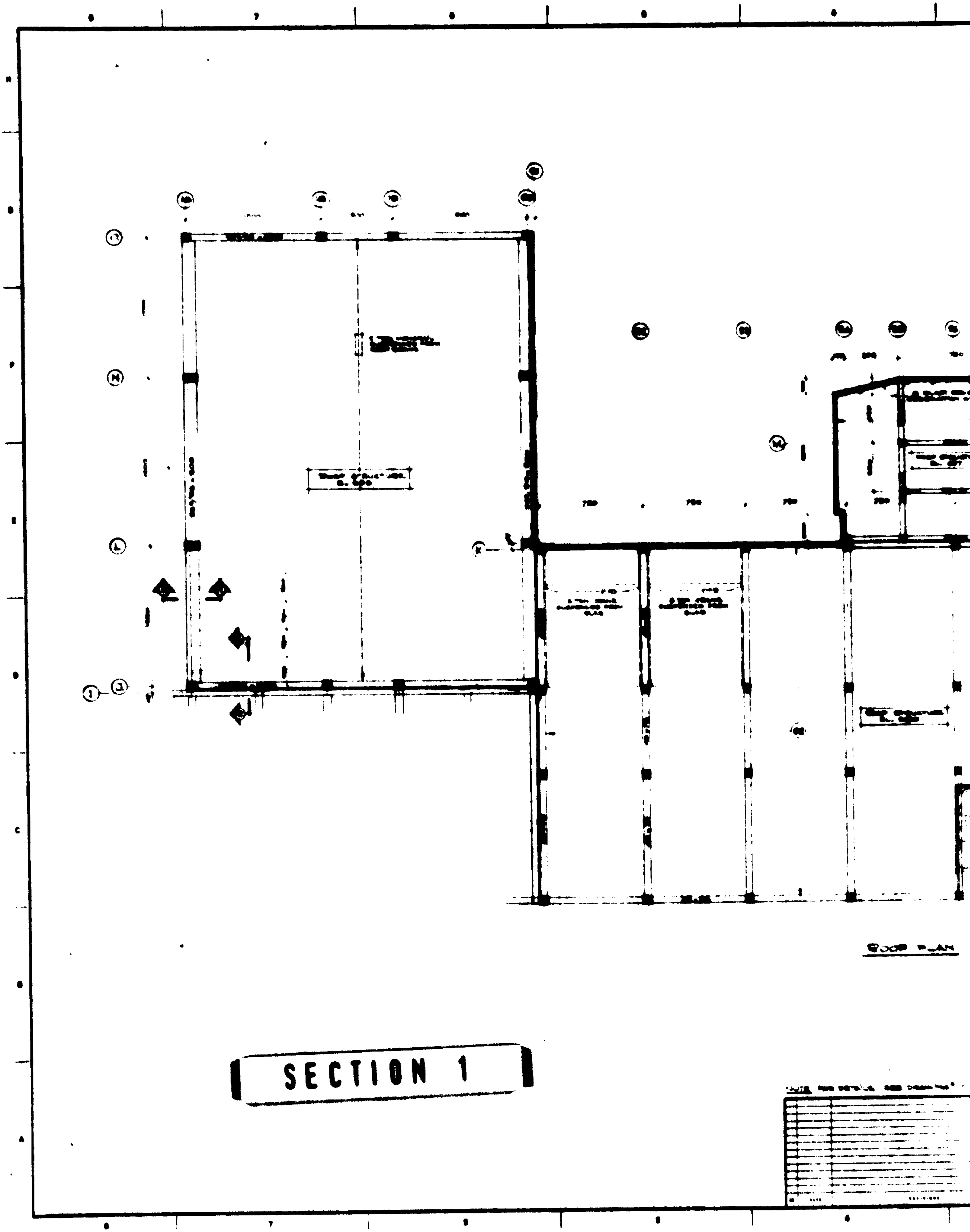
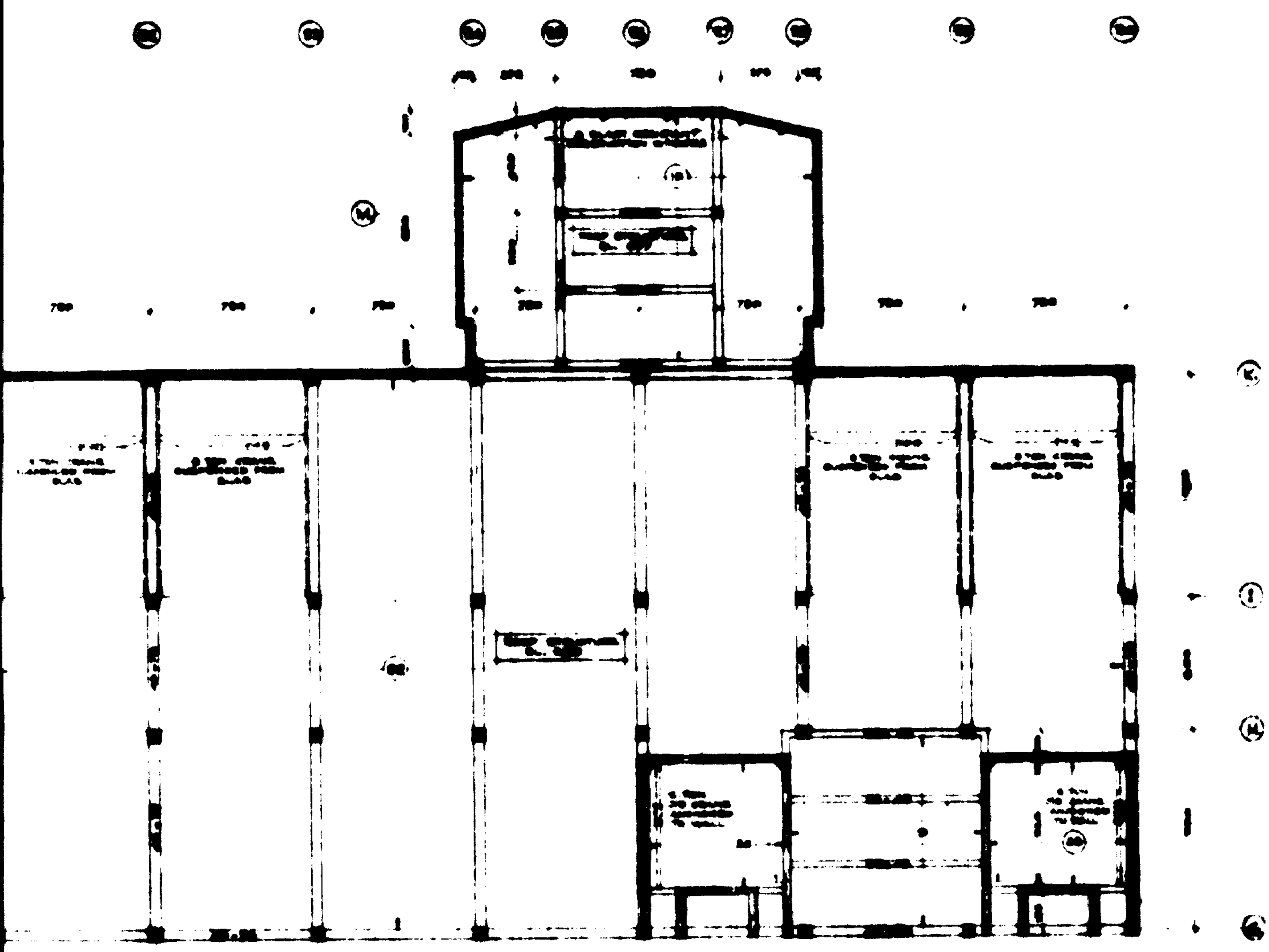


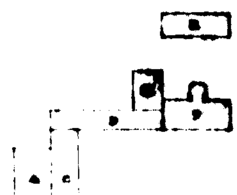
OBSERVATION DECK
EQUIPMENT
GROUND FLOOR PLAN
SECTION 2
KEY PLAN
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID, SPAIN
STRUCTURAL
GROUND FLOOR &
OBSERVATION DECK


ROOF PLAN
SECTION 1



ROOF PLAN

SECTION 2

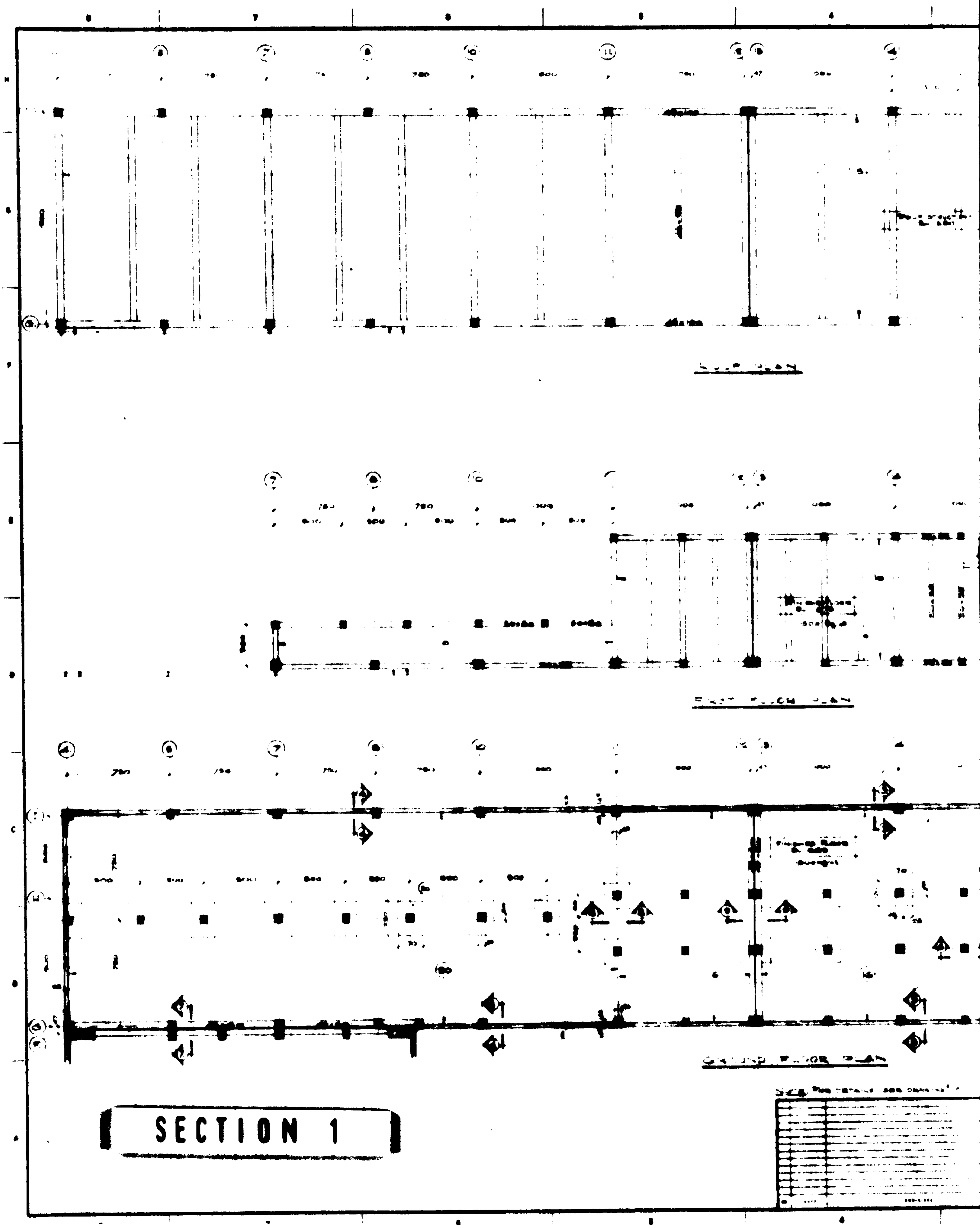


KEY PLAN

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID, SPAIN

STRUCTURAL

"E" & "F" ROOF PLAN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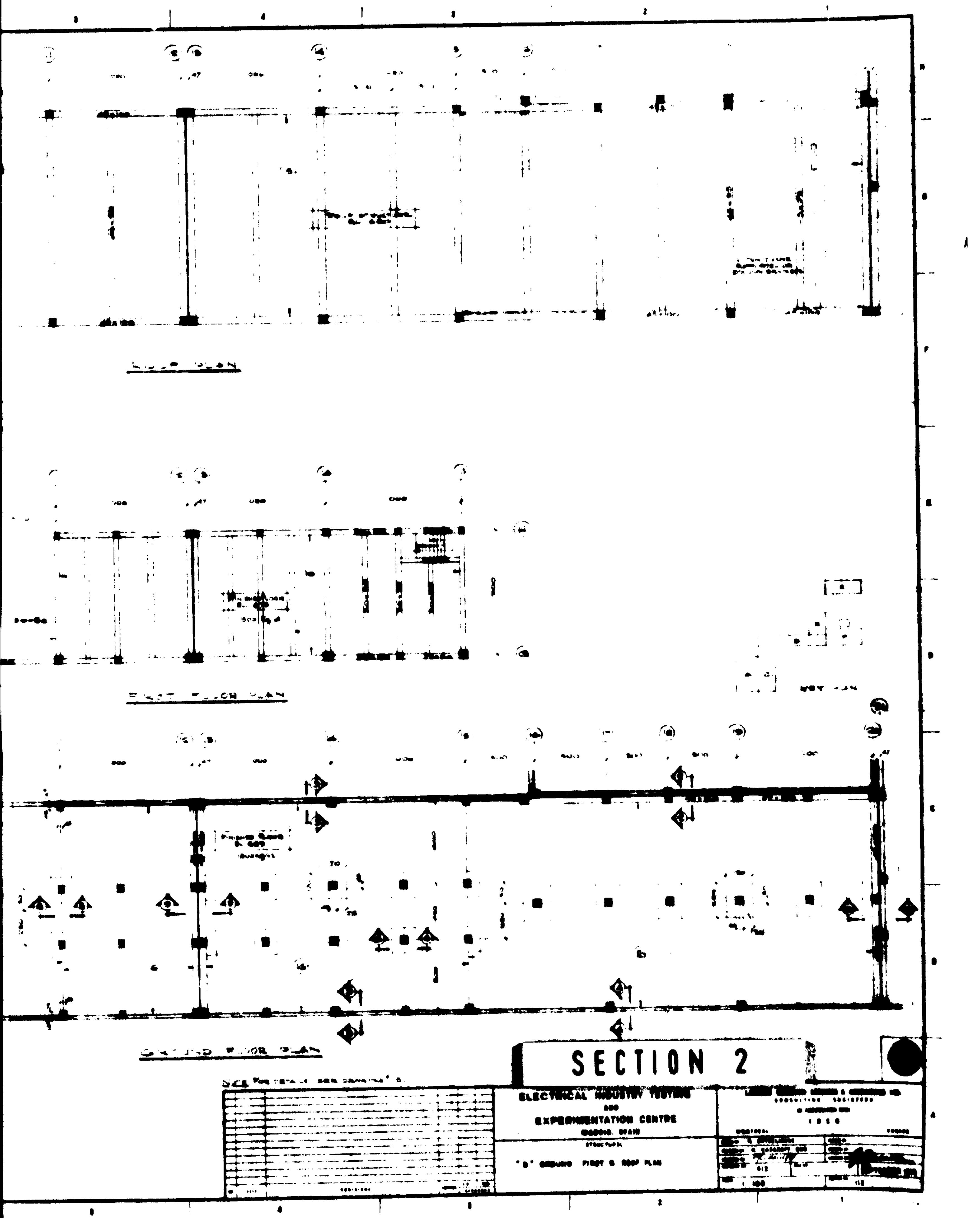
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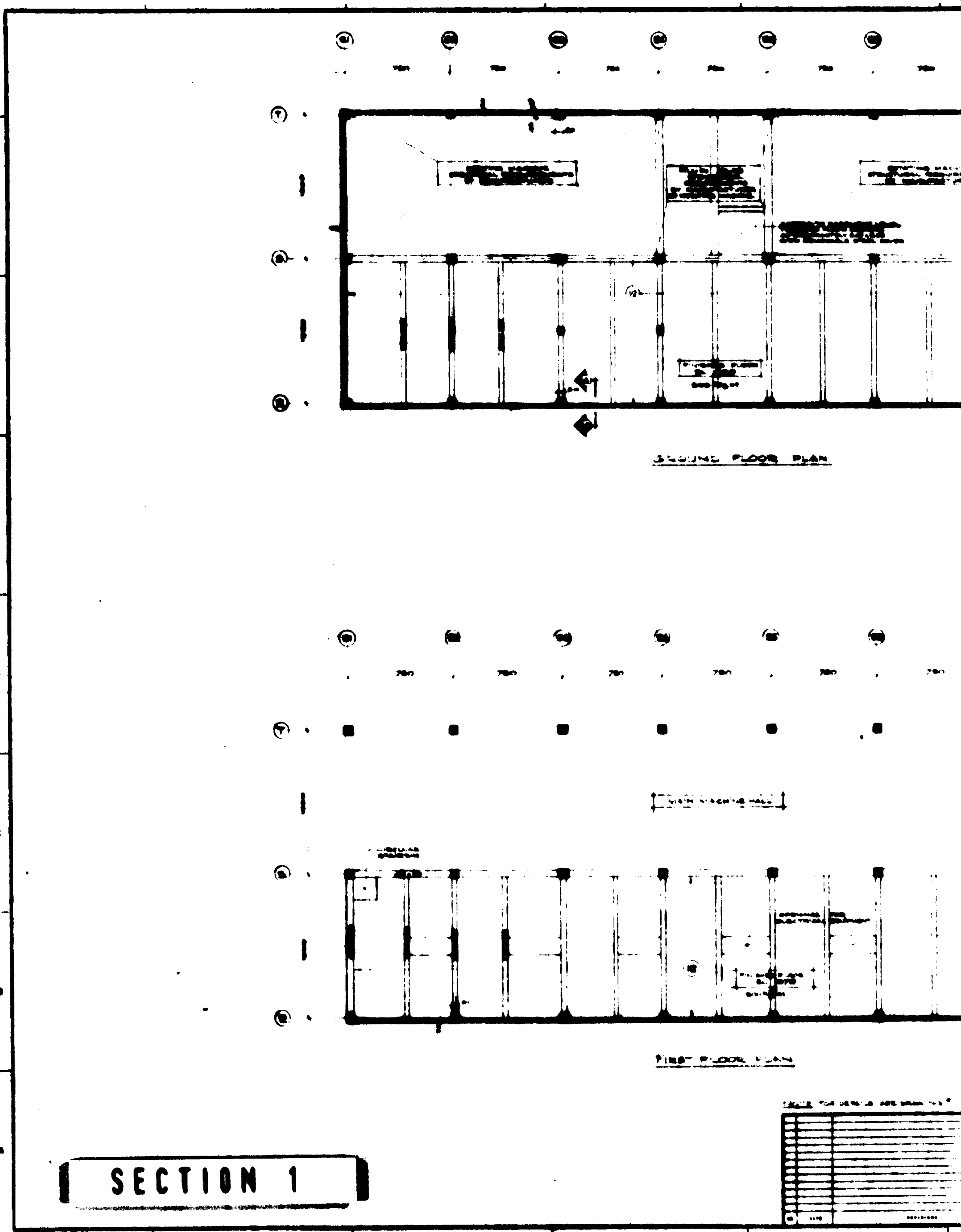
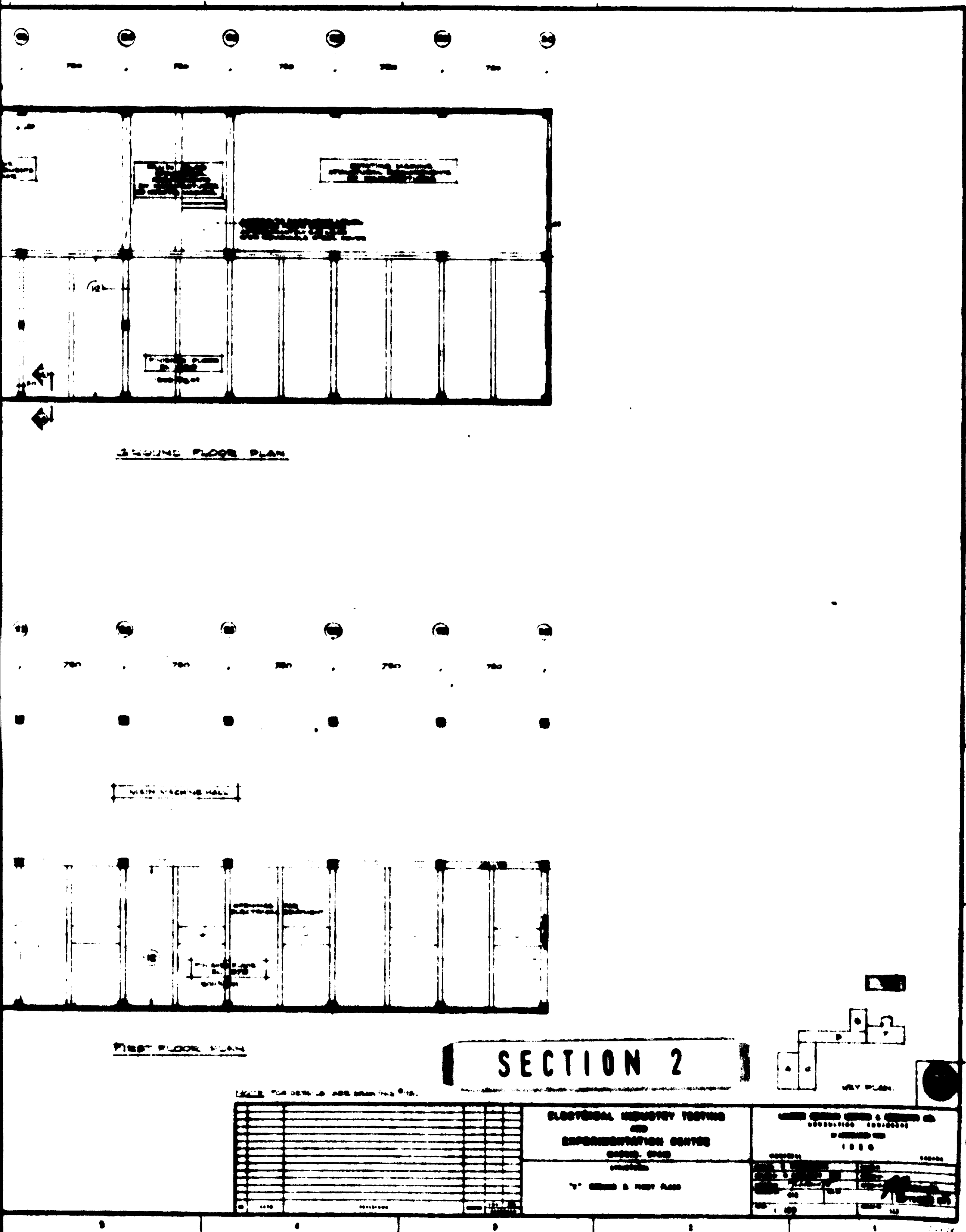
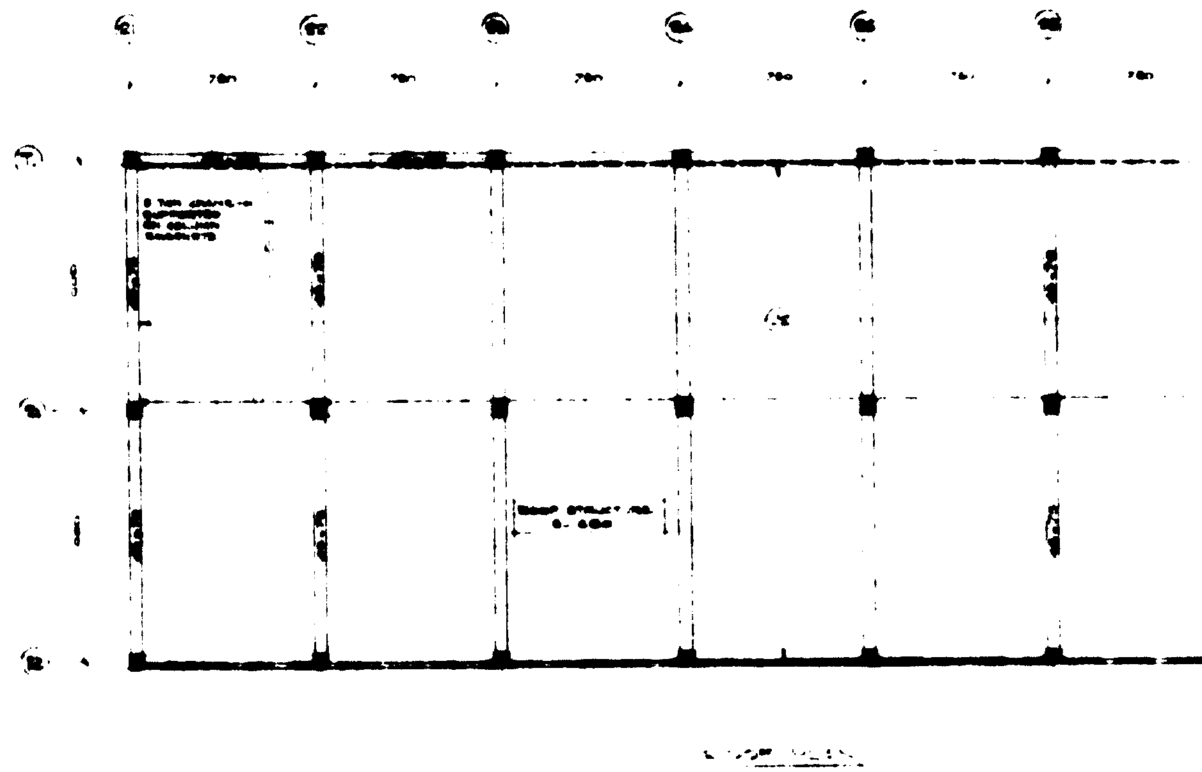
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
STRUCTURAL
GROUND FIRST & ROOF PLAN
1 : 100


GROUND FLOOR PLAN
MAIN MACHINE HALL
FIRST FLOOR PLAN
SECTION 1

SECTION 2


GROUND FLOOR PLAN
FIRST FLOOR PLAN
MAIN MACHINE HALL
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTER
KEY PLAN
1:100



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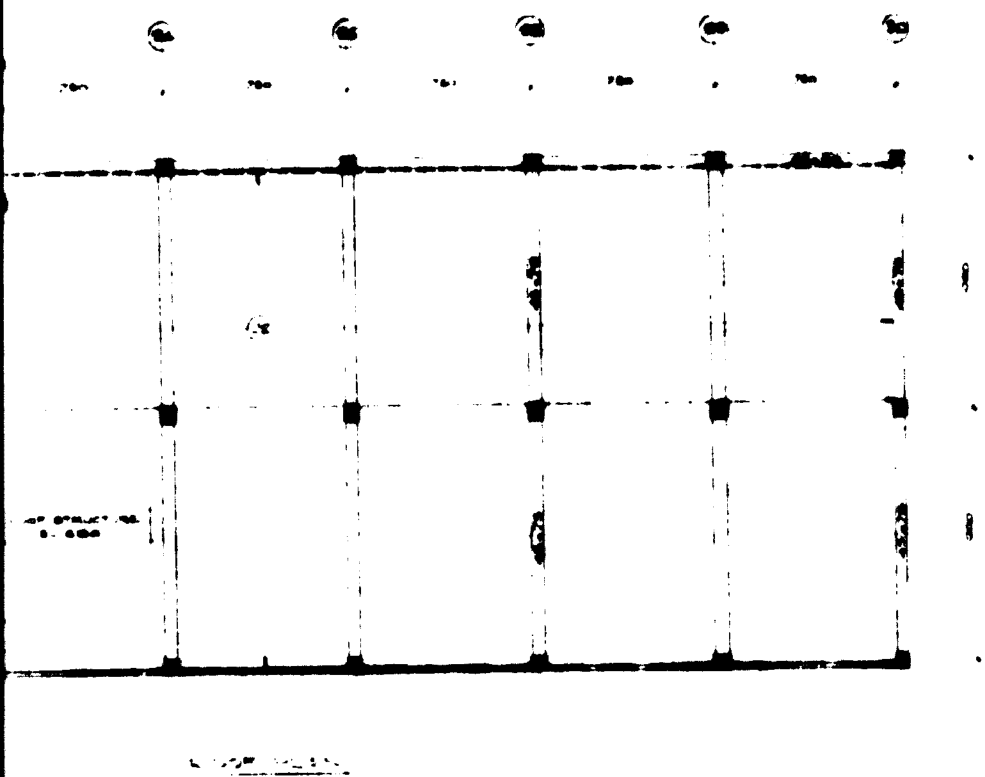
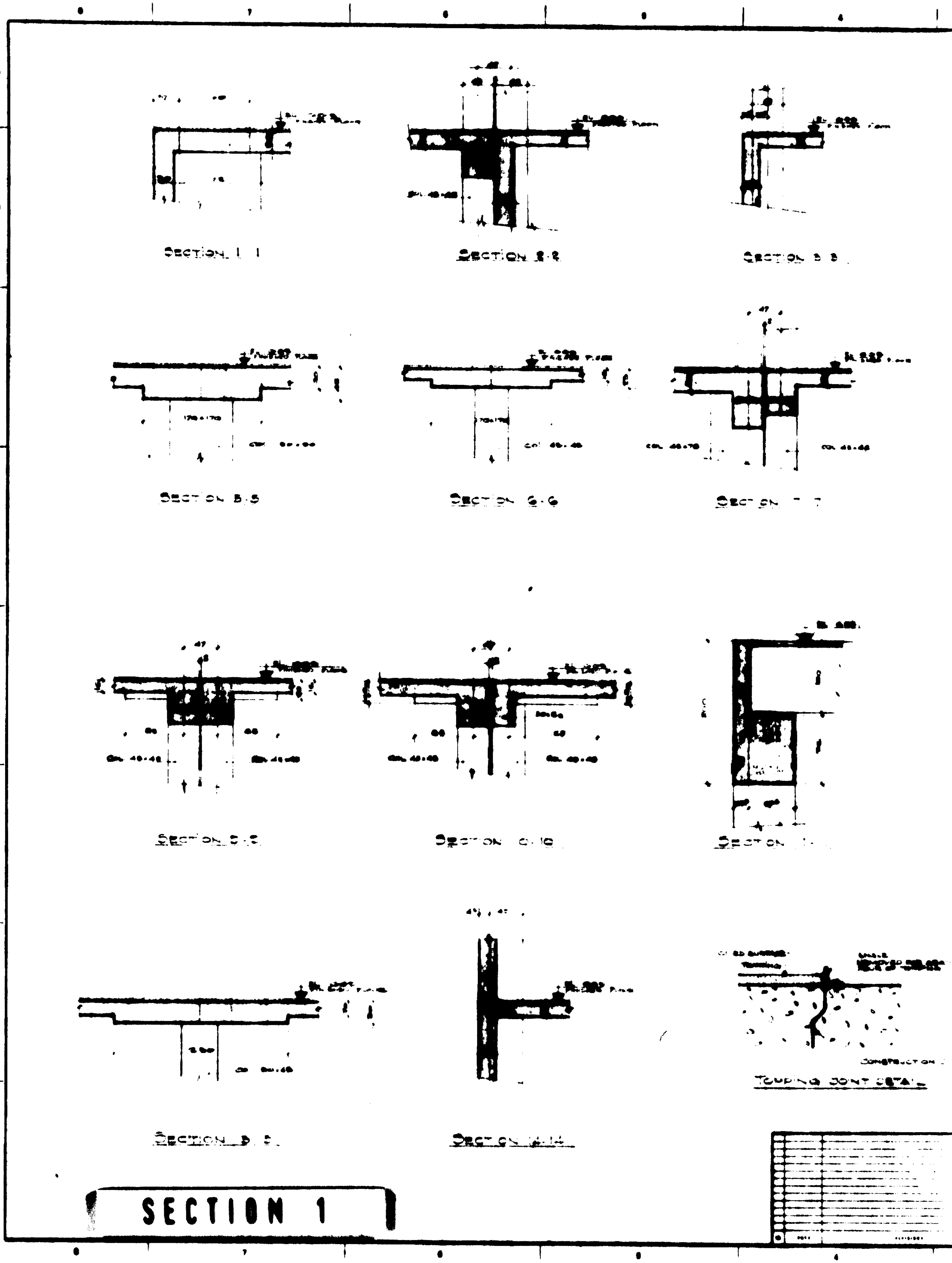


SECTION 2

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE

STRUCTURAL

ROOF PLAN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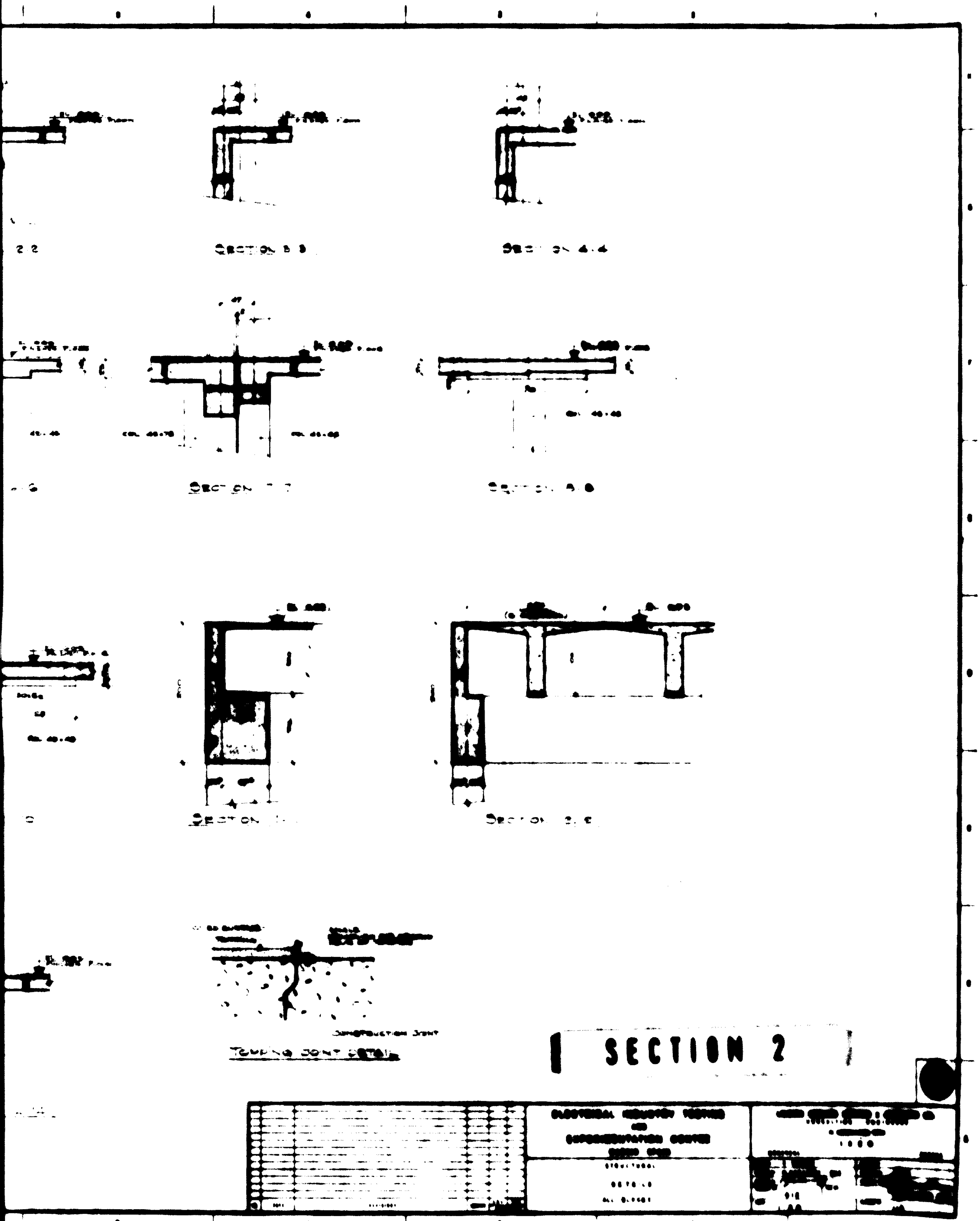
SECTION 2-2
SECTION 5-5
SECTION 6-6
TOPPING JOINT DETAIL
SECTION 1



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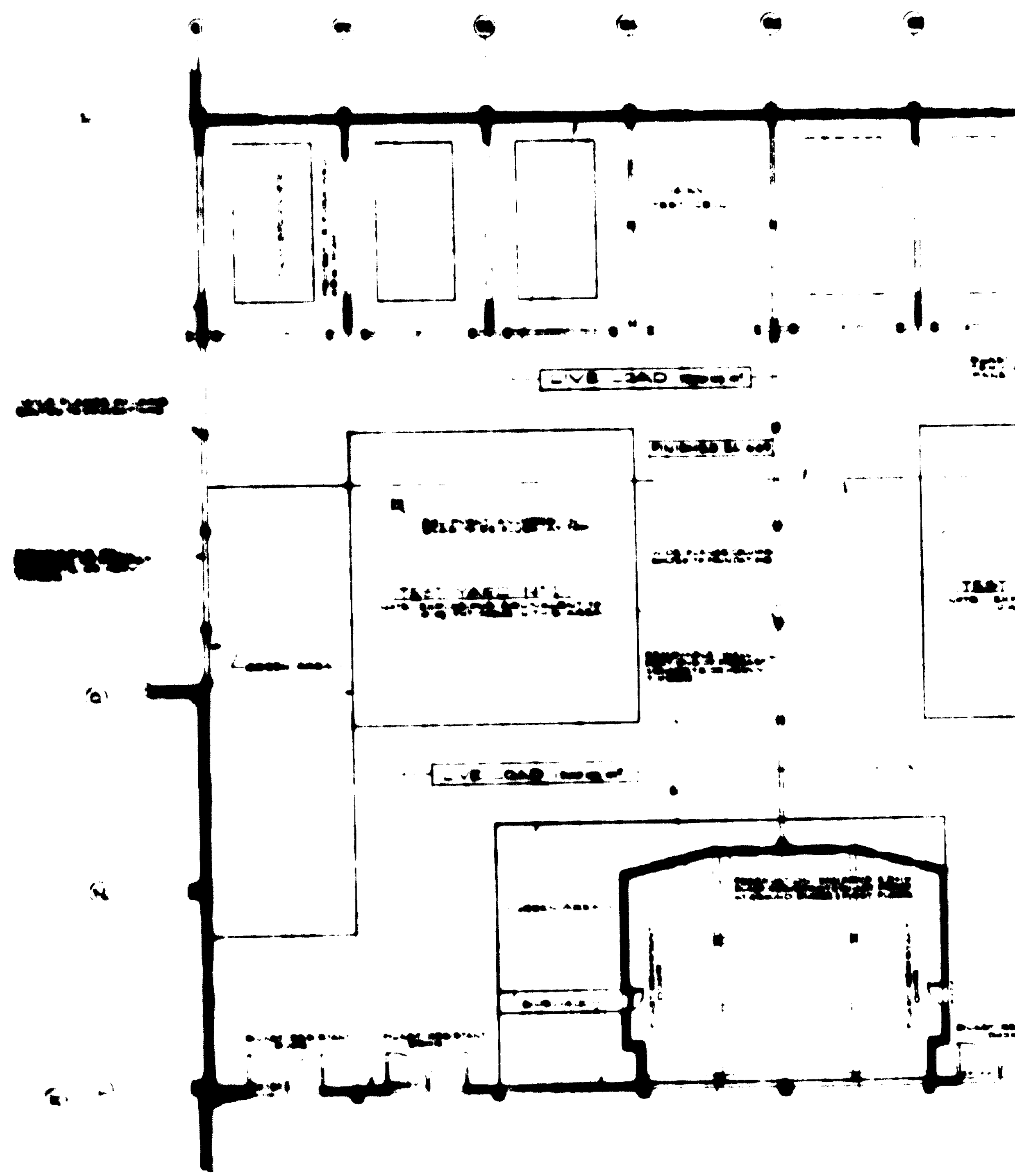

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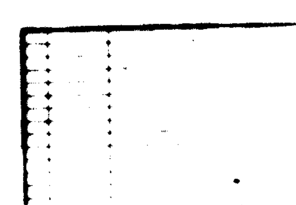

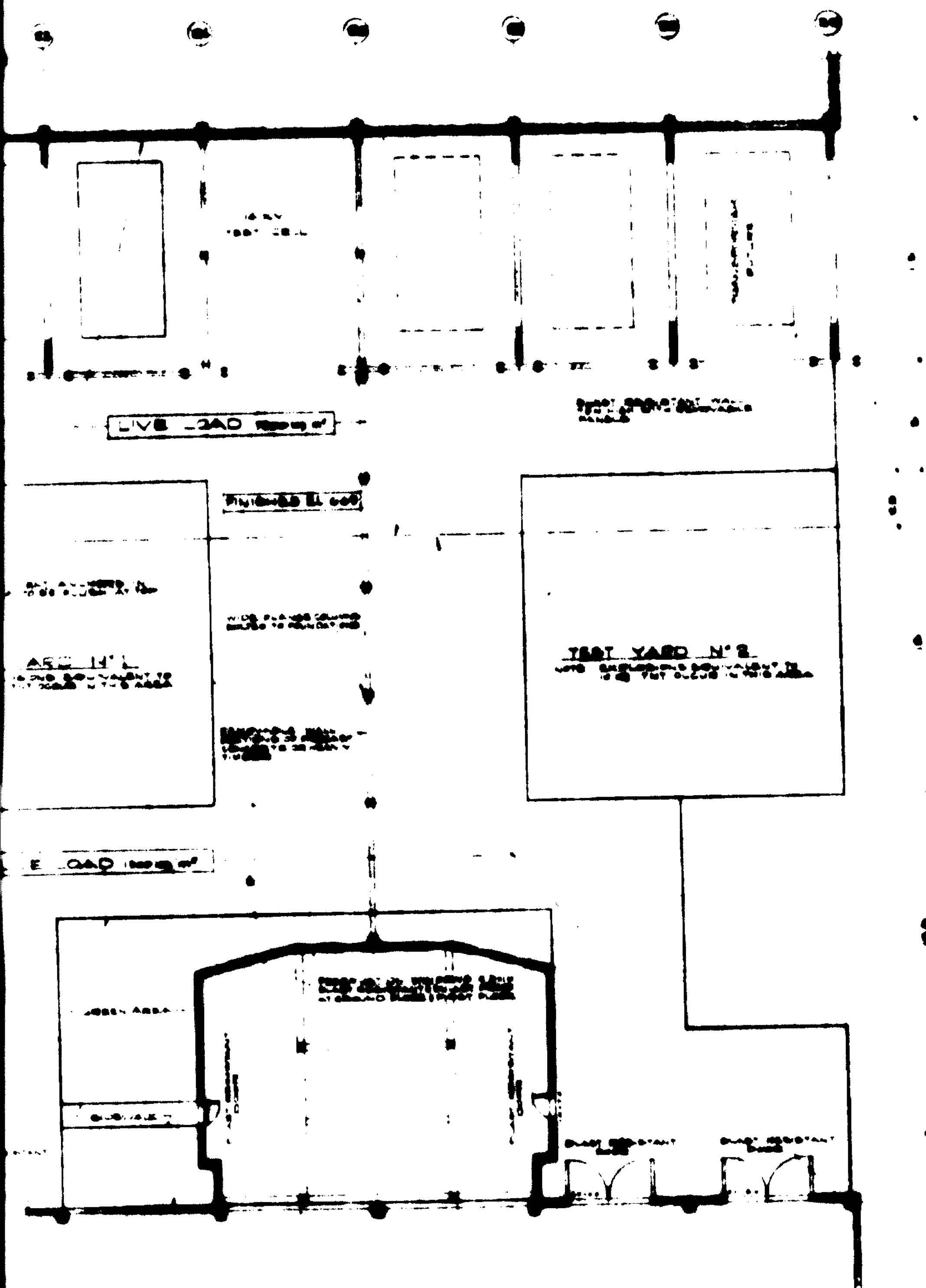

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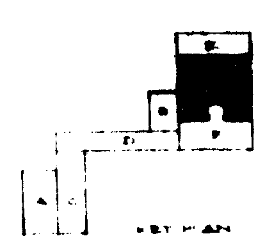
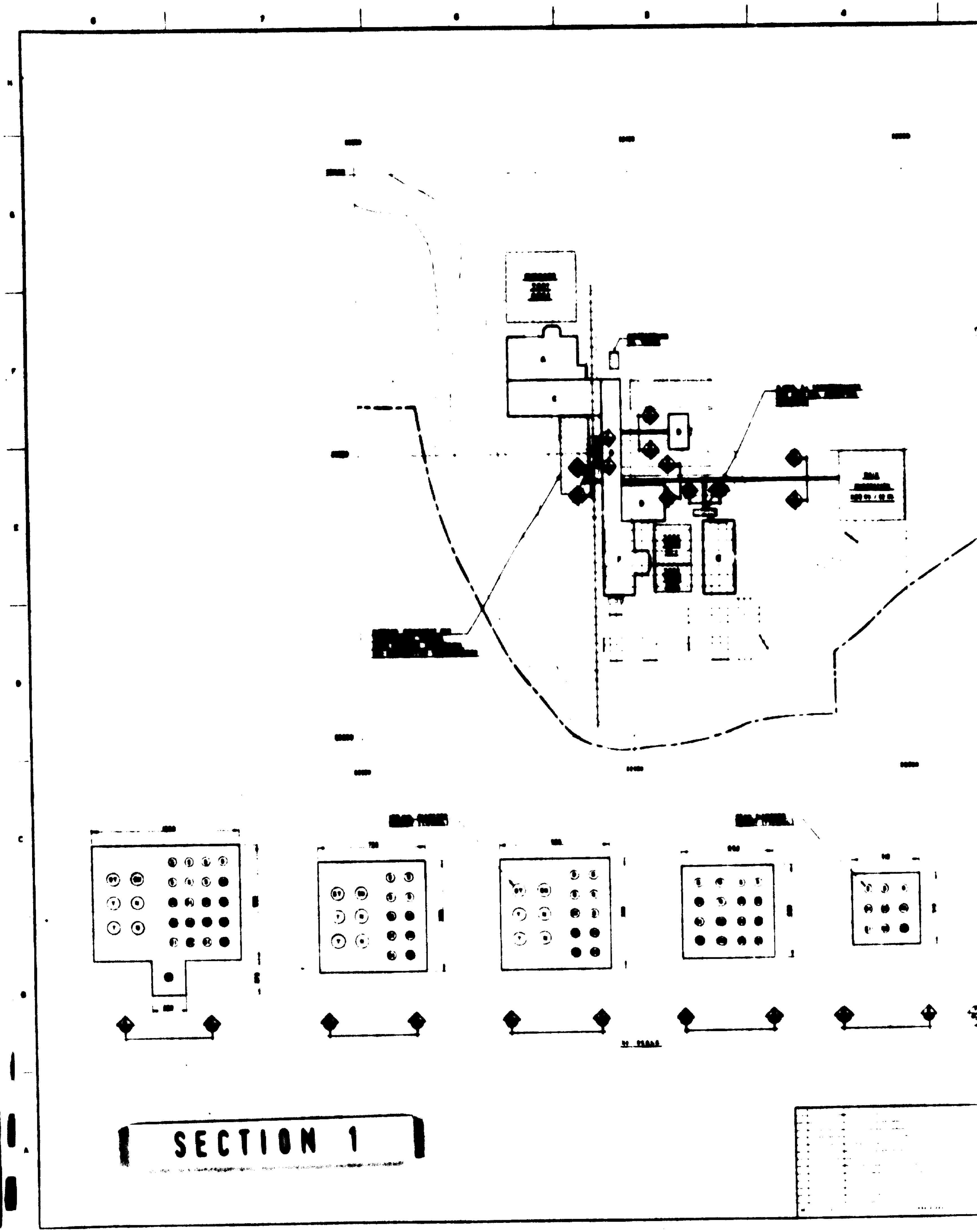


ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID, SPAIN

STRUCTURAL

EXTERIOR TEST YARD



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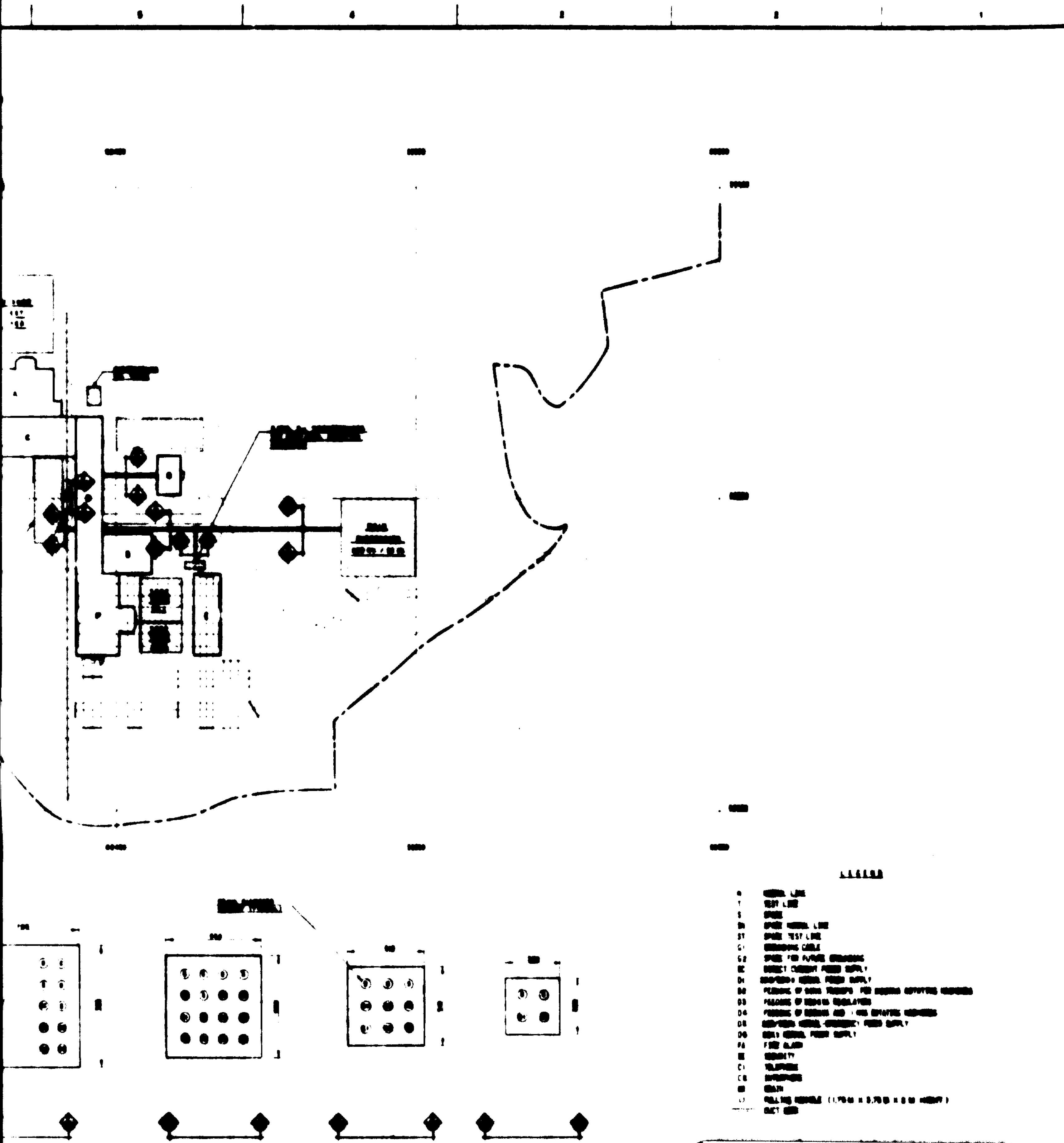
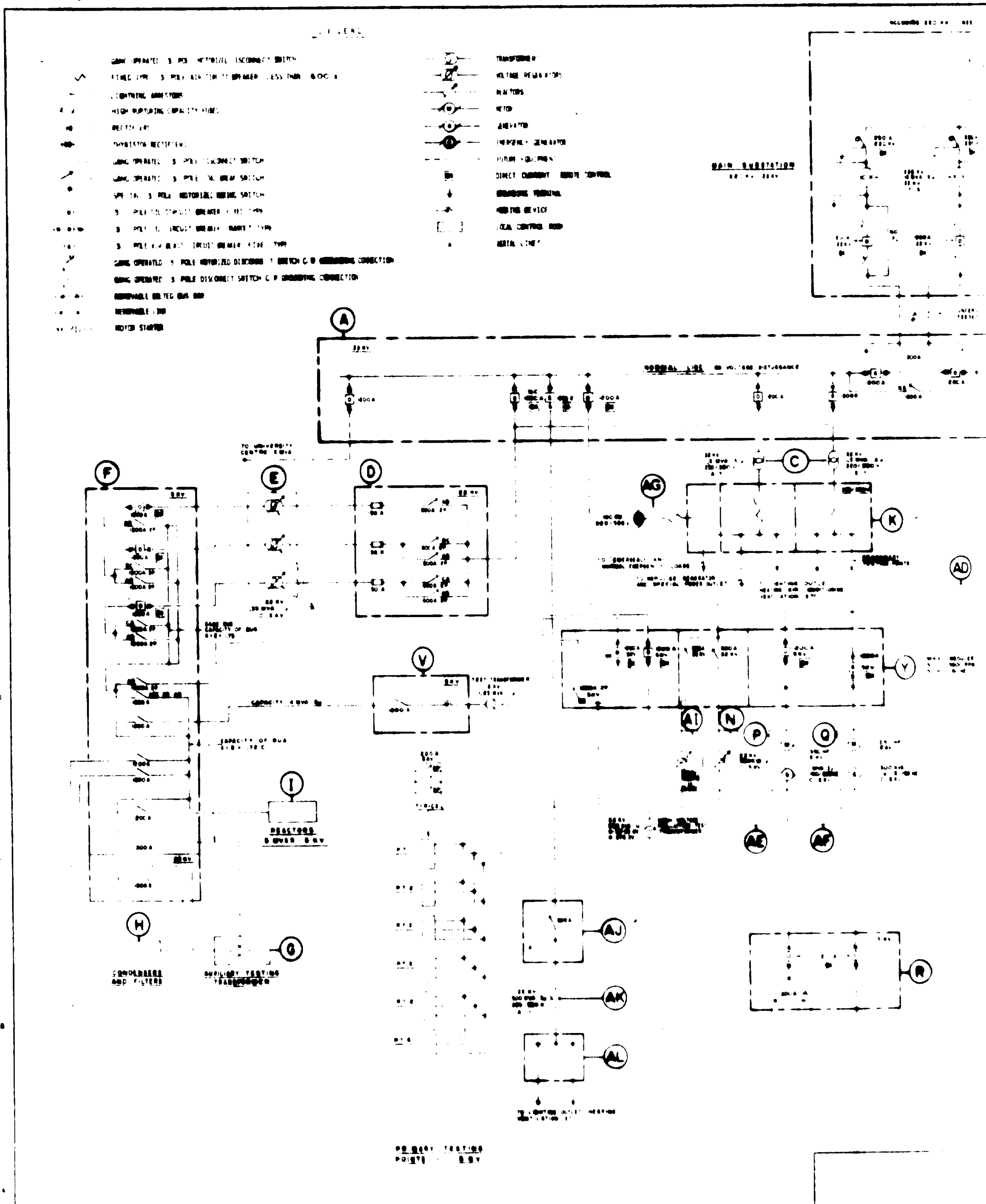


SECTION 2

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID, SPAIN

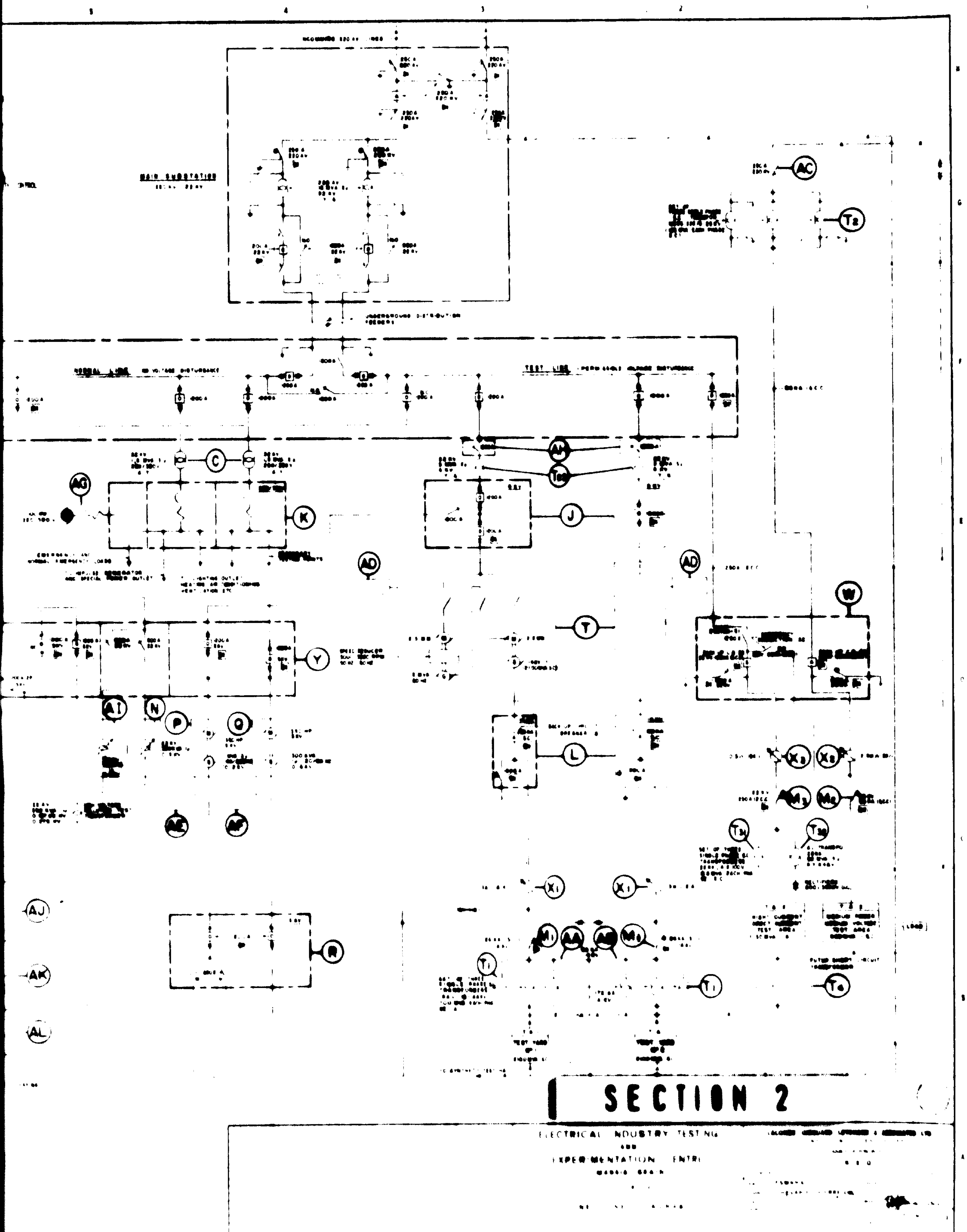
ELECTRICAL

GENERAL LAYOUT &
UNDERGROUND DISTRIBUTION

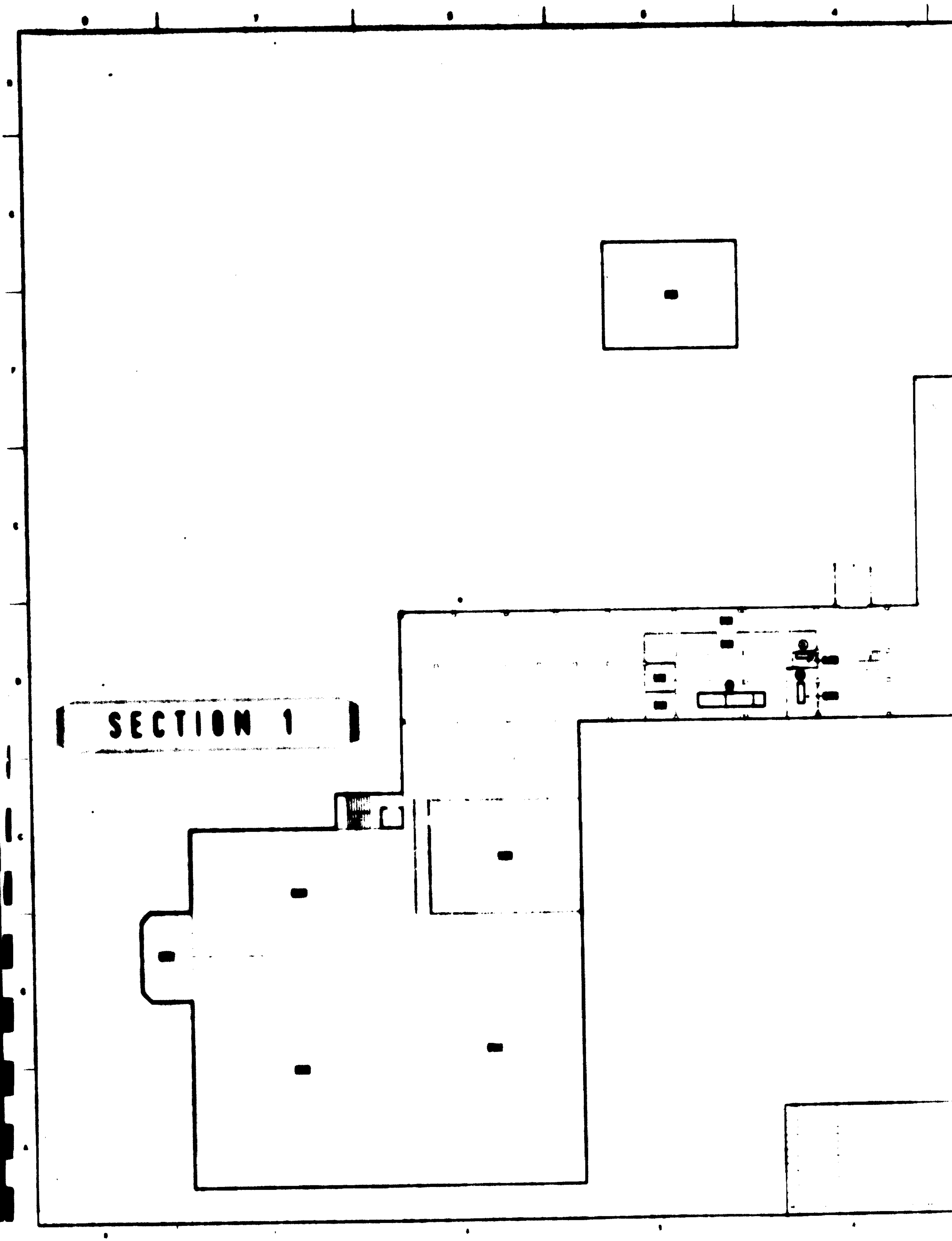


MAIN SUBSTATION
TRANSFORMER
REACTORS
MOTOR
MOTOR STARTER
REACTORS
CONDENSERS AND FILTERS
AUXILIARY TESTING TRANSFORMER
PRIMARY TESTING POINTS
A
C
D
E
F
G
H
I
K
V
Y
R
N
P
Q
AD
AG
AI
AJ
AK
AL

SECTION 1



MAIN SUBSTATION
NORMAL LINE
TEST LINE
SECTION 2
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN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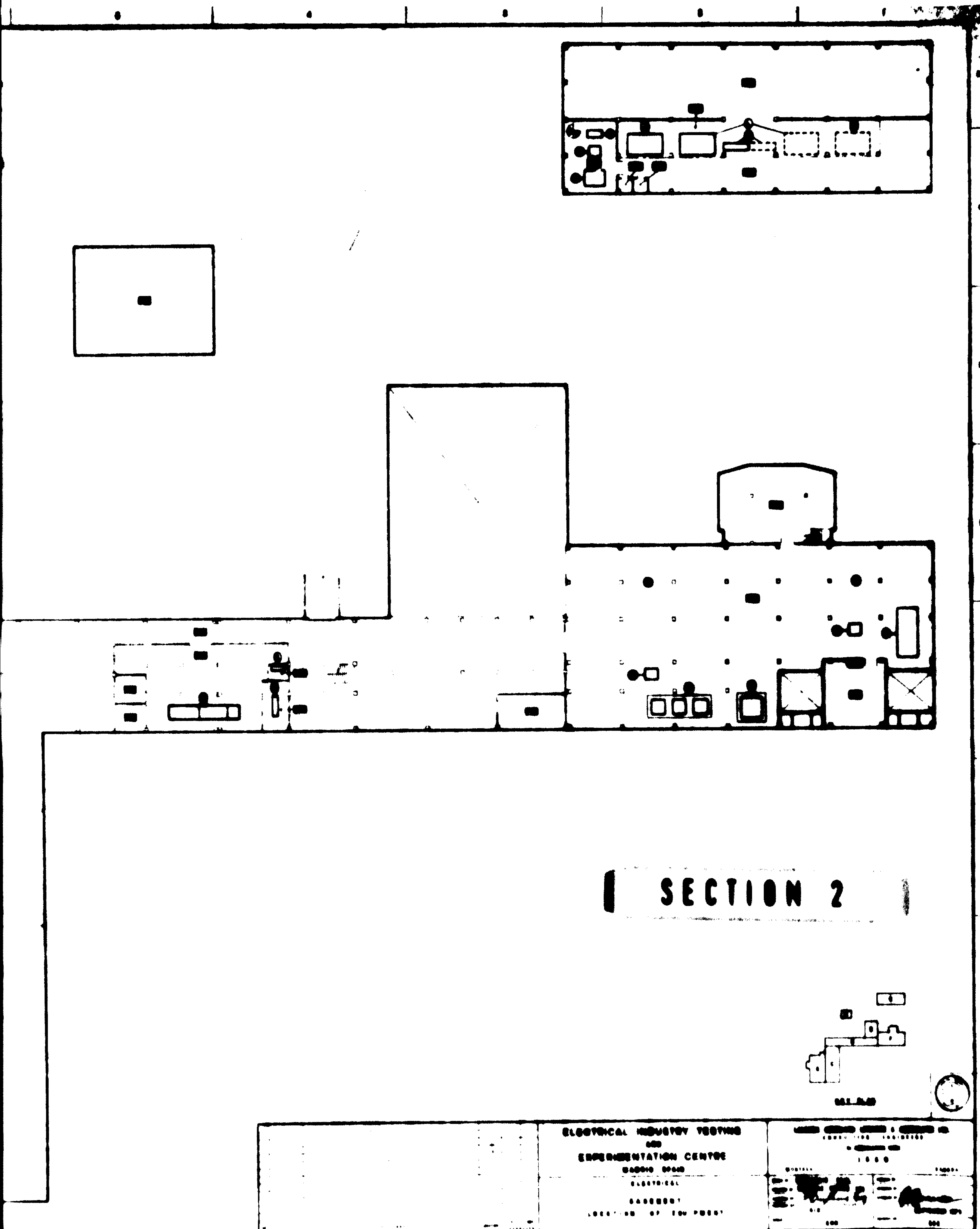
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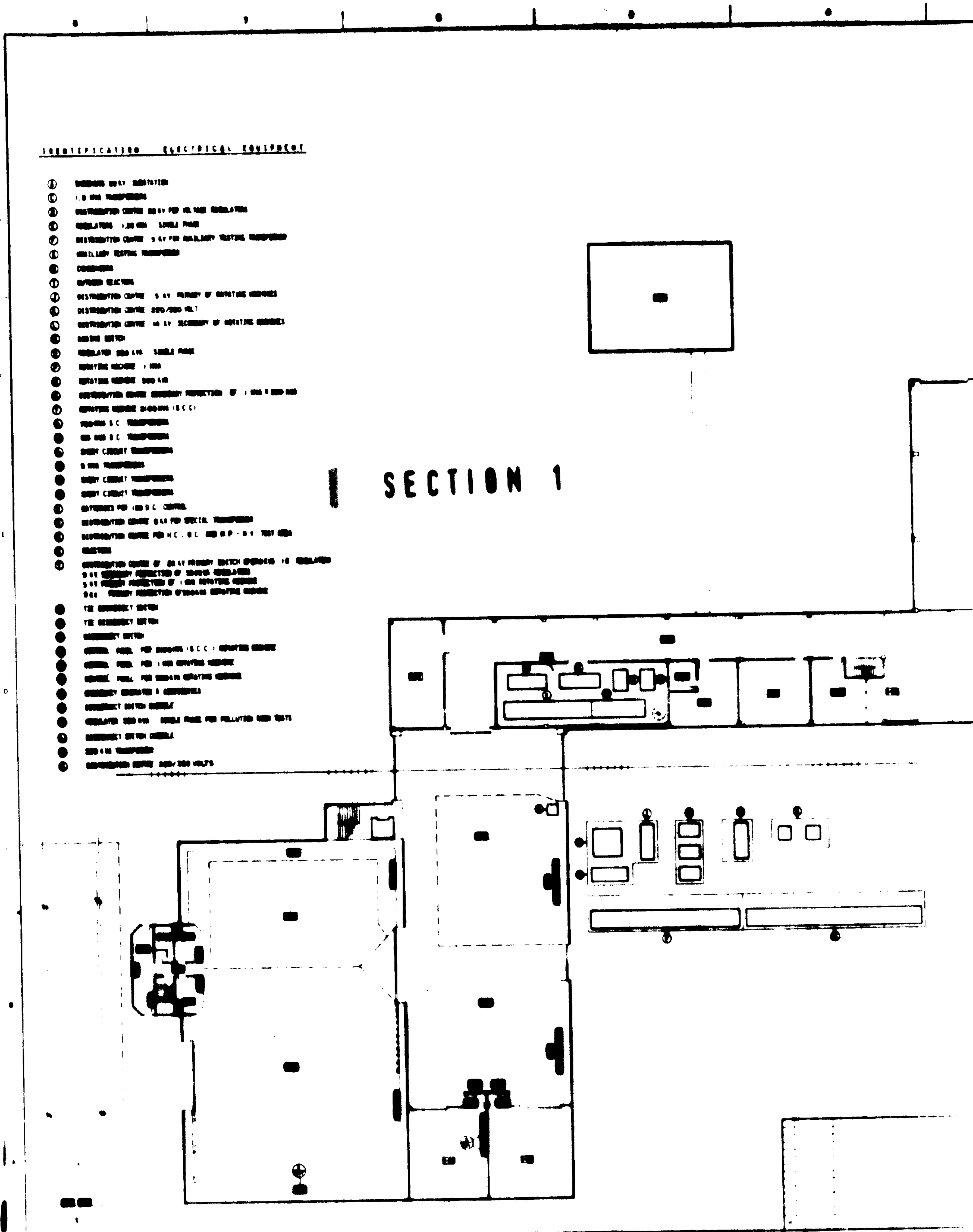
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
ELECTRICAL
BASEMENT
LOCATION OF EQUIPMENT



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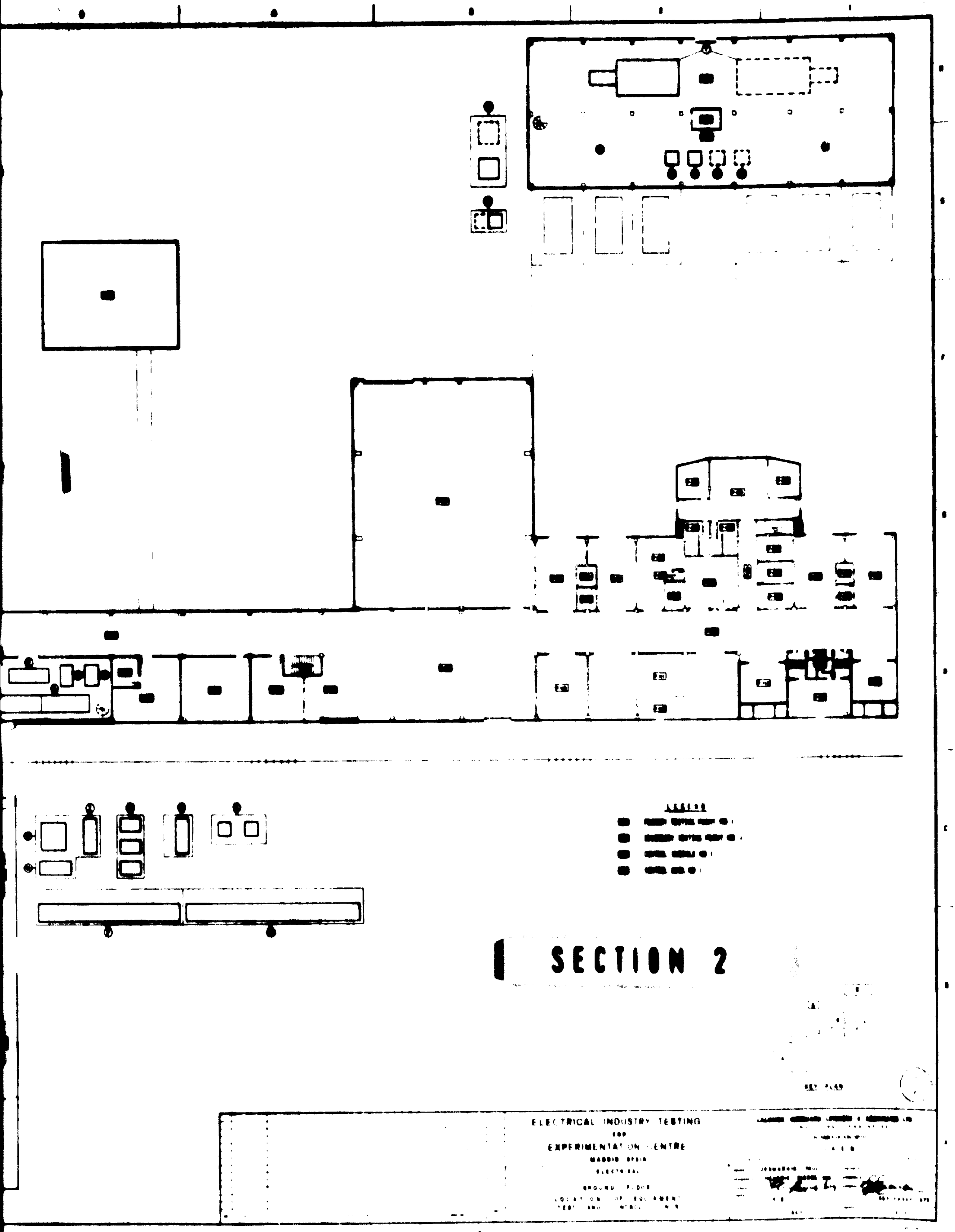
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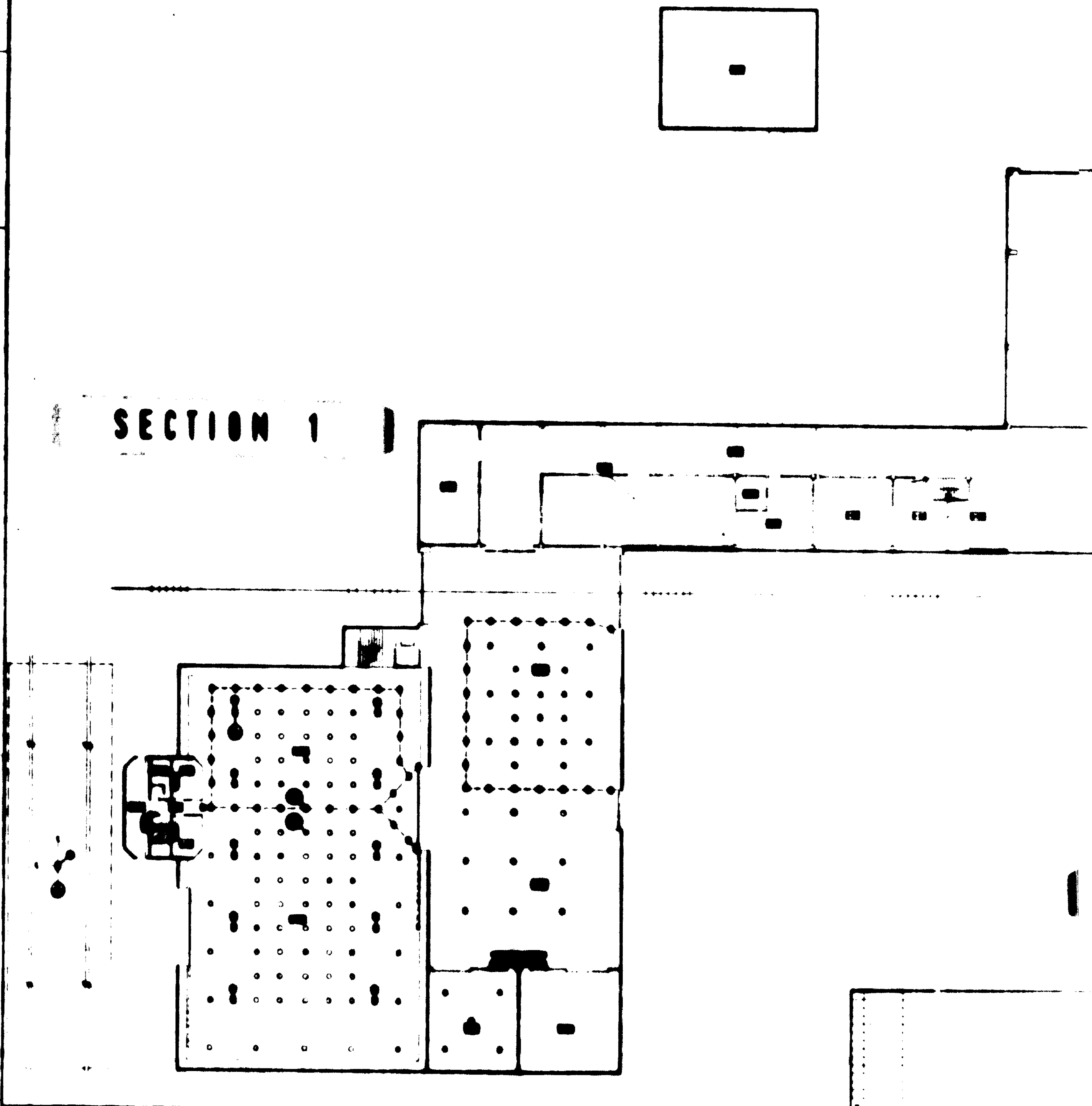
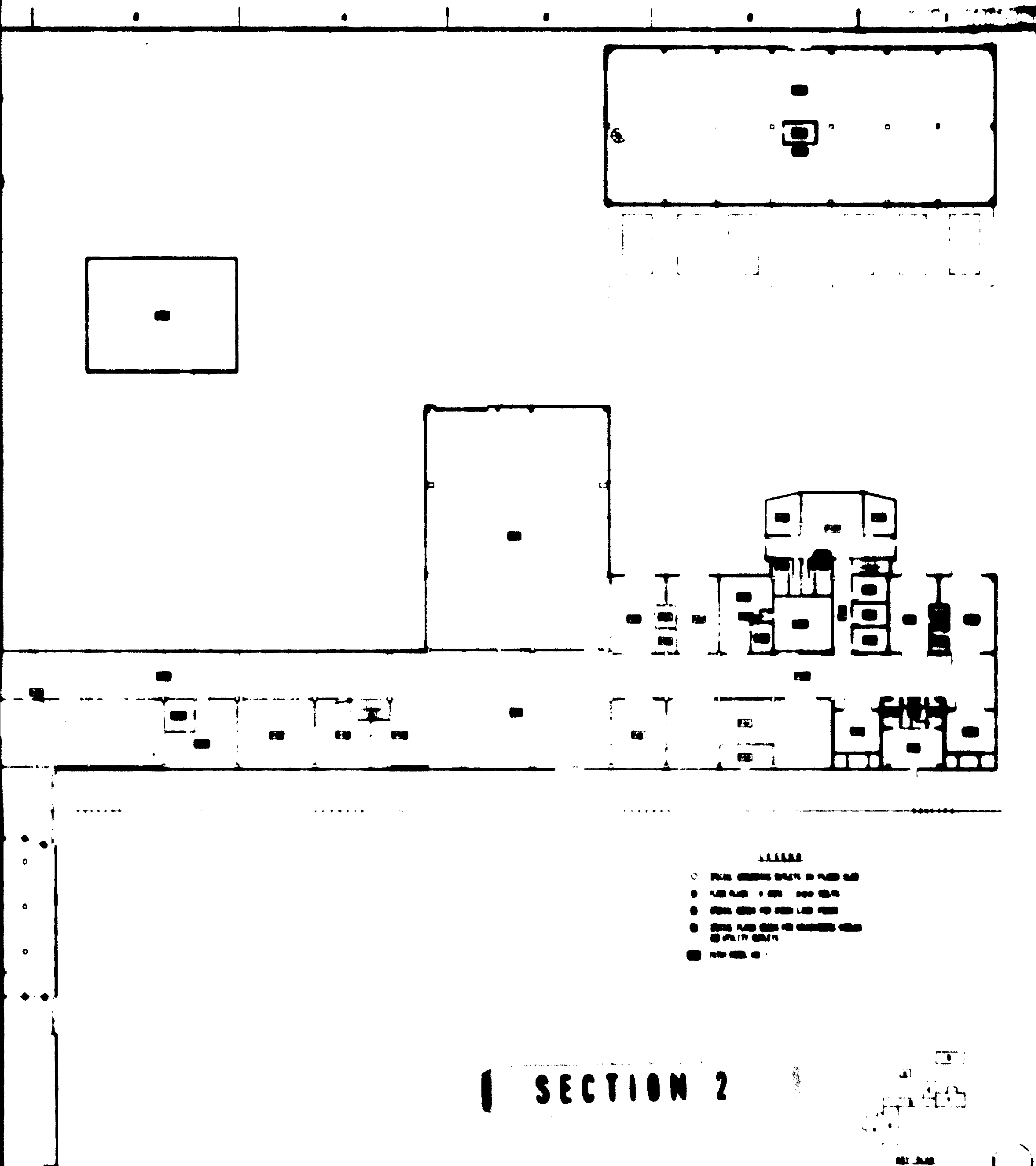
KEY PLAN
ELECTRICAL INDUSTRY TESTING
EXPERIMENTATION CENTRE
GROUND FLOOR

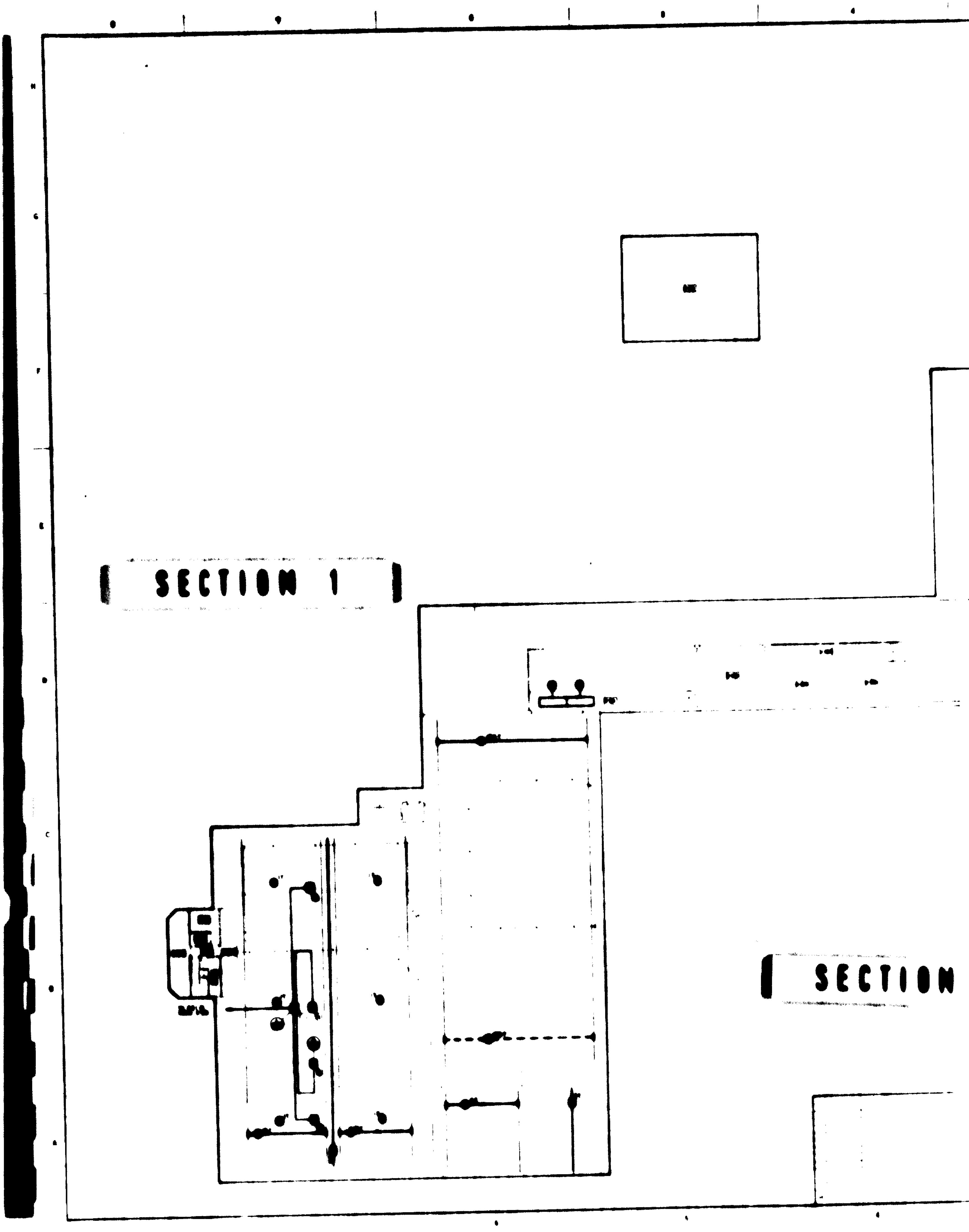
SECTION 1





SECTION 2

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE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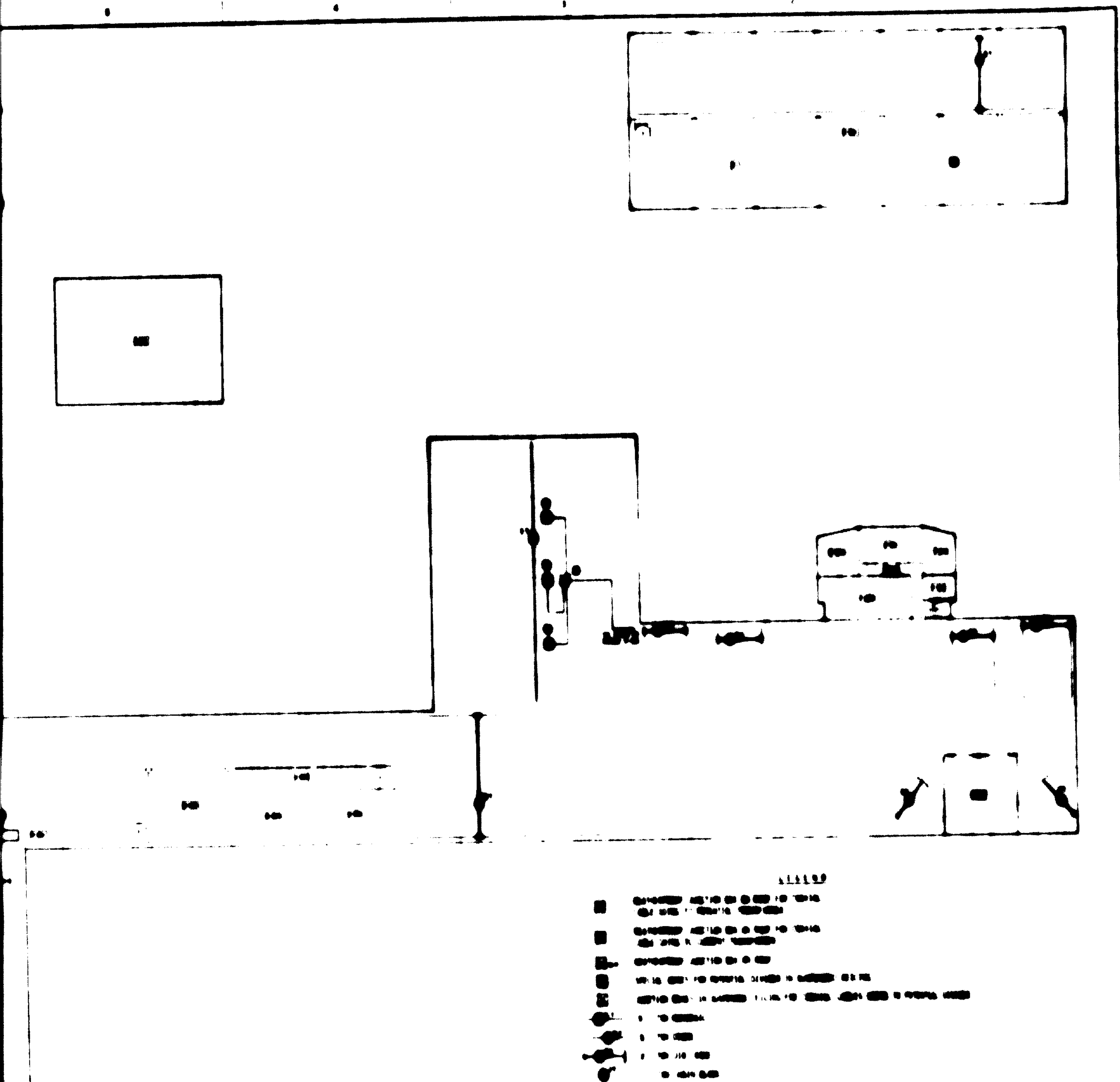
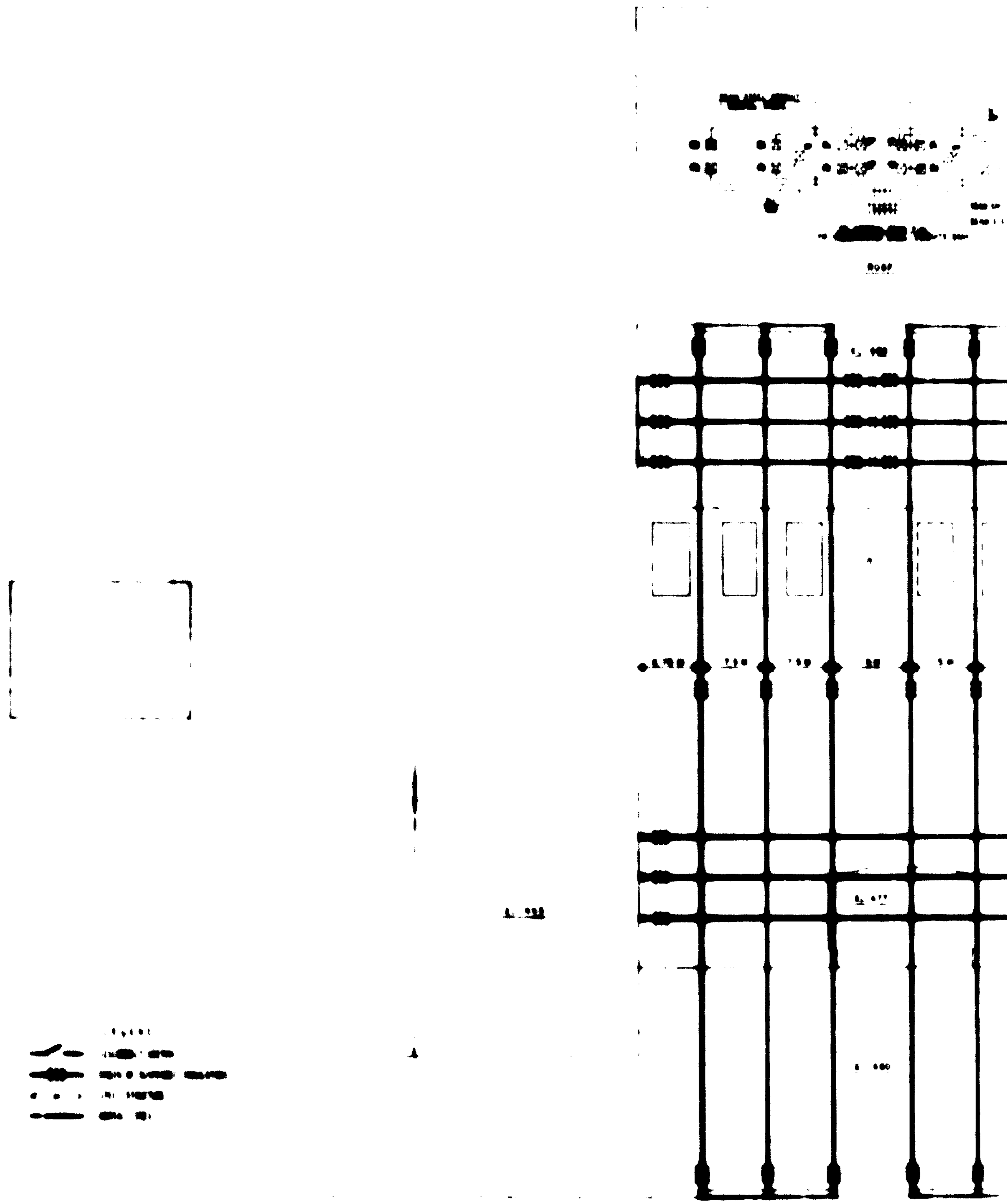
SECTION



SECTION 2

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE



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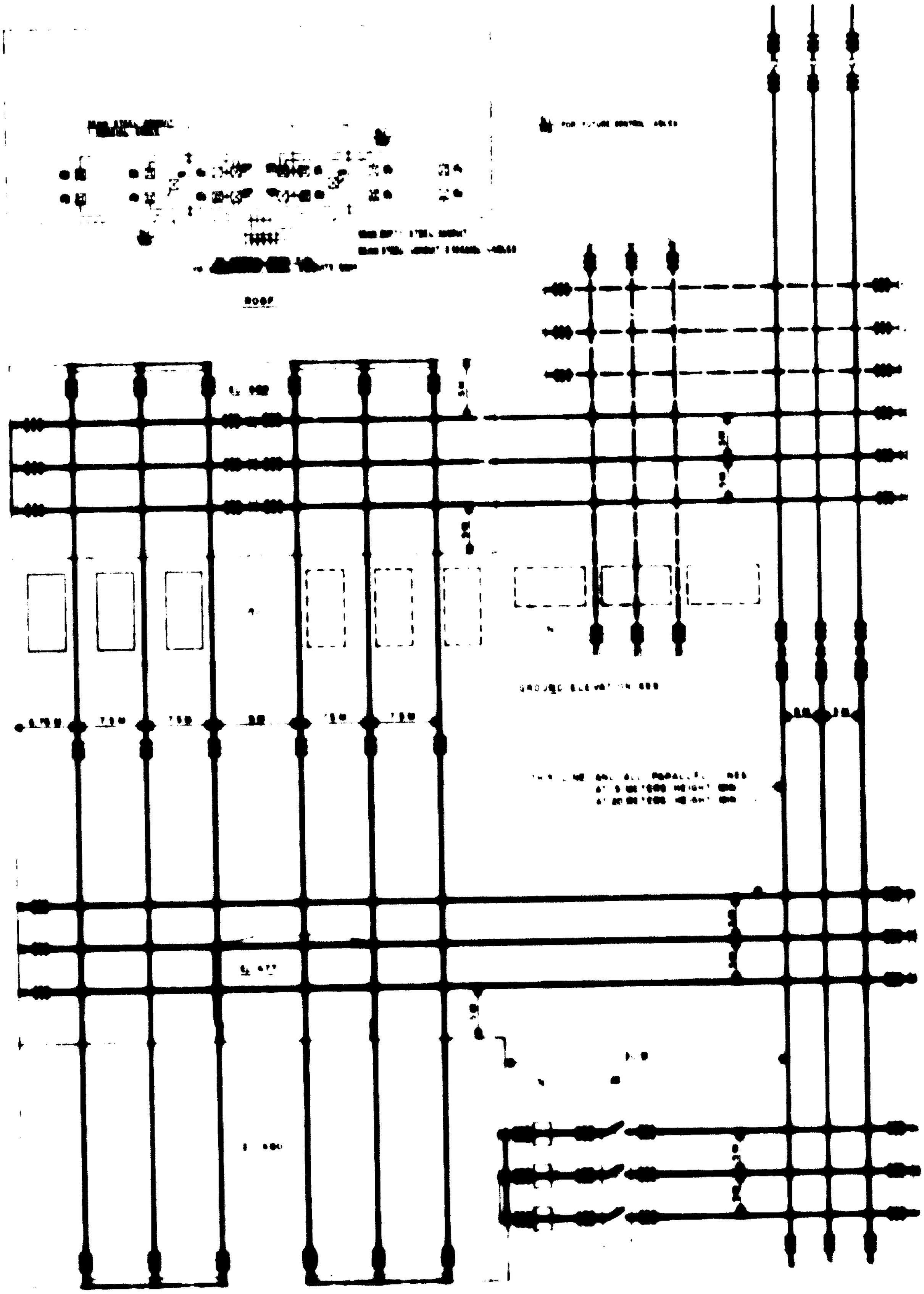
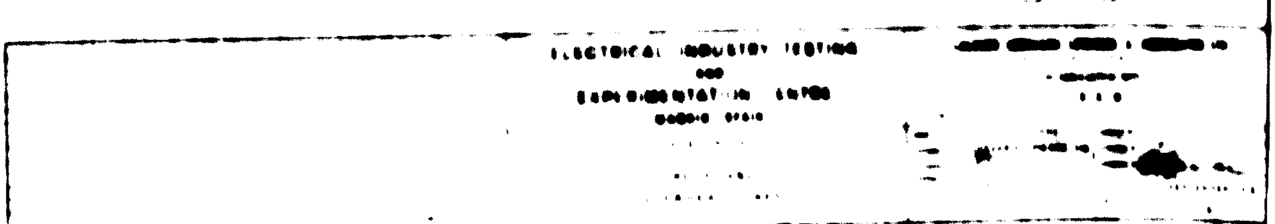
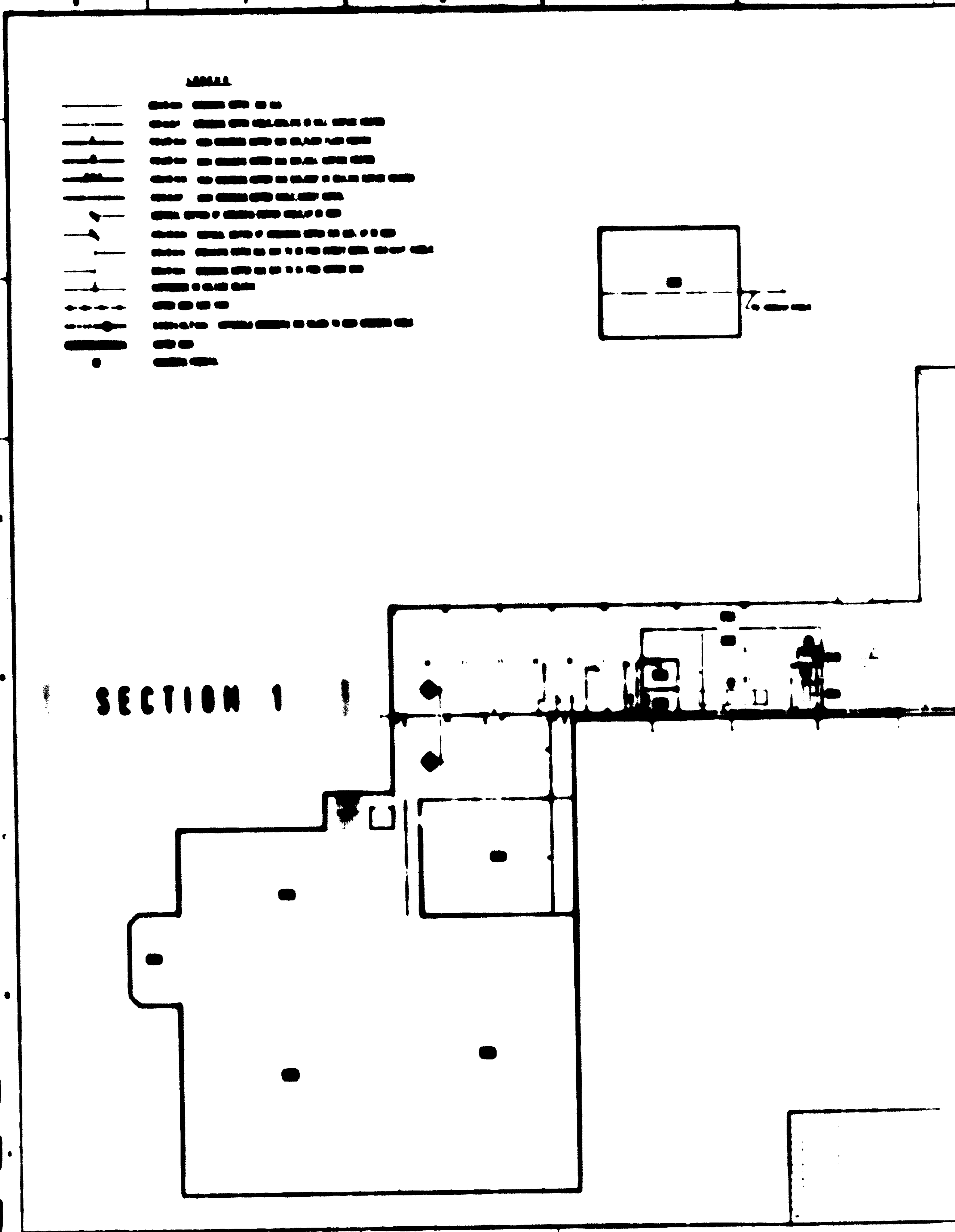

ROOF

SECTION 2


ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTER
MADRID SPAIN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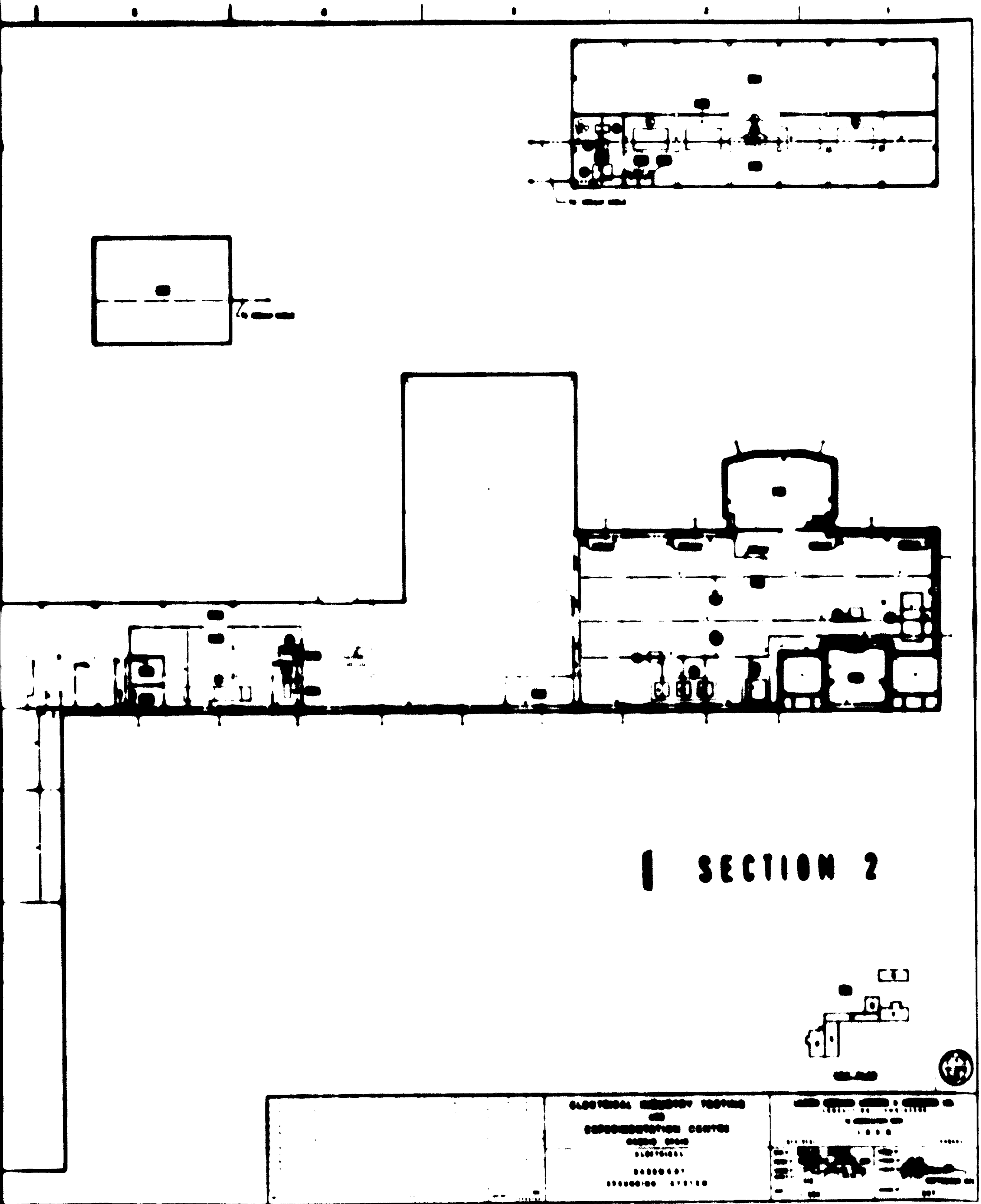
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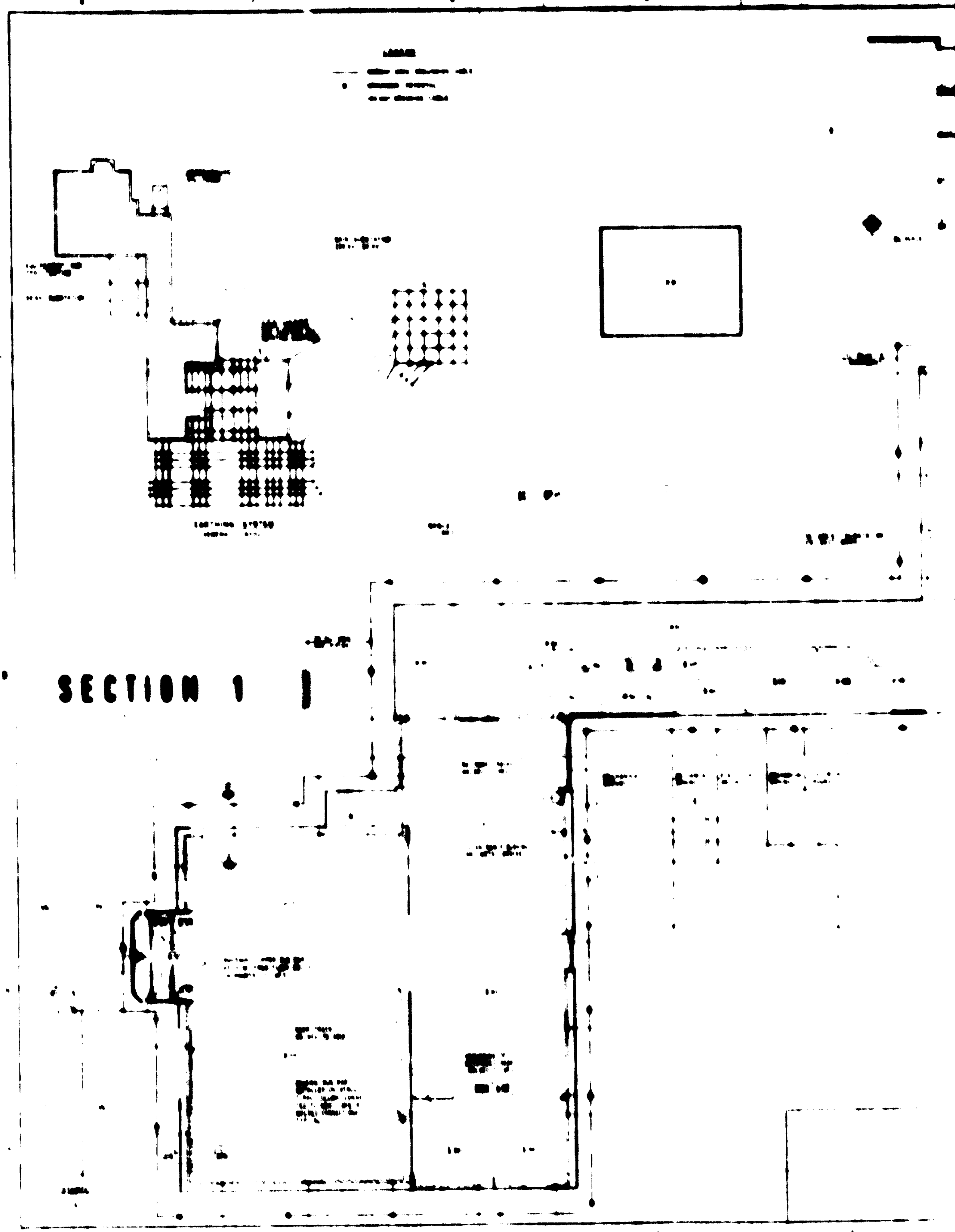
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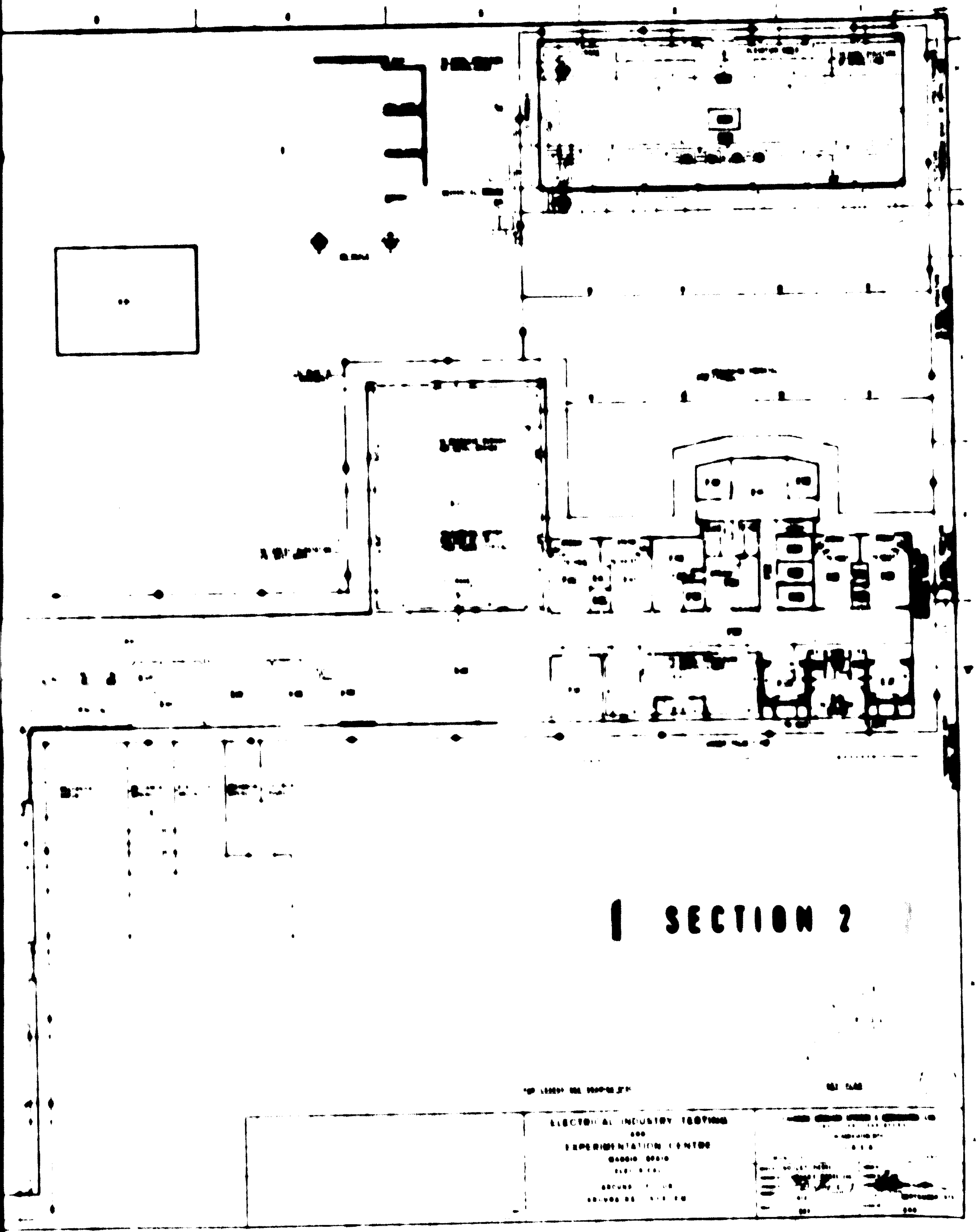

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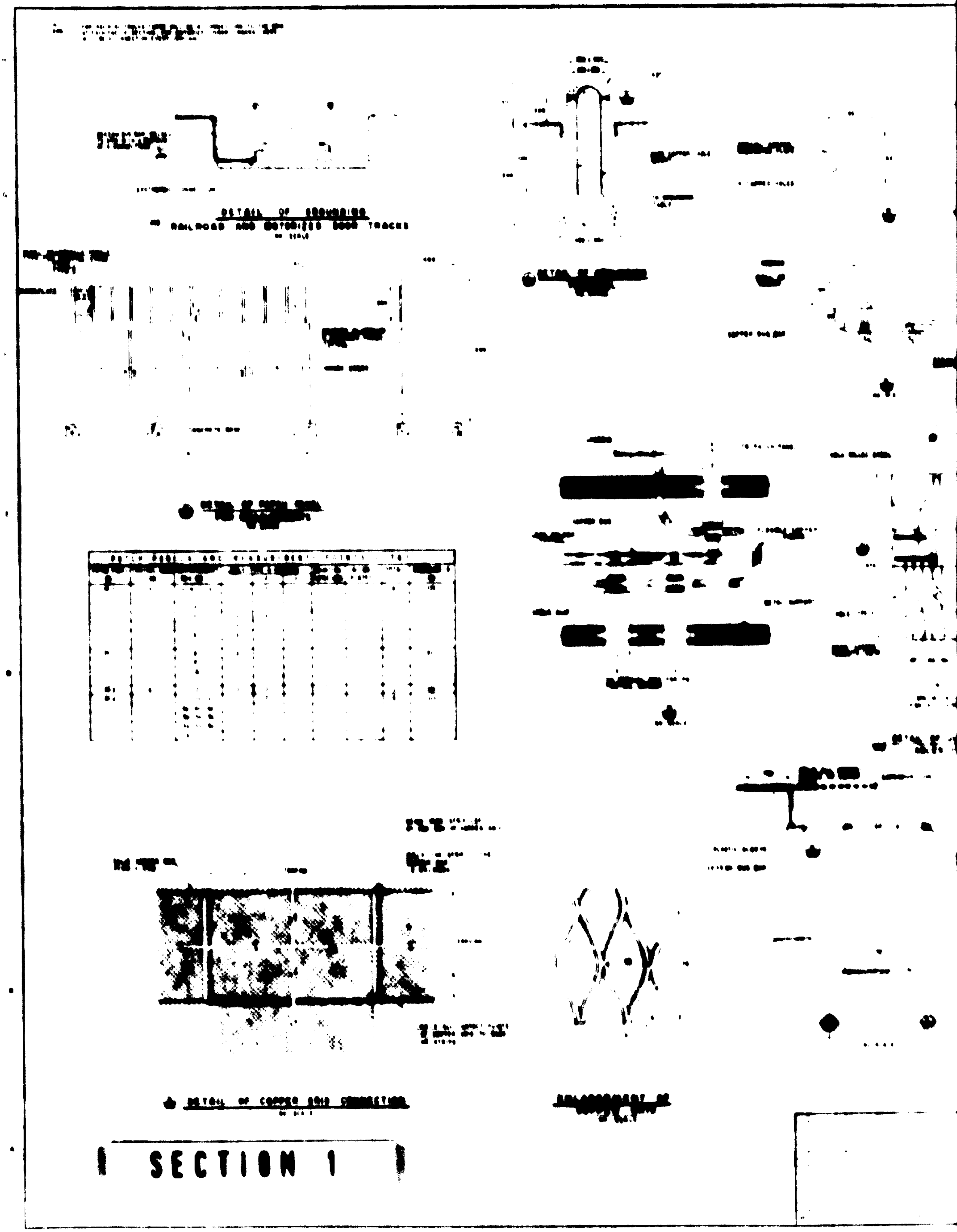
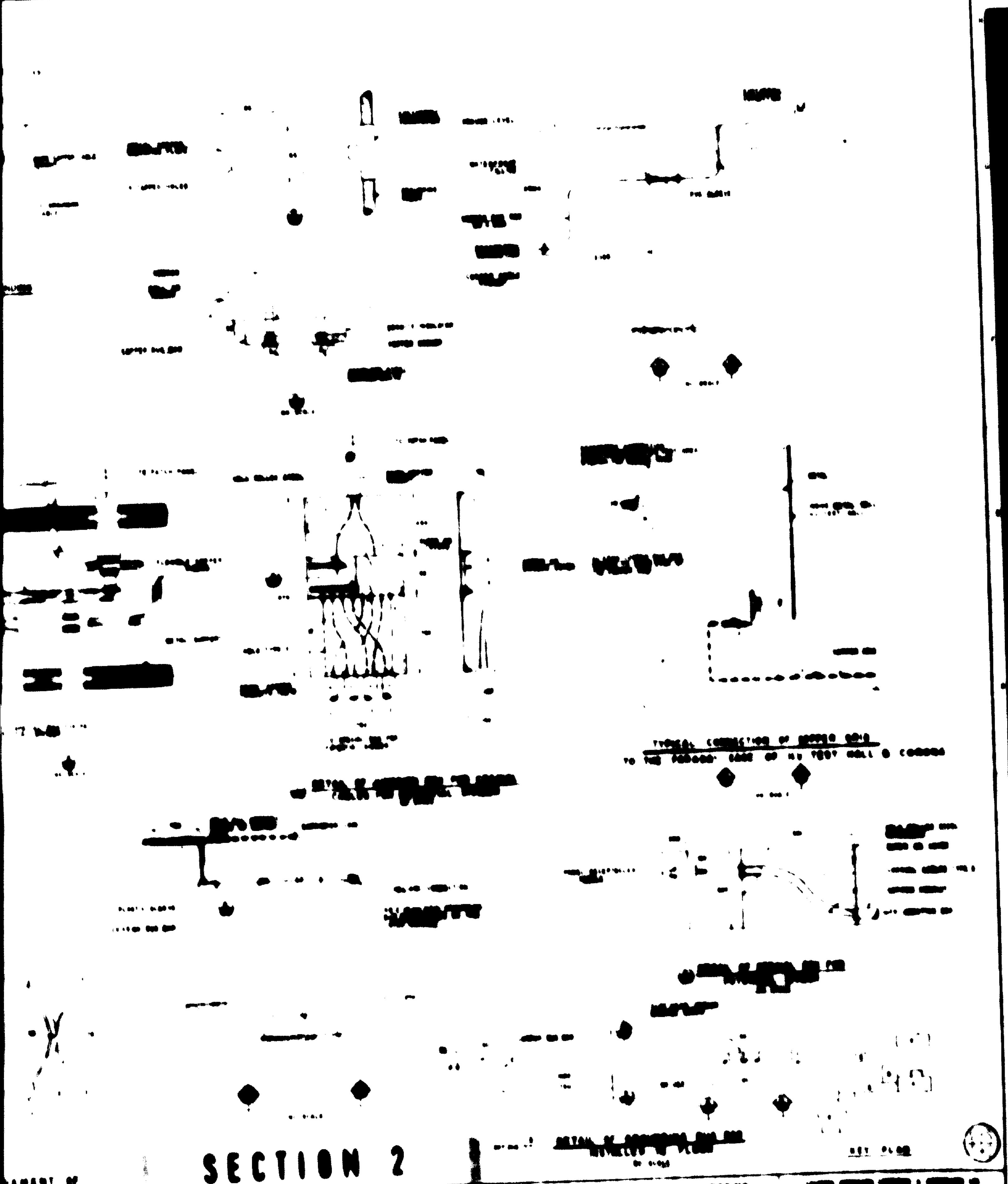
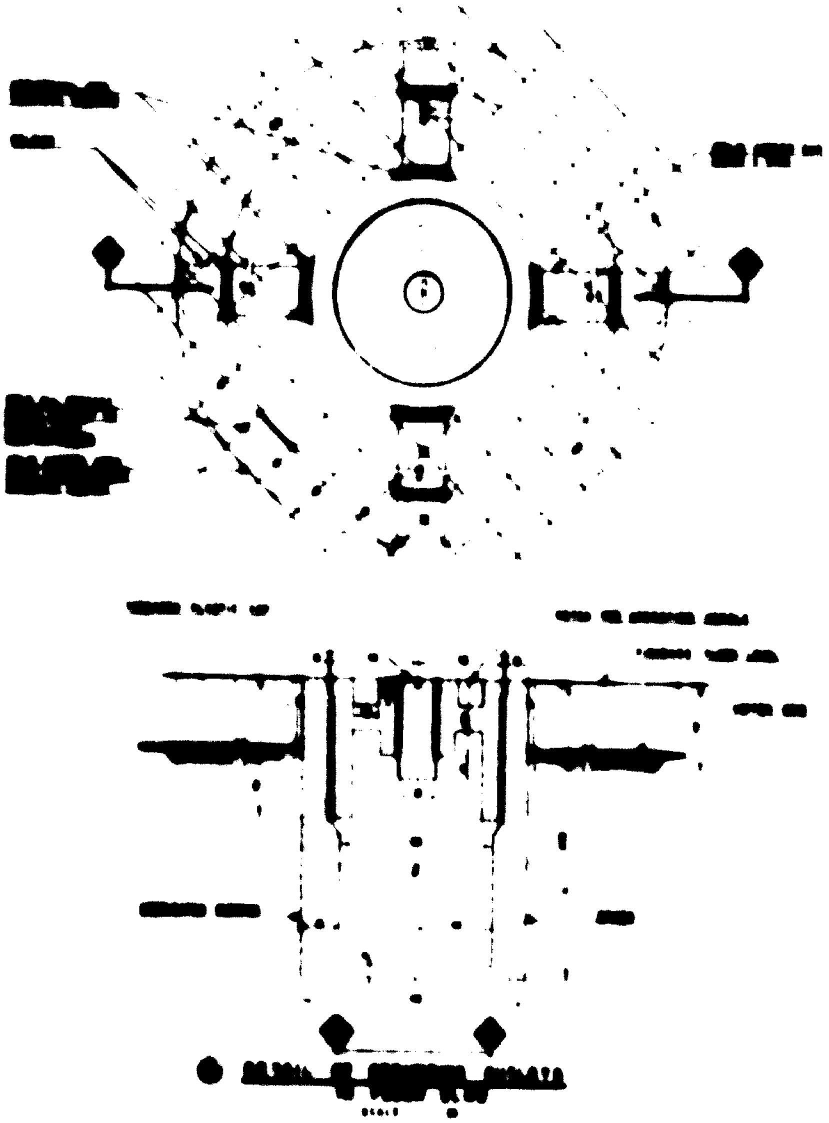
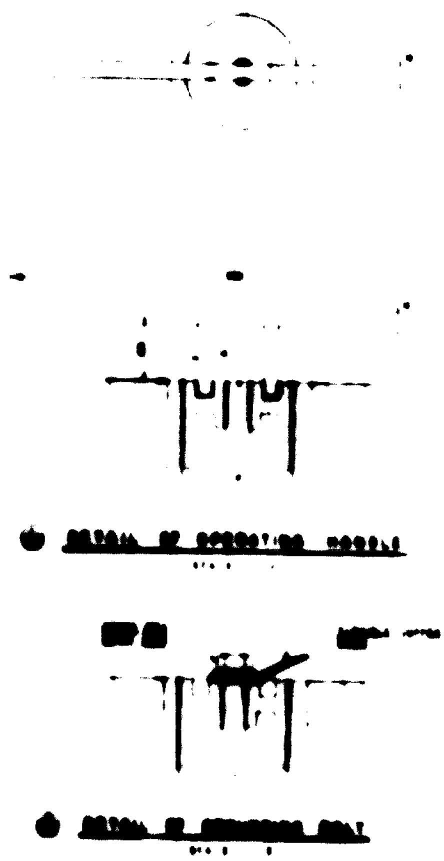

DETAIL OF GROUNDING
RAILROAD AND MOTORIZED DOOR TRACKS
DETAIL OF COPPER GRID CONNECTION
SECTION 1



ELECTRICAL INDUSTRY TESTING

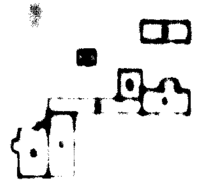
EXPERIMENTATION CENTRE





SECTION 1

SECTION 2



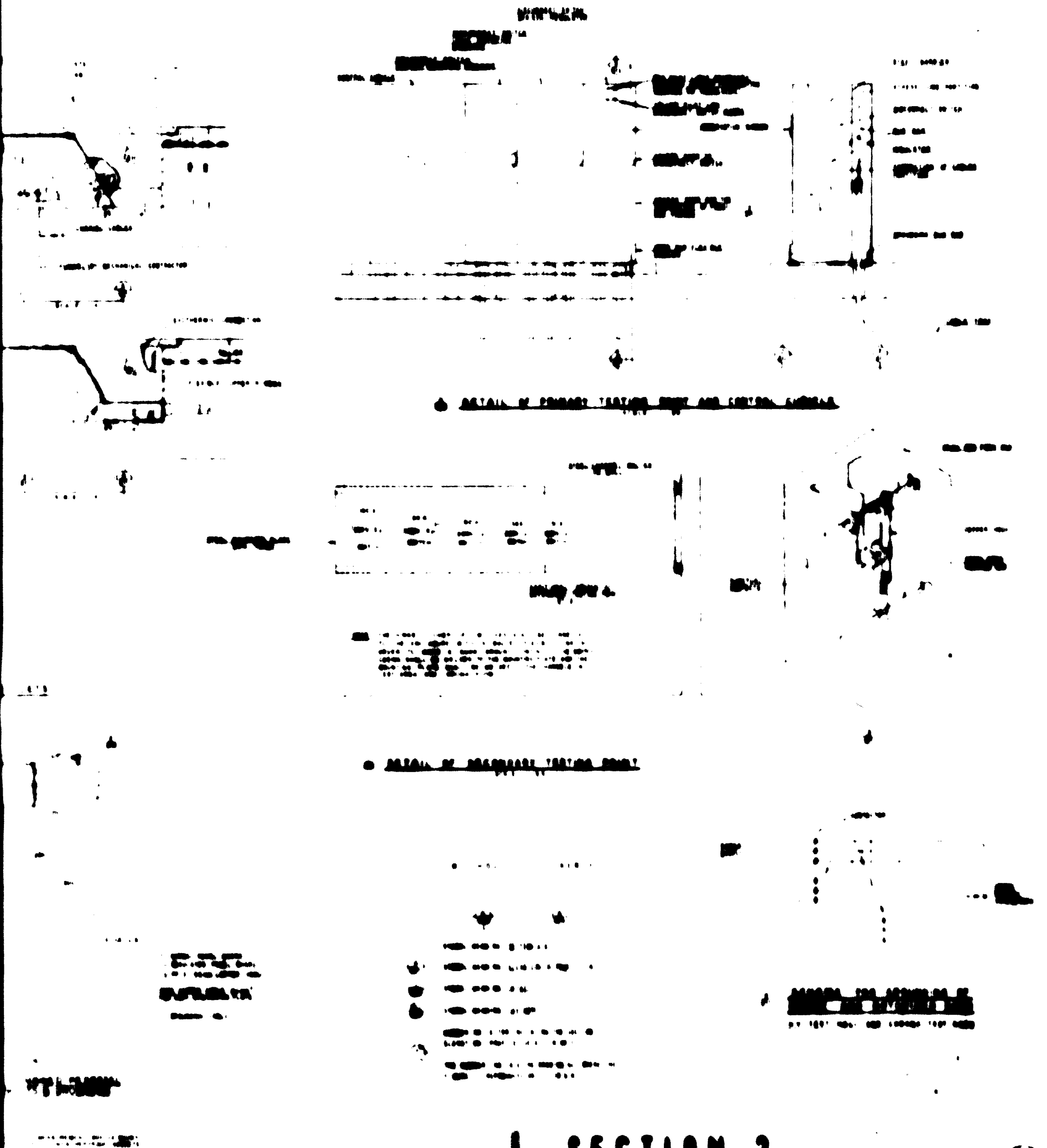
KEY PLAN

ELECTRICAL INDUSTRY TESTING AND EXPERIMENTATION CENTER

ELECTRICAL

DETAILS

SECTION 1



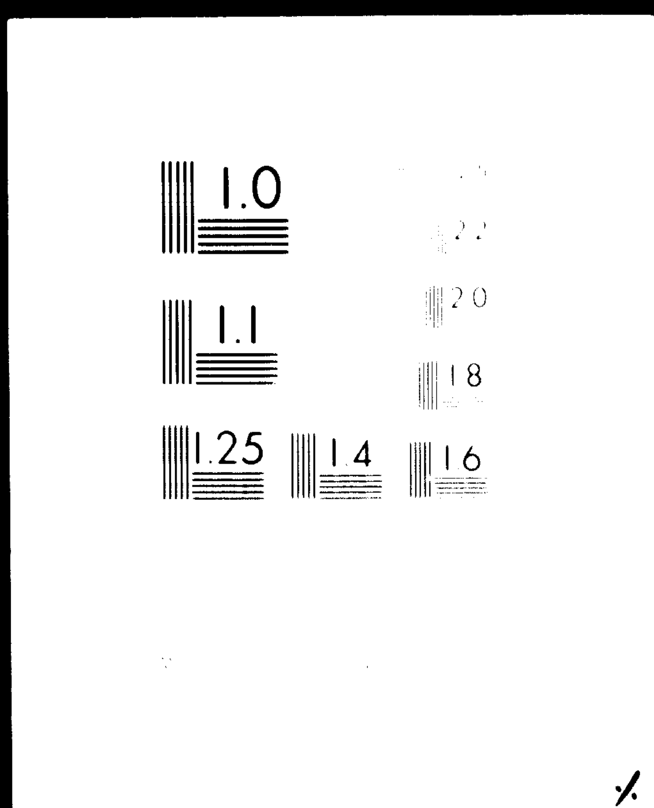
SECTION 2

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

B-055

83.04.05
AD 83.01

6 OF 6



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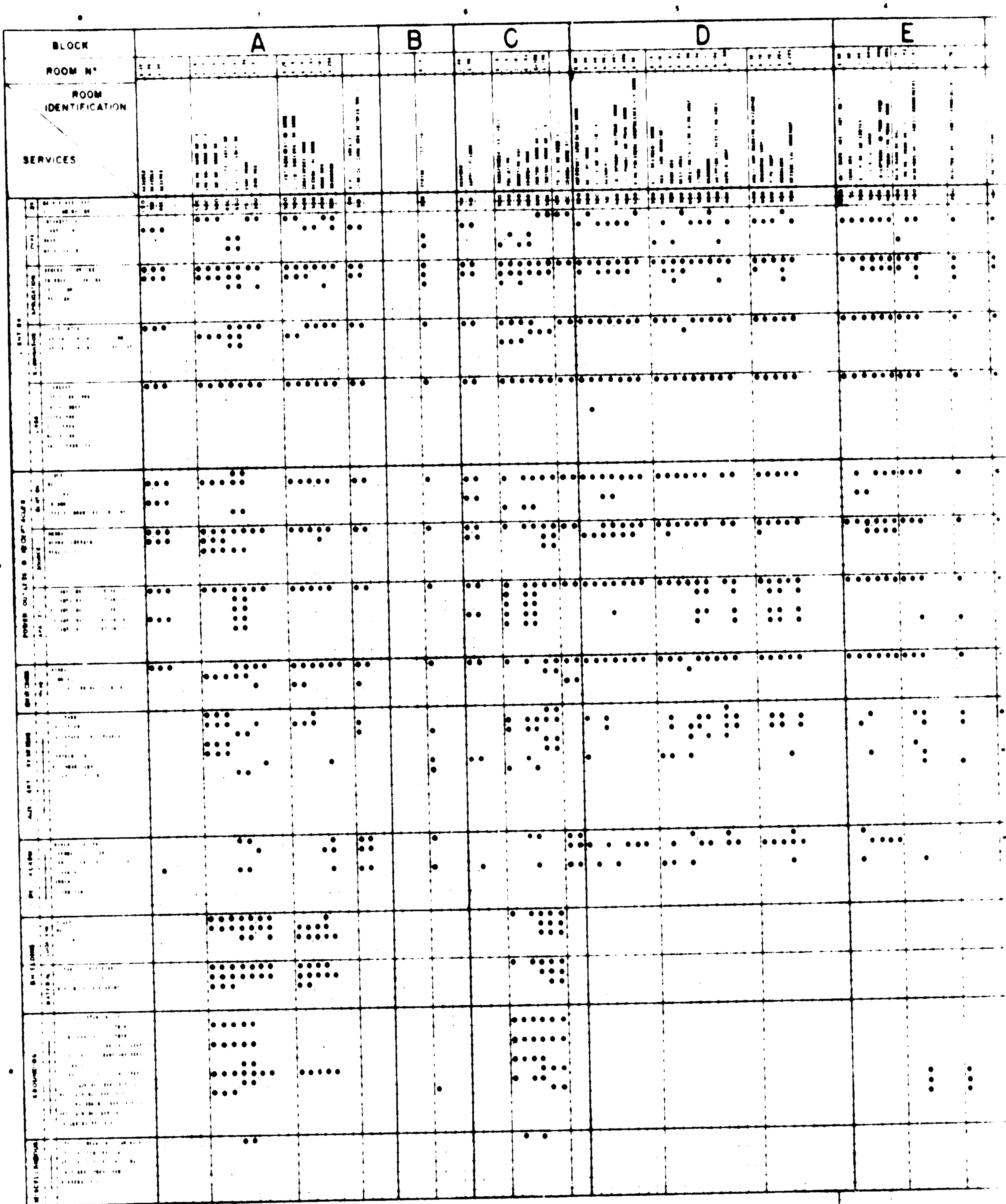
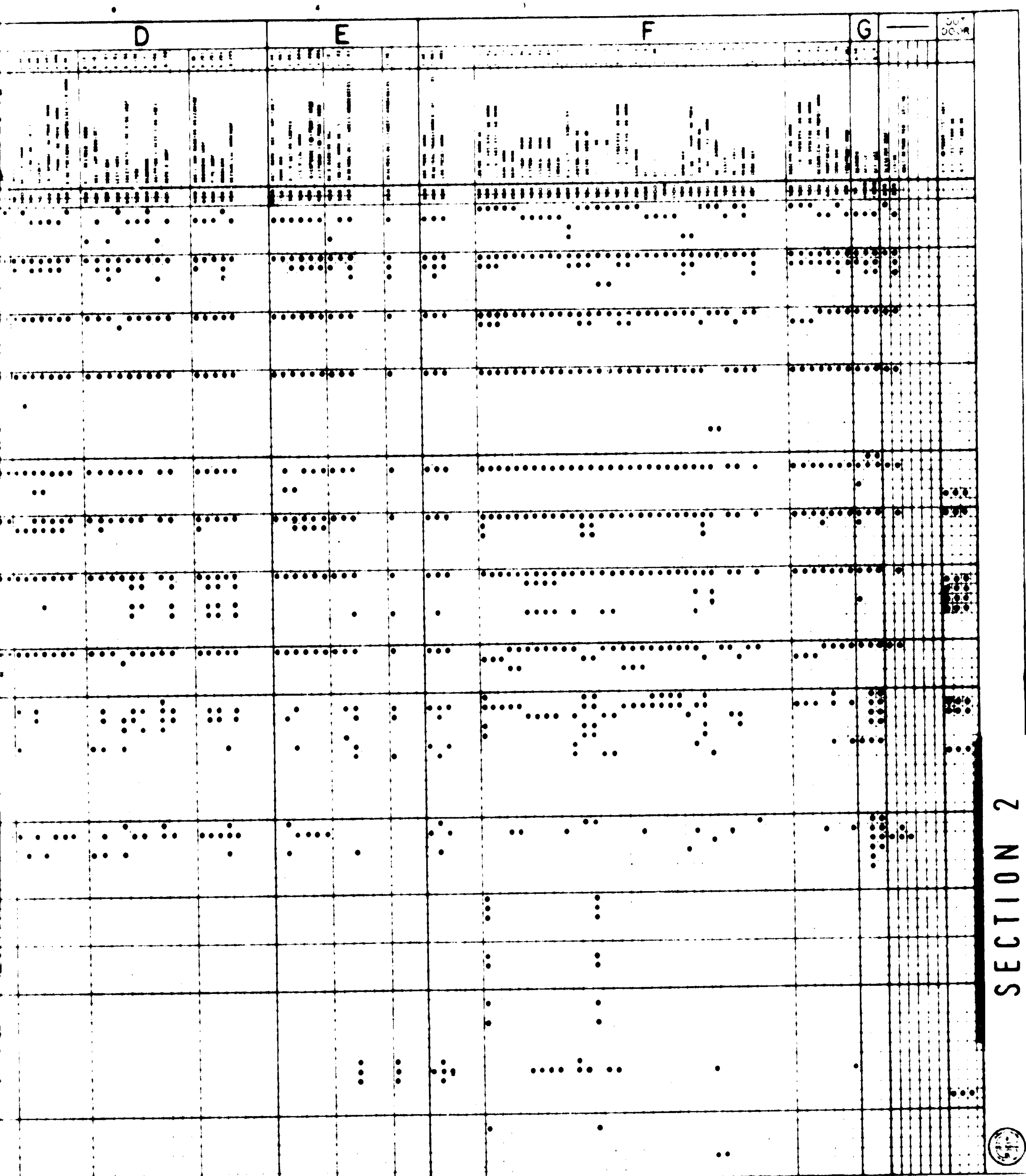


SECTION 1



ELECTRICAL INDUSTRY TESTING

AND

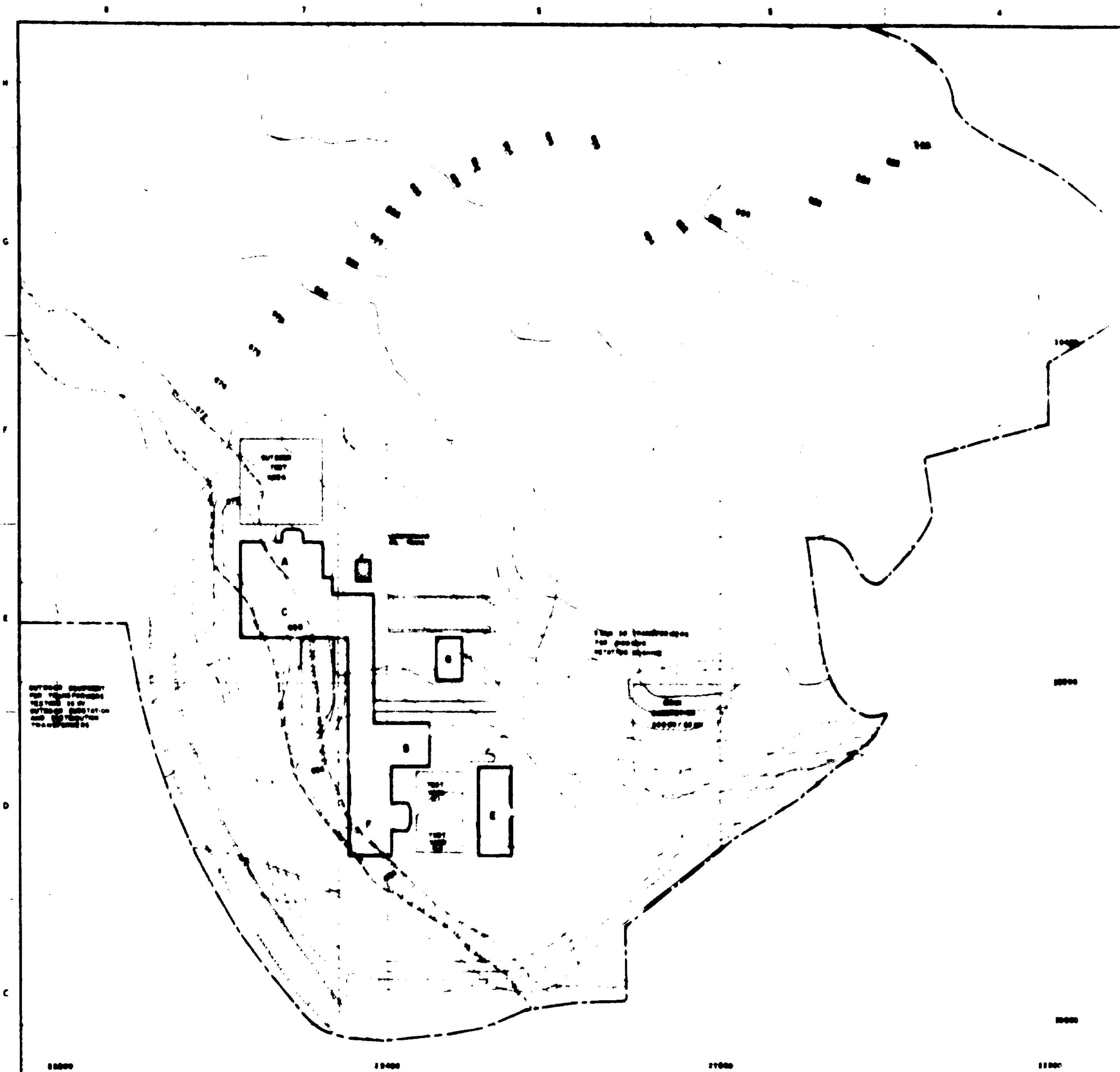
EXPERIMENTATION CENTRE

MADRID SPAIN

SUMMARY OF

ELECTRICAL SERVICES

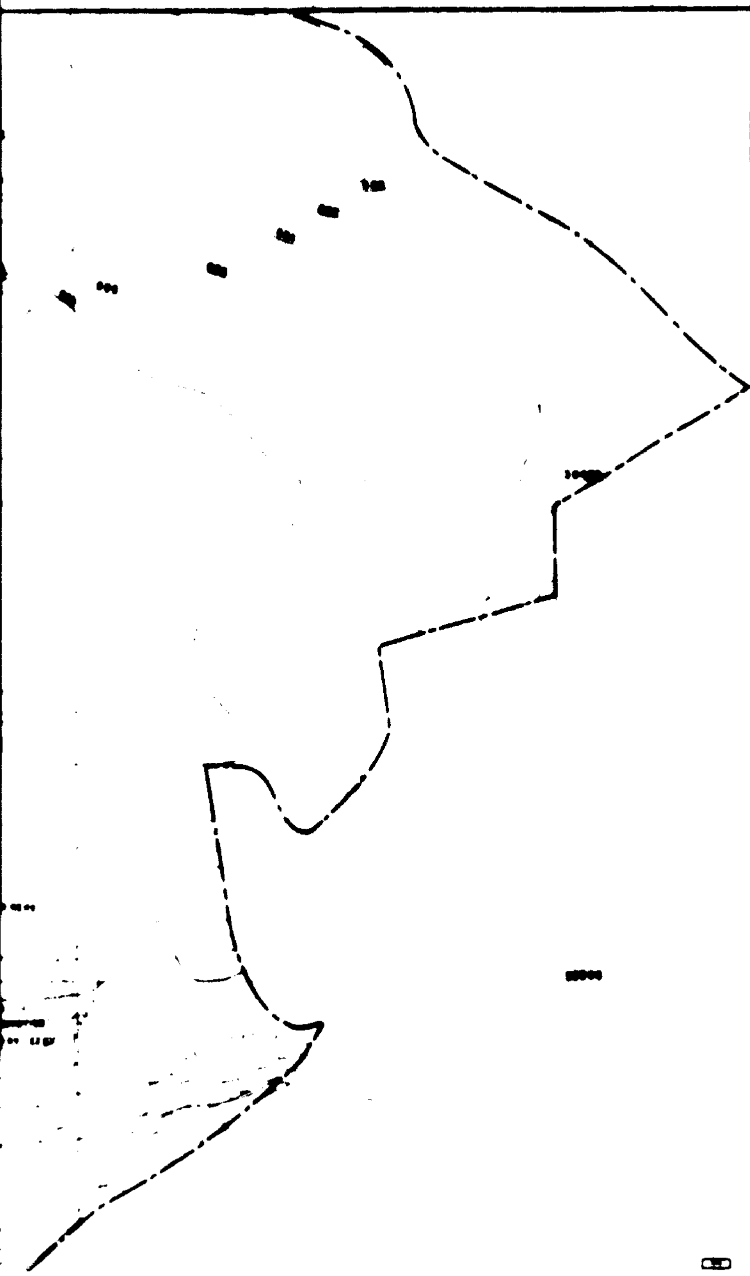
NOT TO SCALE



ABBREVIATIONS

DC DIRECT CURRENT
HC HIGH CURRENT
HV HIGH VOLTAGE
[illegible] STORAGE AREA FOR MOBILE HOSE REELS
[illegible] STORAGE AREA FOR MOBILE PUMP
[illegible] STORAGE AREA FOR MOBILE OIL TREATMENT UNIT
OFP OIL FEED PUMP
ODH OIL DISCHARGE HEADER
ORH OIL RETURN HEADER
OSH OIL SUCTION HEADER
[illegible] ROTATING [illegible]
TRANS TRANSFORMER
[illegible] TREATING EQUIPMENT FOR [illegible] TEST
CH COMPRESSOR HIGH PRESSURE [illegible]
CL COMPRESSOR LOW PRESSURE [illegible]
RH RECEIVER HIGH PRESSURE [illegible]
RR RECEIVER REDUCED PRESSURE [illegible]
RL RECEIVER LOW PRESSURE [illegible]

SECTION 1



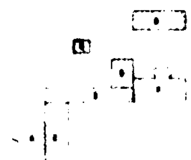
ROOM IDENTIFICATION

A		D		F	
B		E		G	
C					

LEGEND

- HEATING COIL
- COOLING COIL
- AIR FILTER
- FLOOR AIR GRILLE
- OPENING ABOVE THE FLOOR
- AIR VOLUME CONTROL DAMPER
- AIR SUPPLY FAN
- UNIT HEATER
- FRESH AIR INTAKE WITH MOTORIZED DAMPER
- EXHAUST FAN WITH BACK DRAFT DAMPER
- THERMOSTAT
- SUPPLY AIR GRILLE
- RETURN OR EXHAUST AIR GRILLE
- FLOOR DRAIN
- FLOOR DRAIN (H.V. TEST AREAS)
- DRAINED ELECTRICAL FLOOR BOX FOR MEASURING INSTRUMENT
- OIL SUPPLY OUTLET AND RETURN INLET
- RAW WATER OUTLET
- WATER OUTLET FOR WET TEST APPARATUS
- FIRE HOSE AND EXTINGUISHER IN A WALL CABINET
- FIRE HOSE AND EXTINGUISHER IN A SERVICE MODULE

SECTION 2



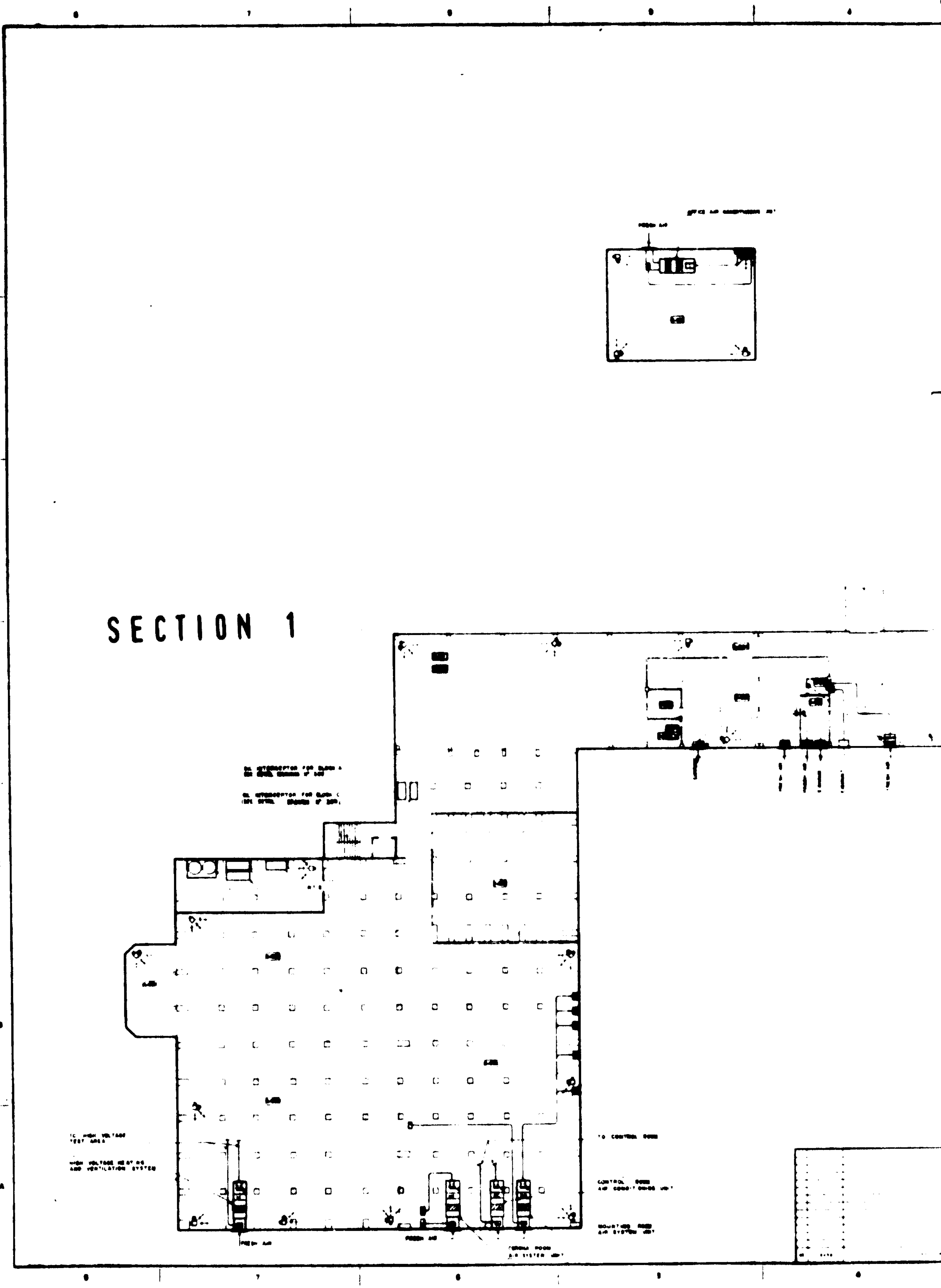
KEY PLAN

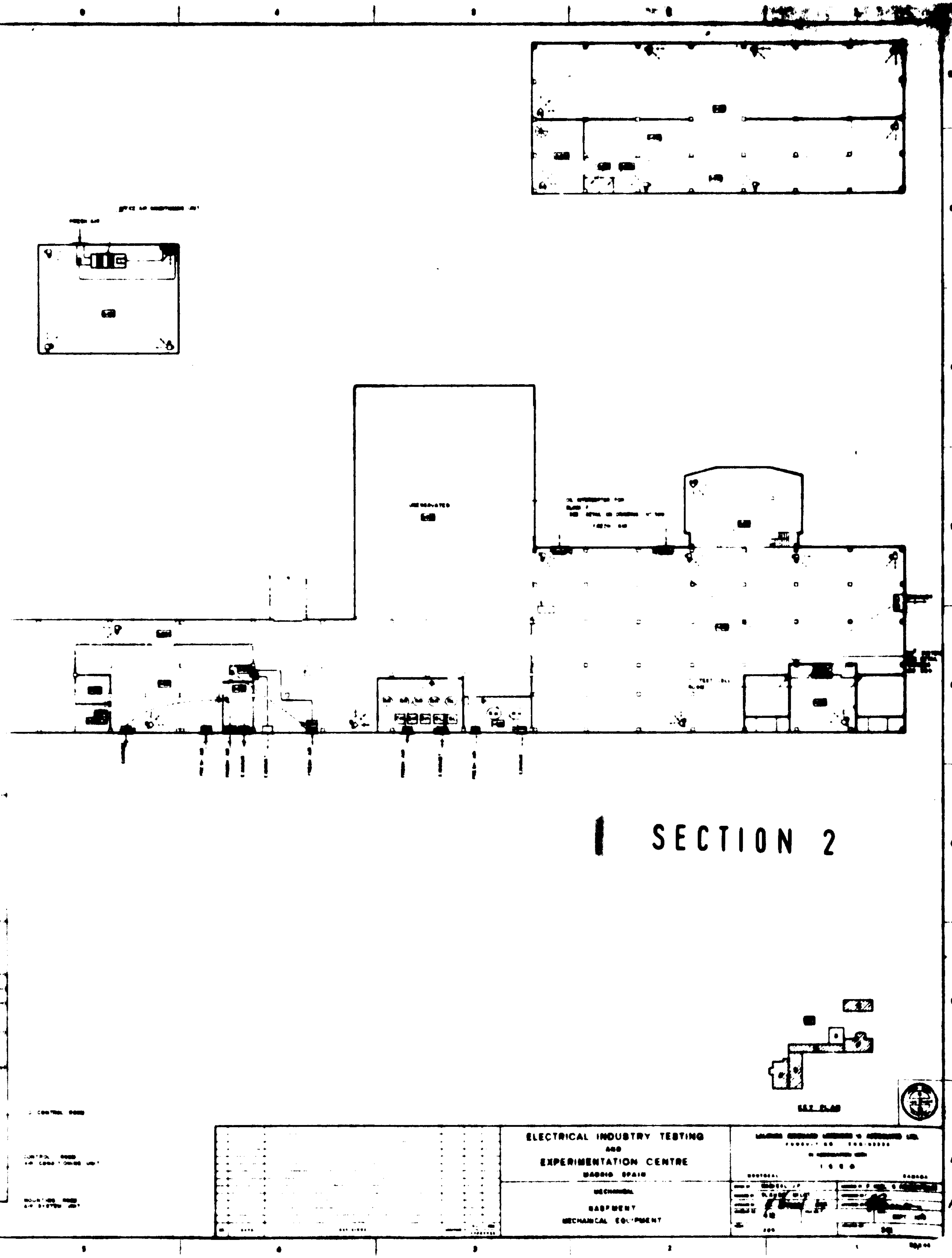
ELECTRICAL INDUSTRY TESTING AND EXPERIMENTATION CENTRE
MADRID SPAIN

MECHANICAL

GENERAL LAYOUT & ROOM IDENTIFICATION LEGEND ABBREVIATIONS

SECTION 1

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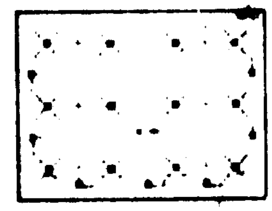
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN
MECHANICAL
BASEMENT
MECHANICAL EQUIPMENT



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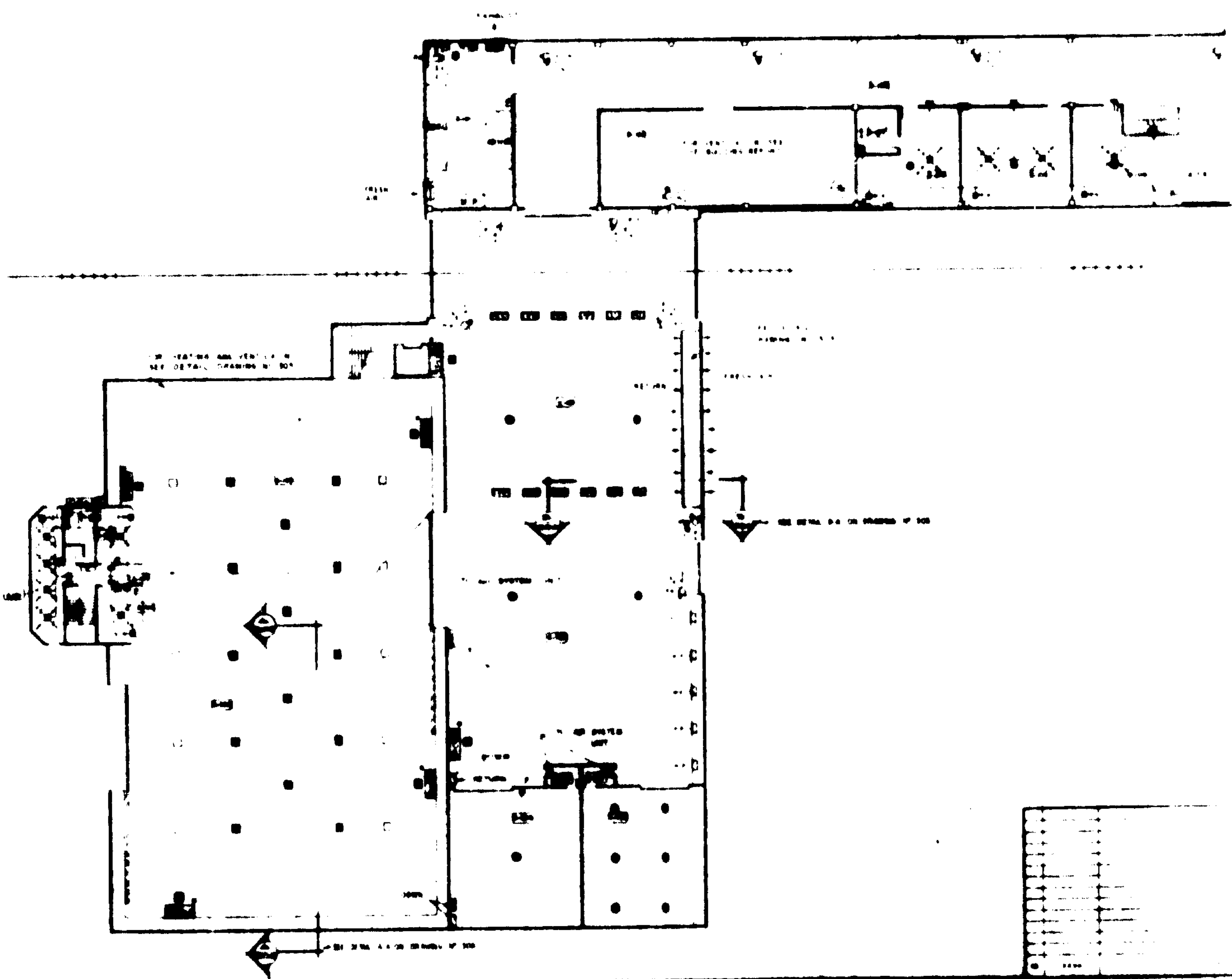
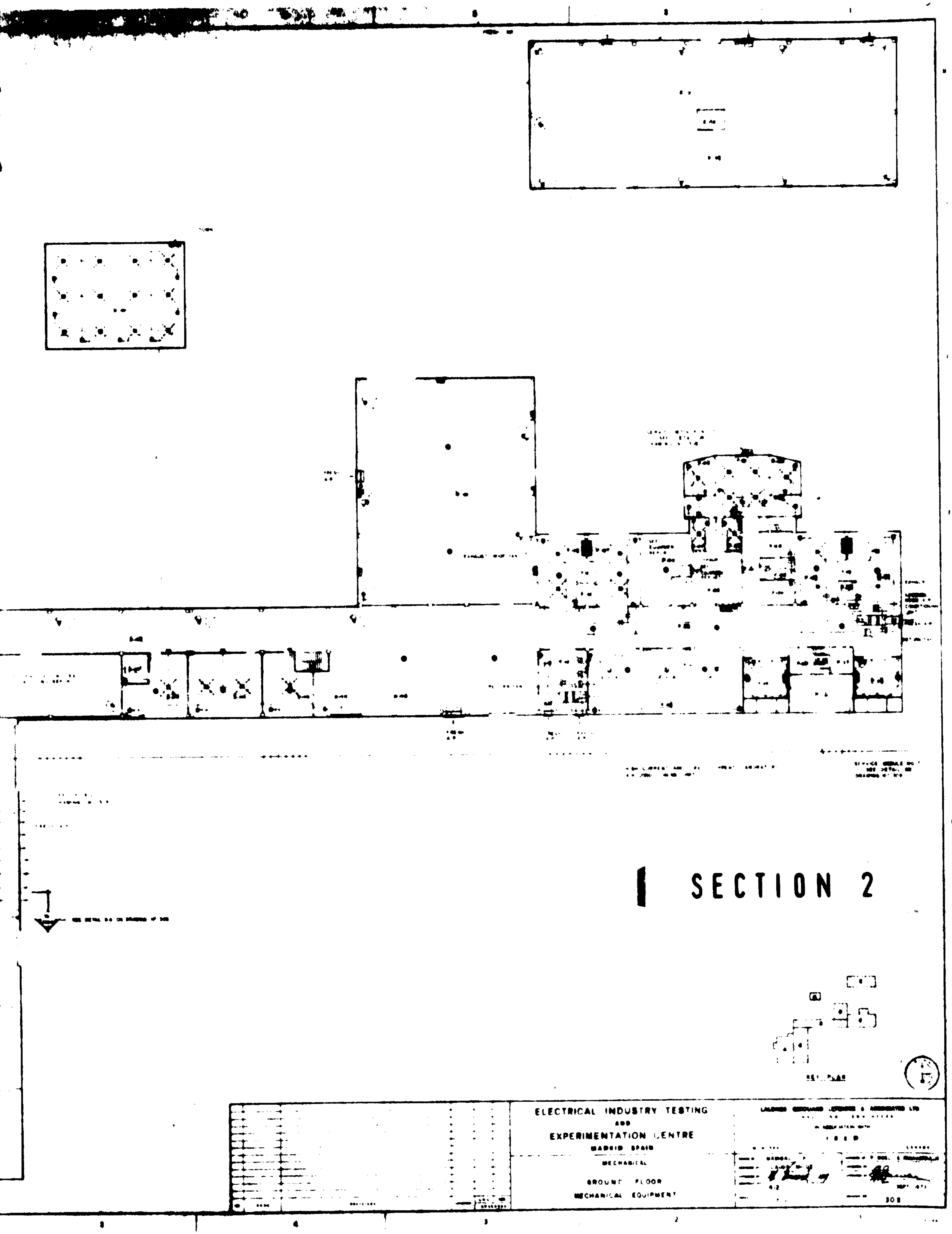
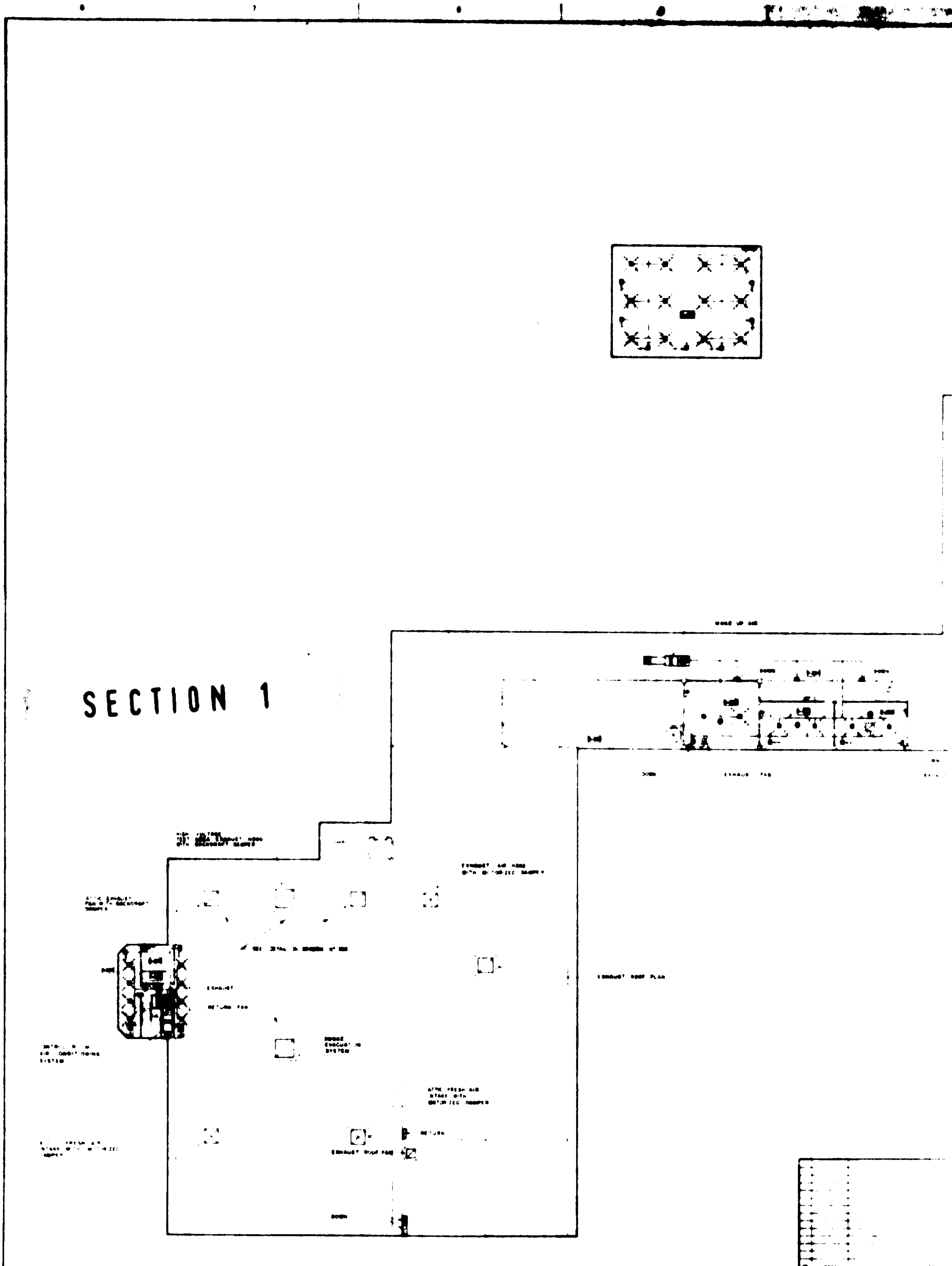



SECTION 2
KEY PLAN
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN
MECHANICAL
GROUND FLOOR
MECHANICAL EQUIPMENT
301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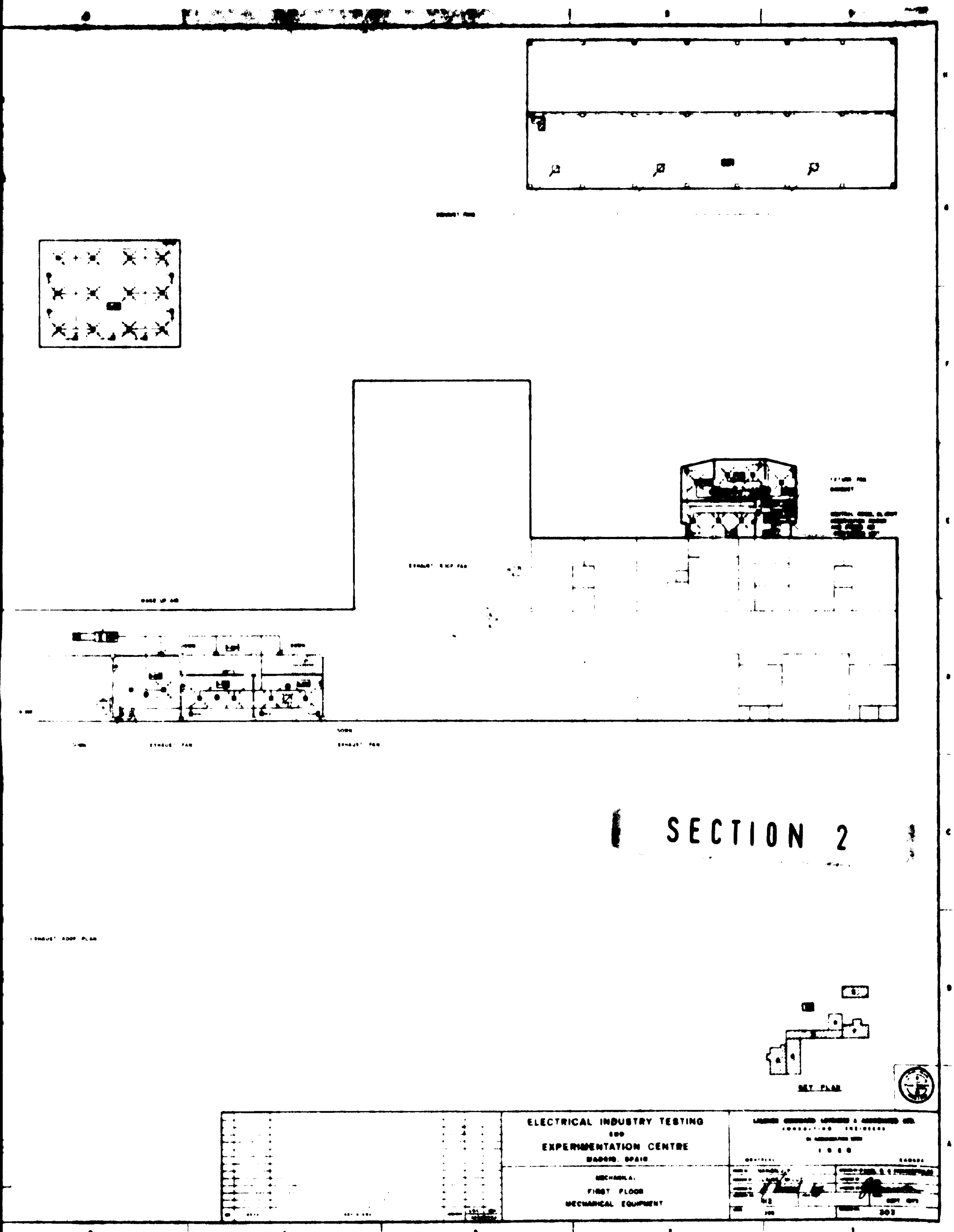
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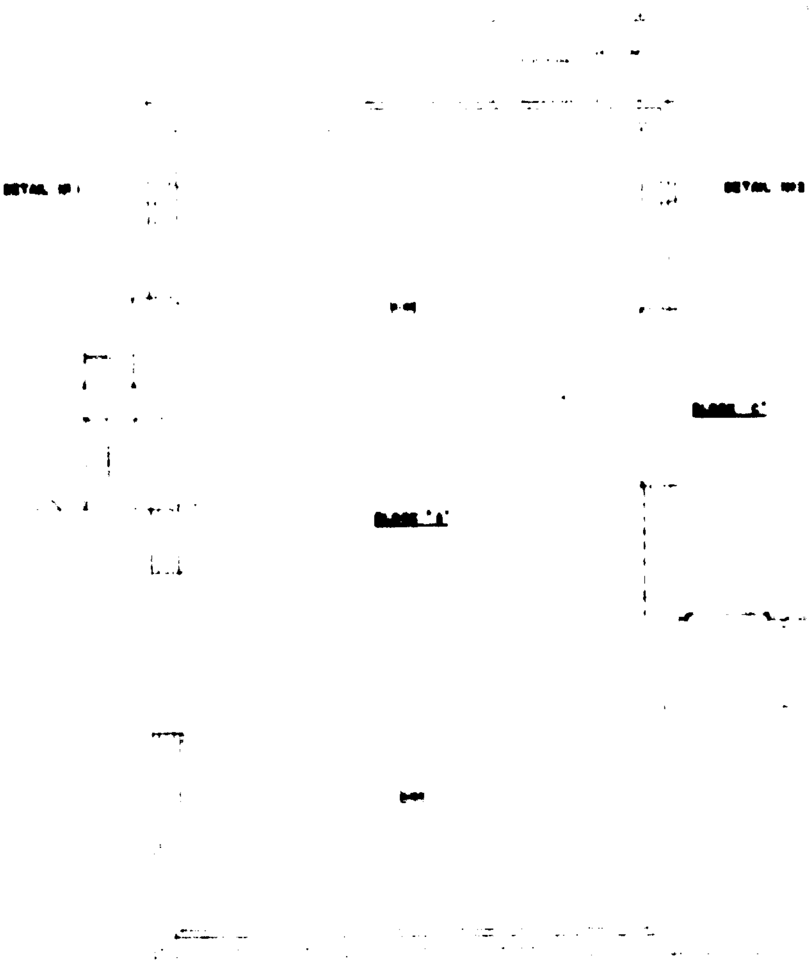
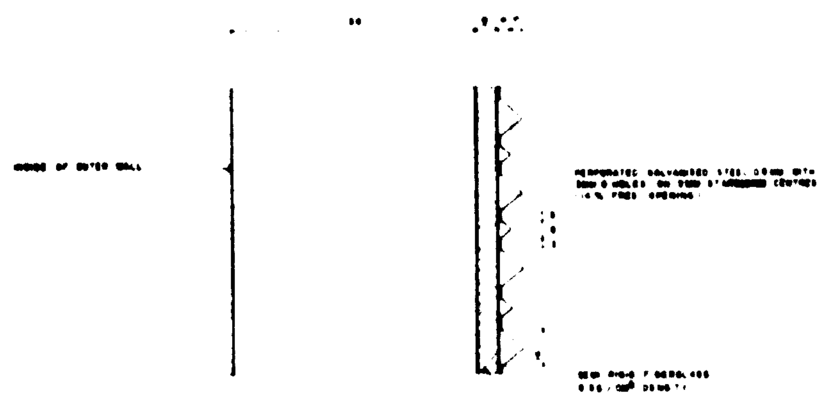
ELECTRICAL INDUSTRY TESTING
EXPERIMENTATION CENTRE
FIRST FLOOR
MECHANICAL EQUIPMENT



HIGH VOLTAGE TEST AREA

DOUBLE WALL DETAIL



TYPICAL WALL DETAIL No 1

HIGH VOLTAGE TEST AREA

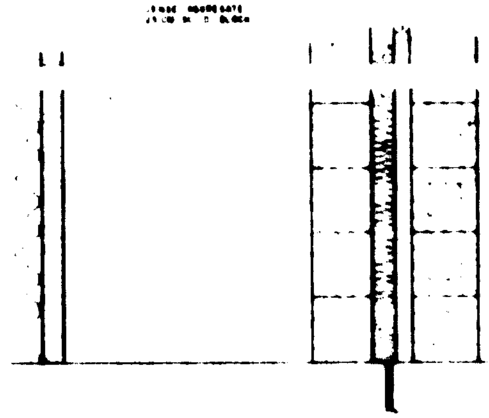
SECTION 1

DETAIL Nº 2

BLOCK 'C'

TYPICAL CEILING DETAIL
HIGH VOLTAGE AREA

SECTION 2

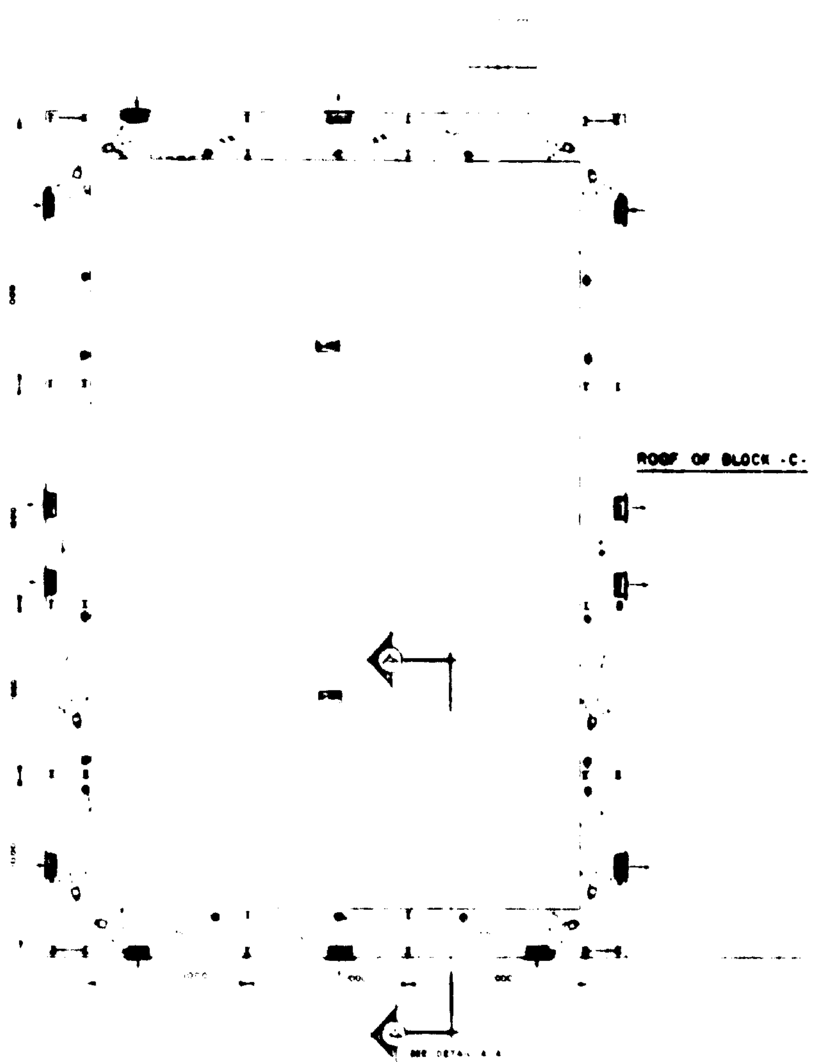


TYPICAL DIVIDING WALL DETAIL Nº 2
BETWEEN BLOCKS A & C

KEY PLAN

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

MECHANICAL
HIGH VOLTAGE AREAS
ACOUSTICAL TREATMENT
OF WALLS AND CEILING



SERVICE CORRIDOR BETWEEN WALLS
FOURTH LEVEL
TYPICAL HEATING & VENTILATING SYSTEMS

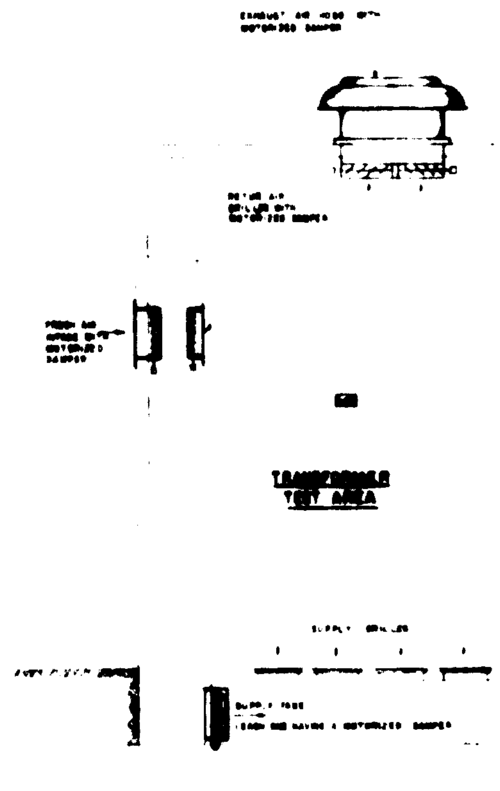
DETAIL A-A

H.V. TEST AREA TYPICAL SECTION

SECTION 1

DETAIL A-A

H.V. TEST AREA TYPICAL SECTION

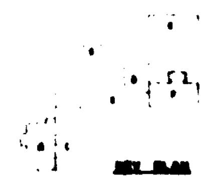


DETAIL B-B

TRANSFORMER TEST AREA TYPICAL SECTION

VENTILATION SYSTEM

SECTION 2



ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

MECHANICAL

HIGH VOLTAGE TEST AREAS
AND TRANSFORMER TEST AREA

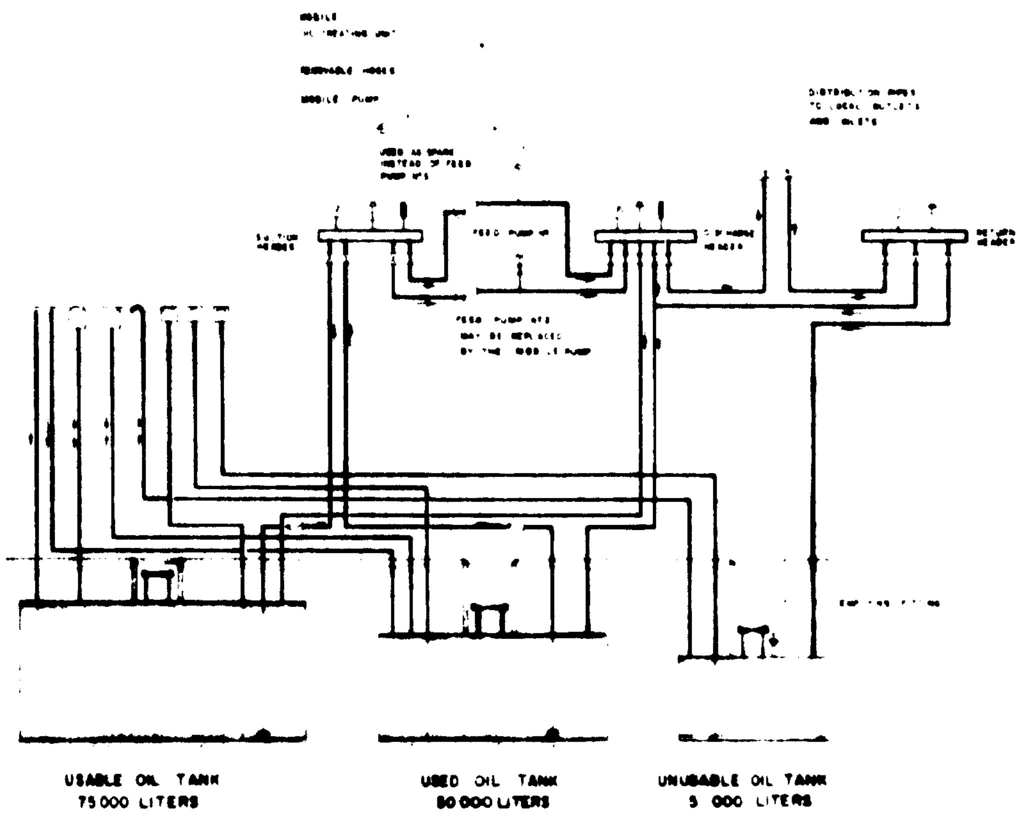
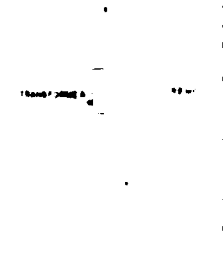


DIAGRAM FOR TRANSFORMER OIL HANDLING SYSTEM



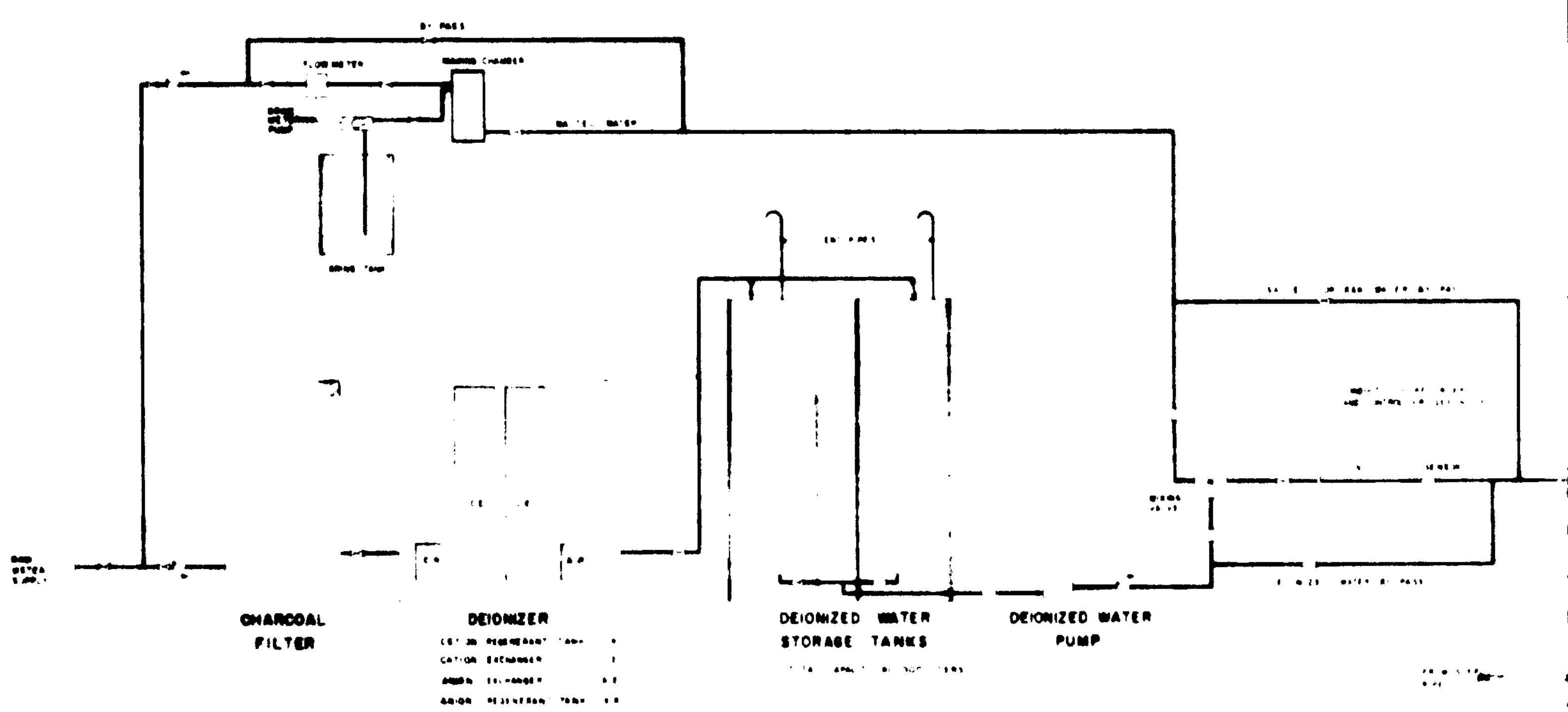
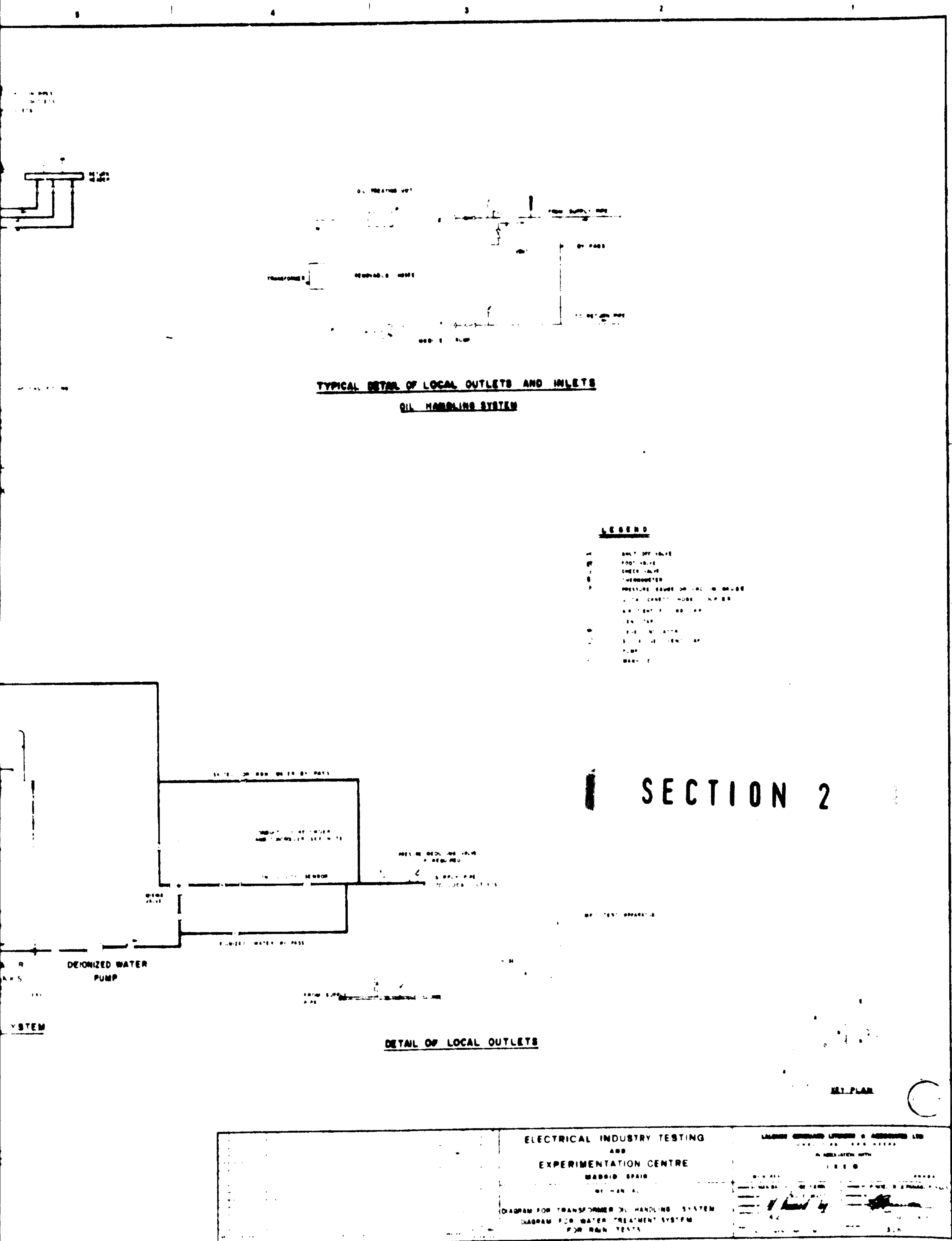


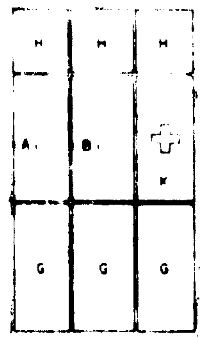
DIAGRAM FOR WATER TREATMENT SYSTEM
FOR RAIN TESTS

NOTE – THE CONDUCTIVITY AND ALL THE CONTROLS AND ALARMS OF THE SYSTEM ARE LOCATED IN THE CONTROL ROOM OF H.V. TEST AREA [illegible]

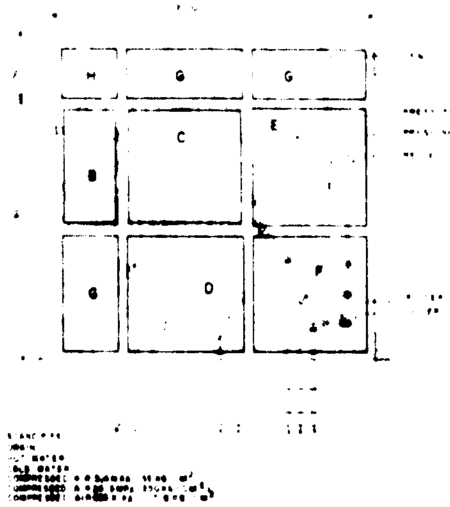
SECTION 1



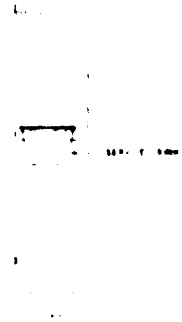
TYPICAL DETAIL OF LOCAL OUTLETS AND INLETS
OIL HANDLING SYSTEM
LEGEND
SECTION 2
DEIONIZED WATER PUMP
DETAIL OF LOCAL OUTLETS
KEY PLAN
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN
DIAGRAM FOR TRANSFORMER OIL HANDLING SYSTEM
DIAGRAM FOR WATER TREATMENT SYSTEM
FOR RAIN TESTS



ELEVATION
SERVICE MODULES Nº1



ELEVATION
SERVICE MODULES Nº2



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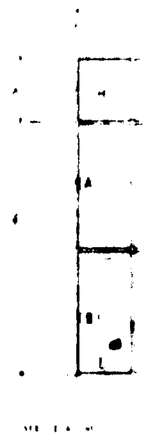
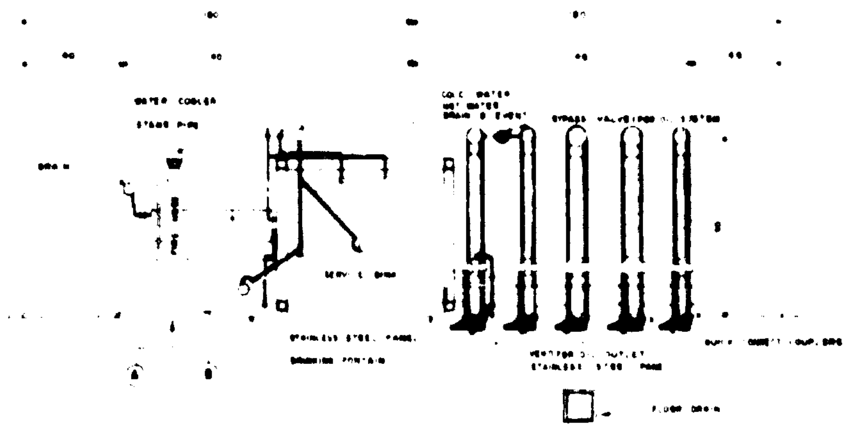
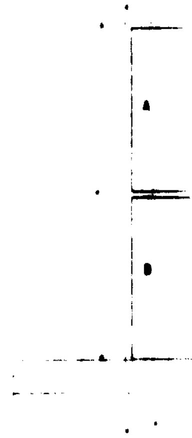
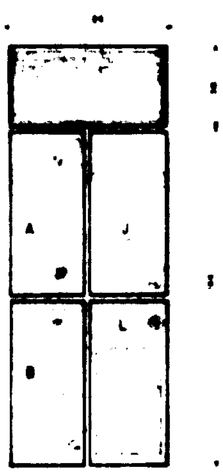


SECTION 1



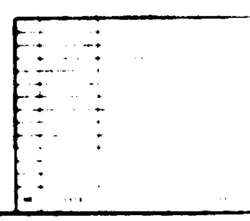
PLAN
SERVICE MODULES Nº 5

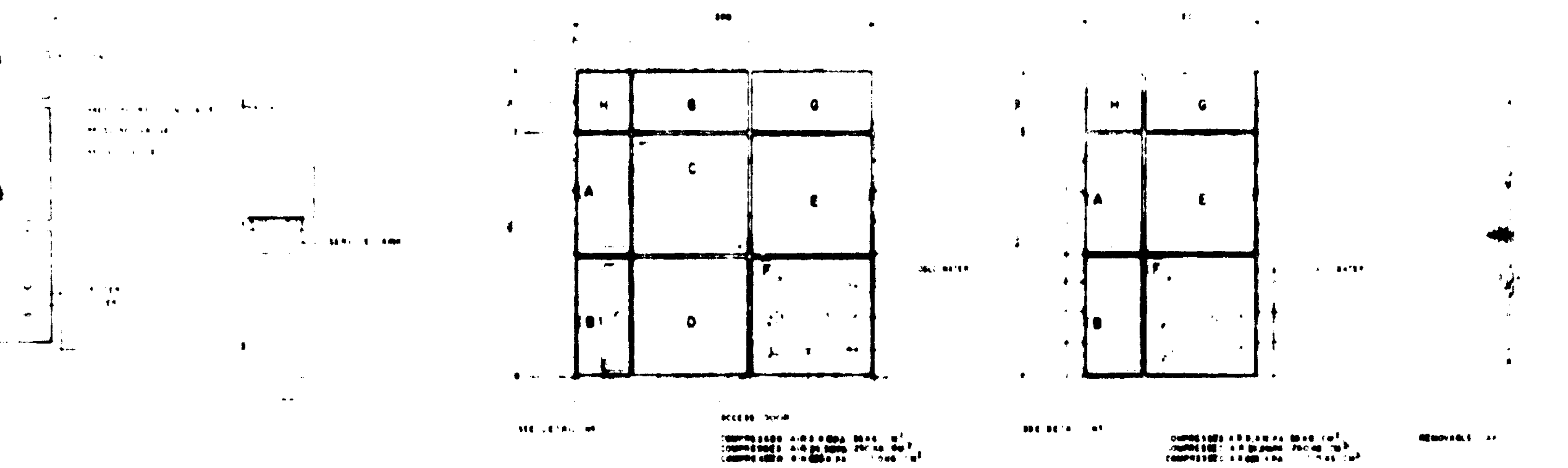




ELEVATION
SERVICE MODULES Nº 6

MODULES	TYPES DIMENSIONS
A	FIRE HOSE CABINET
B	FIRE EXTINGUISHER
C	OPENING ABOVE SINK
D	SERVICE SINK
E	ACCESS PANEL
F	PANEL WITH ACCESS DOOR
G	PANEL
H	PANEL
J	DRINKING FOUNTAIN
K	FIRST AID
L	WATER COOLER
M	DIRECTORY BOARD



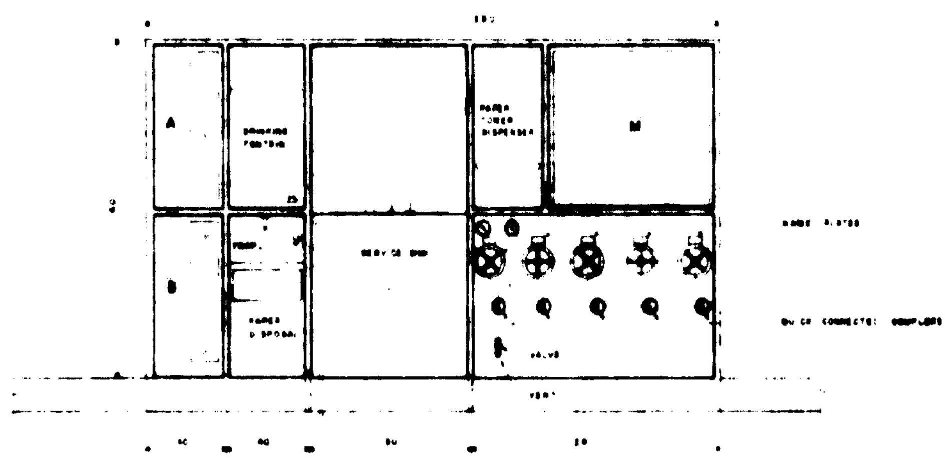


SECTION

ELEVATION
SERVICE MODULES Nº3

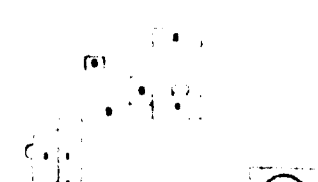
ELEVATION
SERVICE MODULES Nº4

DETAIL Nº1



ELEVATION

SECTION 2



KEY PLAN

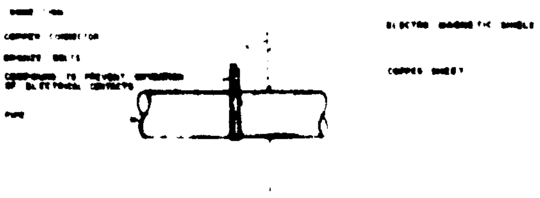
	TYPES DIMENSIONS
	FIRE HOSE CABINET
	FIRE EXTINGUISHER
	OPENING ABOVE SINK
	SERVICE SINK
	ACCESS PANEL
	PANEL WITH ACCESS DOOR
	PANEL
	PANEL
	DRINKING FOUNTAIN
	FIRST AID
	WATER COOLER
	DIRECTORY BOARD

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

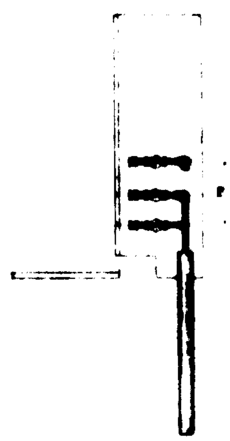
MECHANICAL

SERVICE MODULES
DETAILS

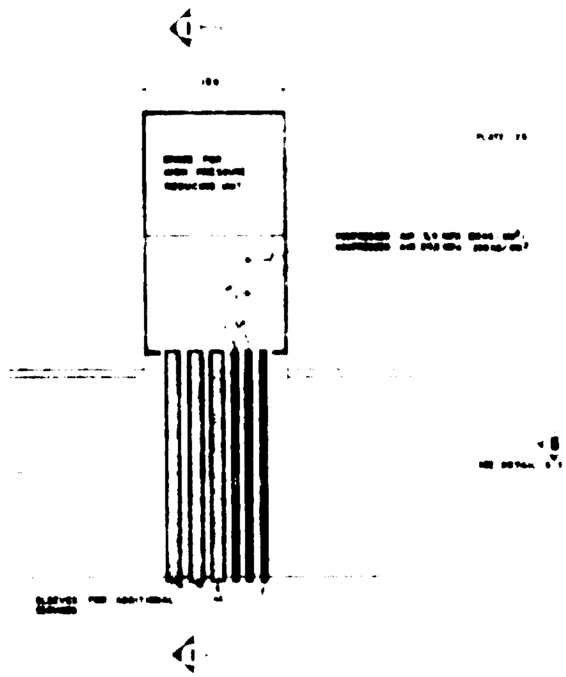
[illegible]
1 9 6 9
MONTREAL
412
397



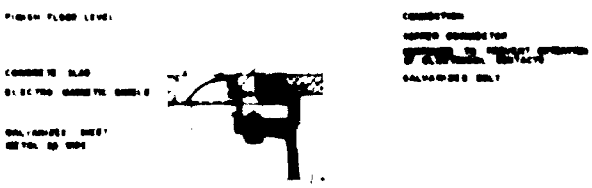
TYPICAL PIPE CONNECTION TO
ELECTRO-MAGNETIC SHIELD



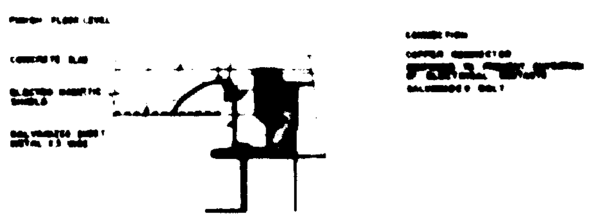
SECTION 1



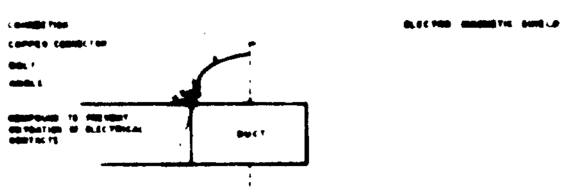
INSIDE VIEW
SERVICE MODULES UP 7
PIPING



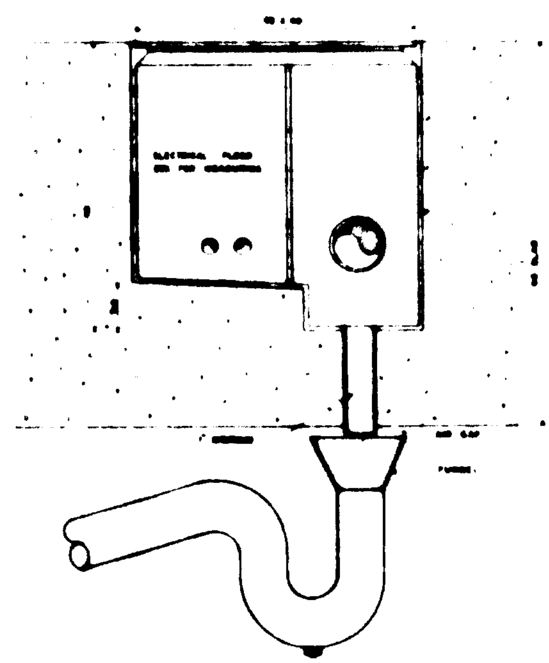
TYPICAL DRAIN CONNECTION TO
ELECTRO-MAGNETIC SHIELD



TYPICAL MAN HOLES CONNECTION TO
ELECTRO-MAGNETIC SHIELD

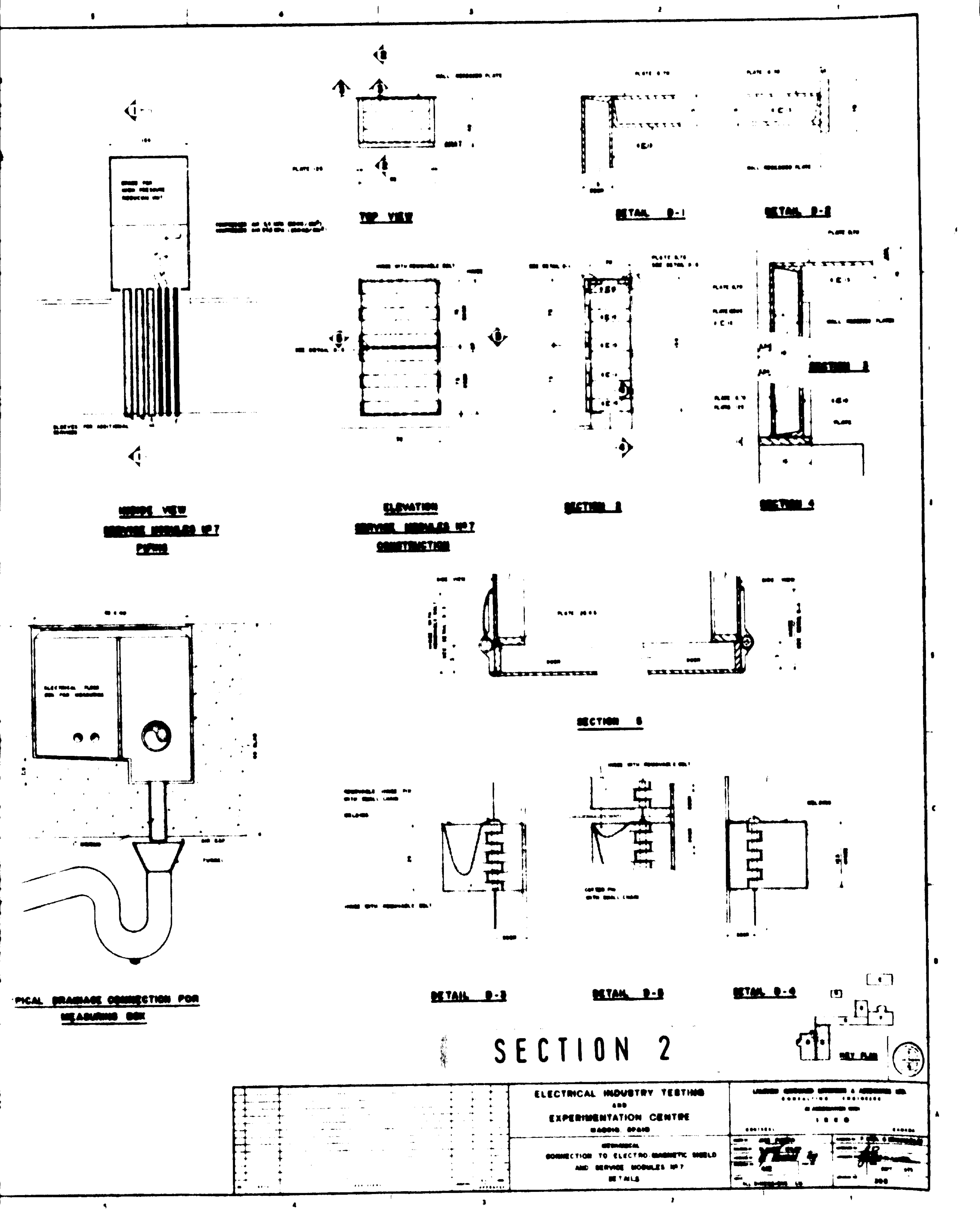


TYPICAL DUCT CONNECTION TO
ELECTRO-MAGNETIC SHIELD

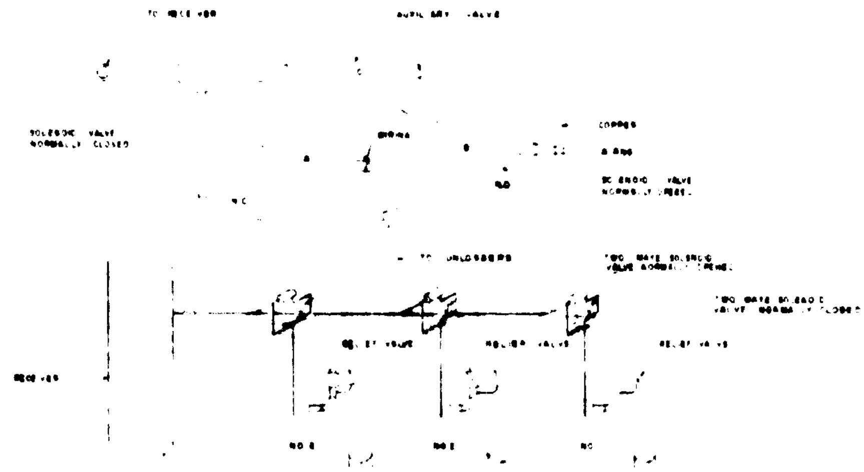


TYPICAL DRAINAGE CONNECTION FOR
MEASURING BOX

SECTION 1



TOP VIEW
DETAIL D-1
DETAIL D-2
SECTION 3
INSIDE VIEW
SERVICE MODULES Nº7
PIPING
ELEVATION
SERVICE MODULES Nº7
CONSTRUCTION
SECTION 3
SECTION 4
SECTION 5
PICAL DRAINAGE CONNECTION FOR
MEASURING BOX
DETAIL D-3
DETAIL D-5
DETAIL D-4
SECTION 2
KEY PLAN
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID, SPAIN
CONNECTION TO ELECTRO-MAGNETIC SHIELD
AND SERVICE MODULES Nº7
DETAILS



LOW PRESSURE AIR COMPRESSORS (686 kPa 7.0 kg/cm^2)

OPERATING SEQUENCE

[illegible]

DIAGRAM FOR COMPRESSED AIR SYSTEM

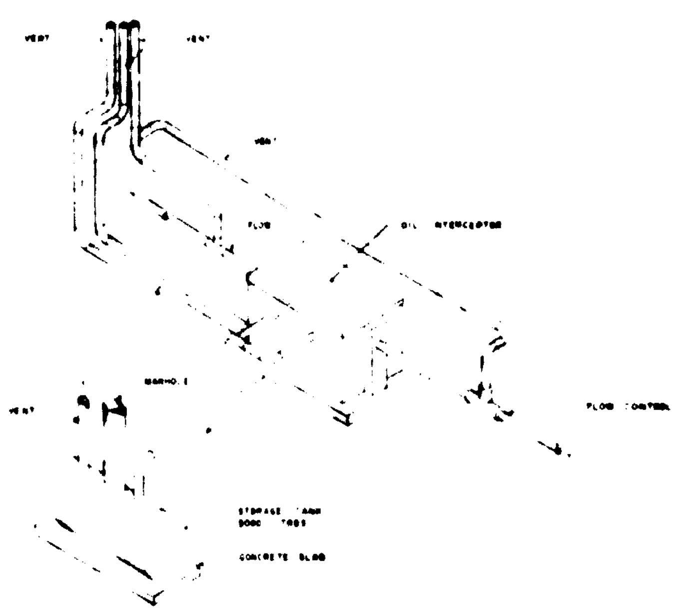
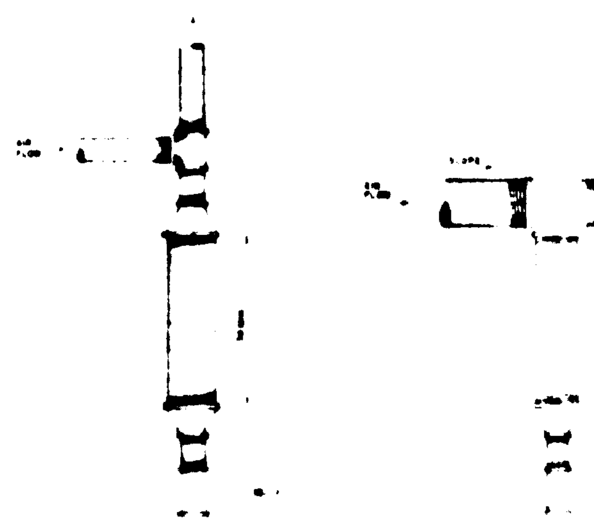


DIAGRAM FOR OIL INTERCEPTOR



LOCAL OUTLET

MAIN

DETAIL OF DRIP LEG
IN THE COMPRESSED AIR PIPING

SECTION 1

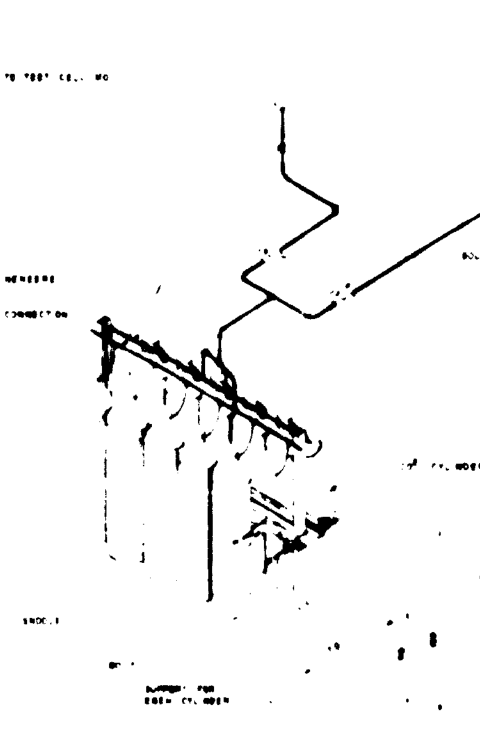


DIAGRAM FOR CO^2 SYSTEM

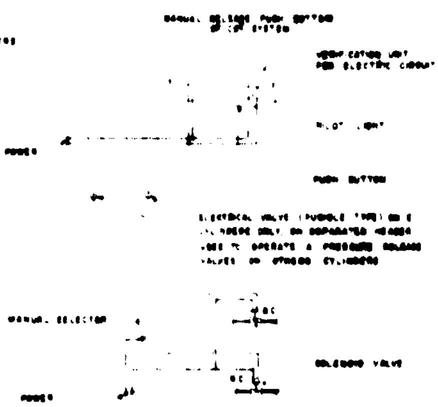
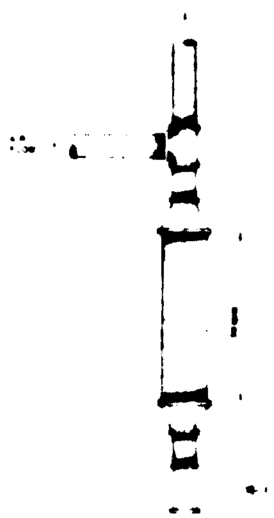
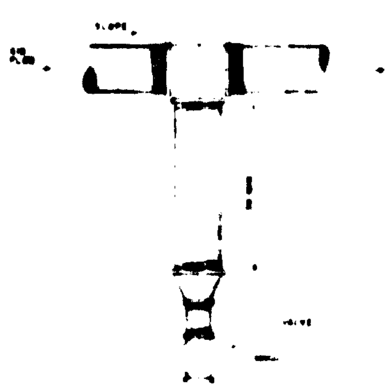


DIAGRAM FOR ELECTRIC WIRING

DETAIL OF CO^2 SYSTEM FOR TEST CELL

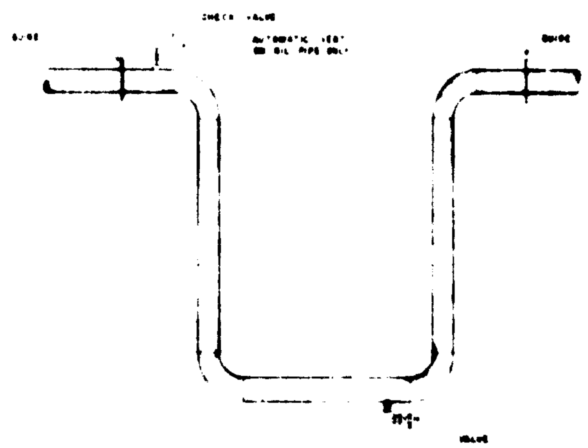


LOCAL OUTLET



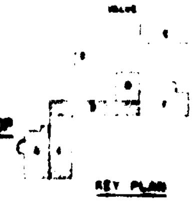
MAIN PIPE

DETAIL OF DRIP LEG
IN THE COMPRESSED AIR PIPING



DETAIL OF EXPANSION LOOP

SECTION 2



KEY PLAN

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

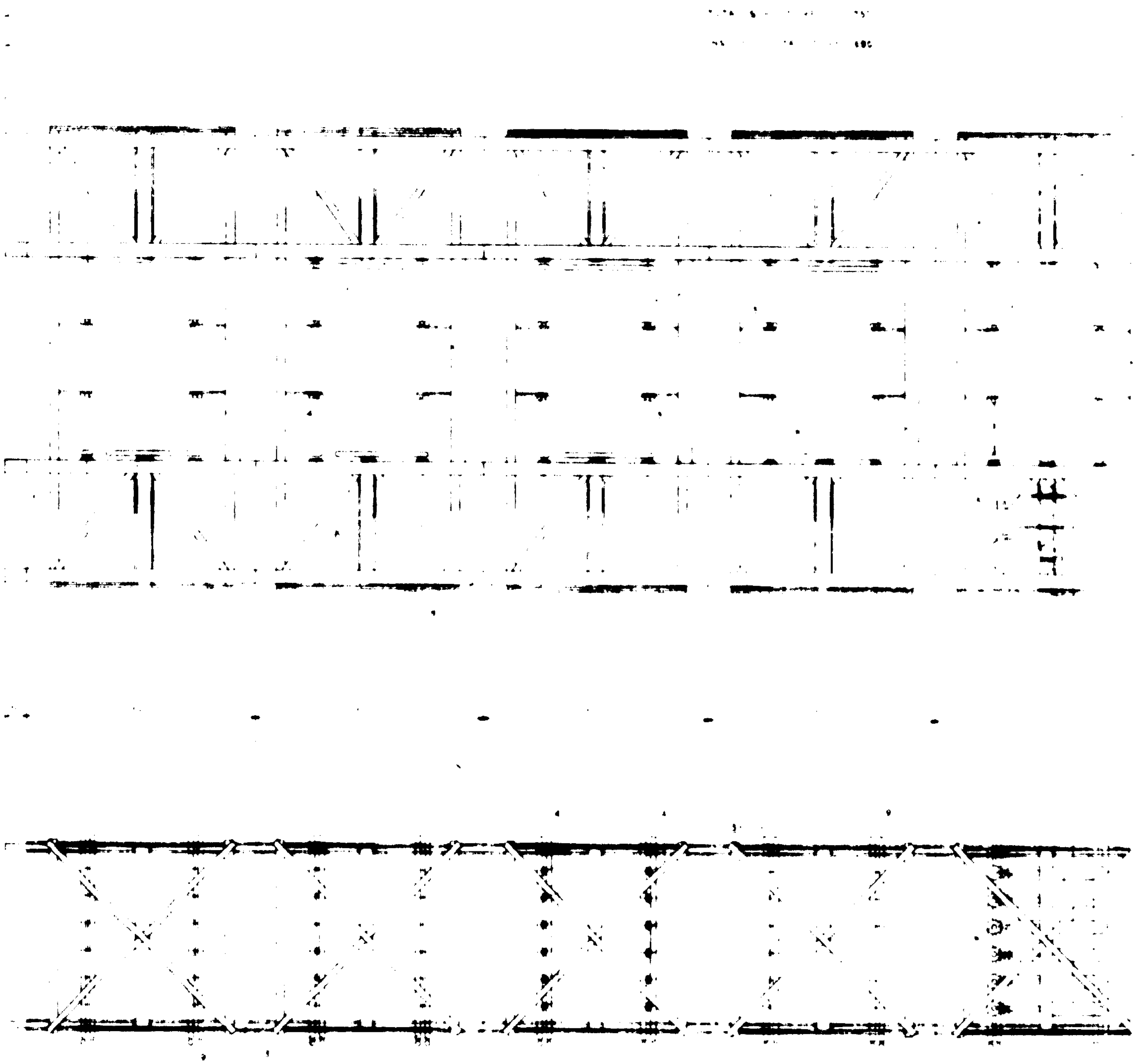
MECHANICAL

DIAGRAM FOR COMPRESSED AIR
SYSTEM AND CO^2 SYSTEM

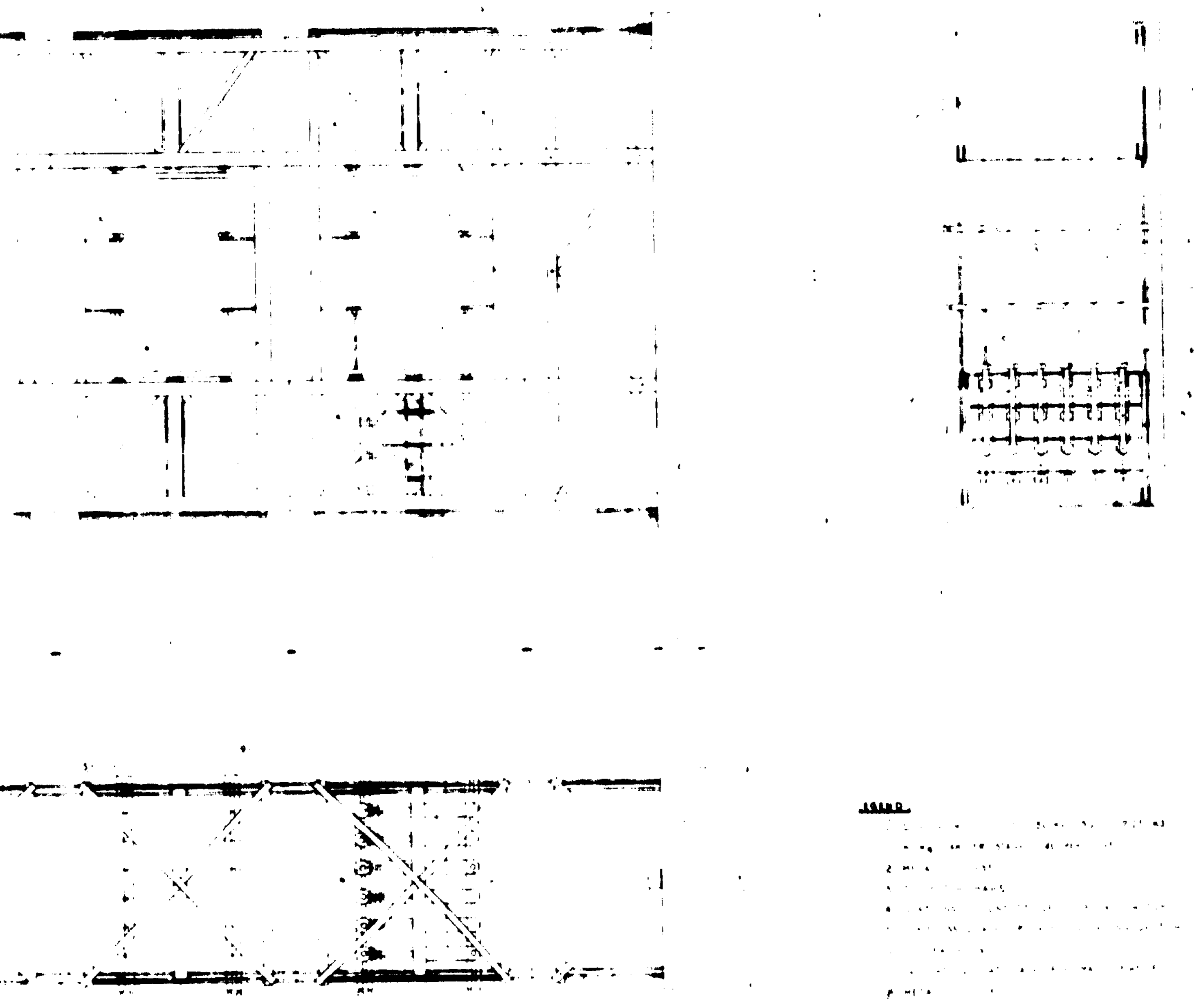
1960

418

300



SECTION 1

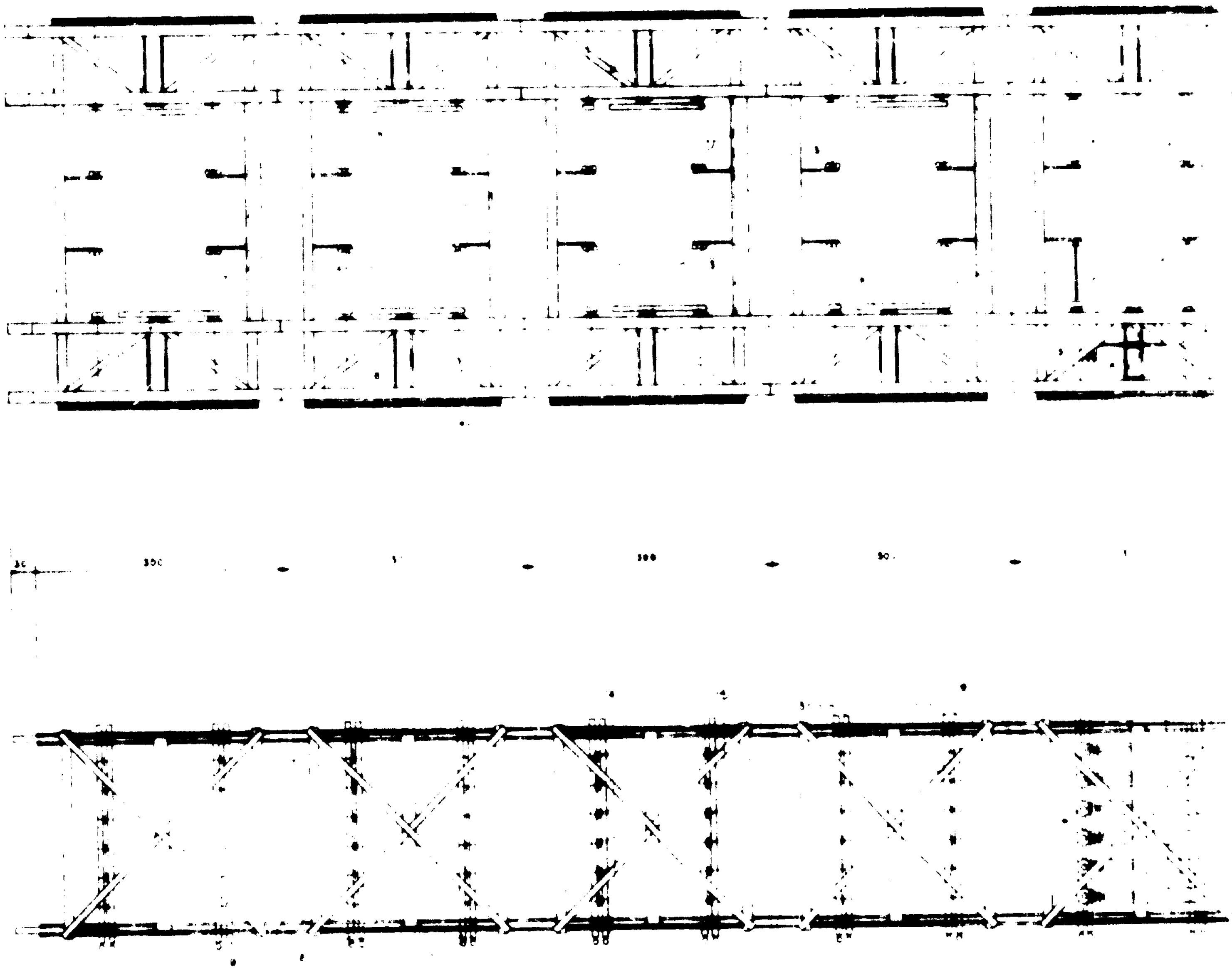


LEGEND

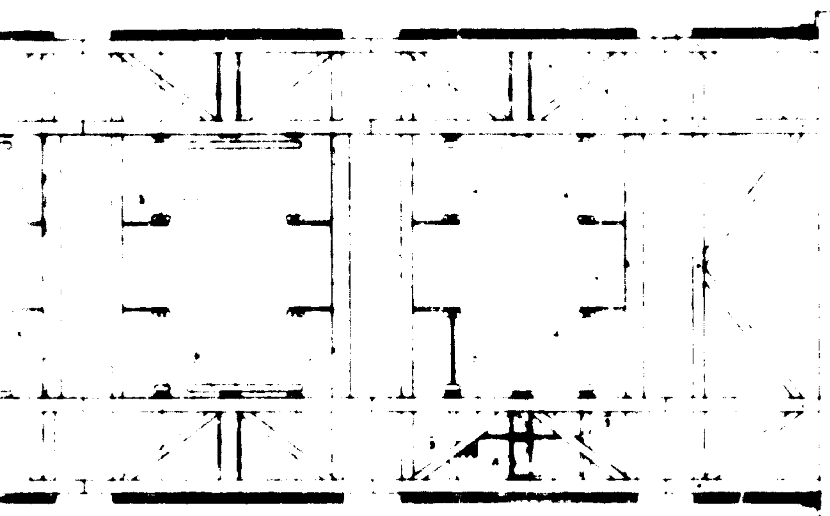
NOTE

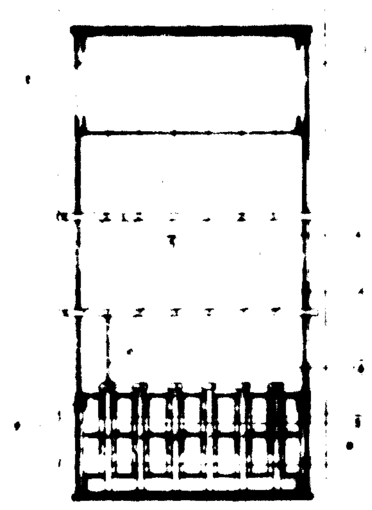
SECTION 2

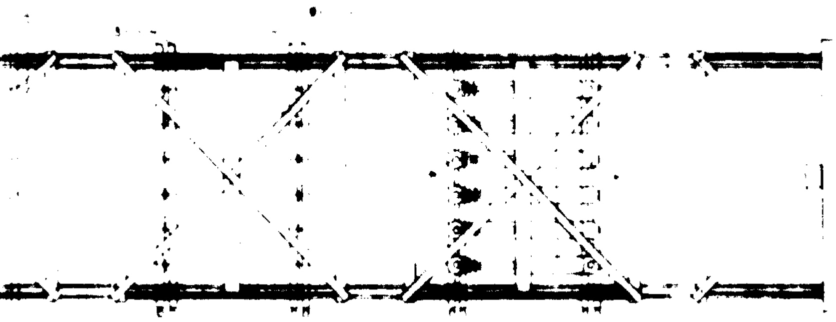
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE



SECTION 1







SECTION 2

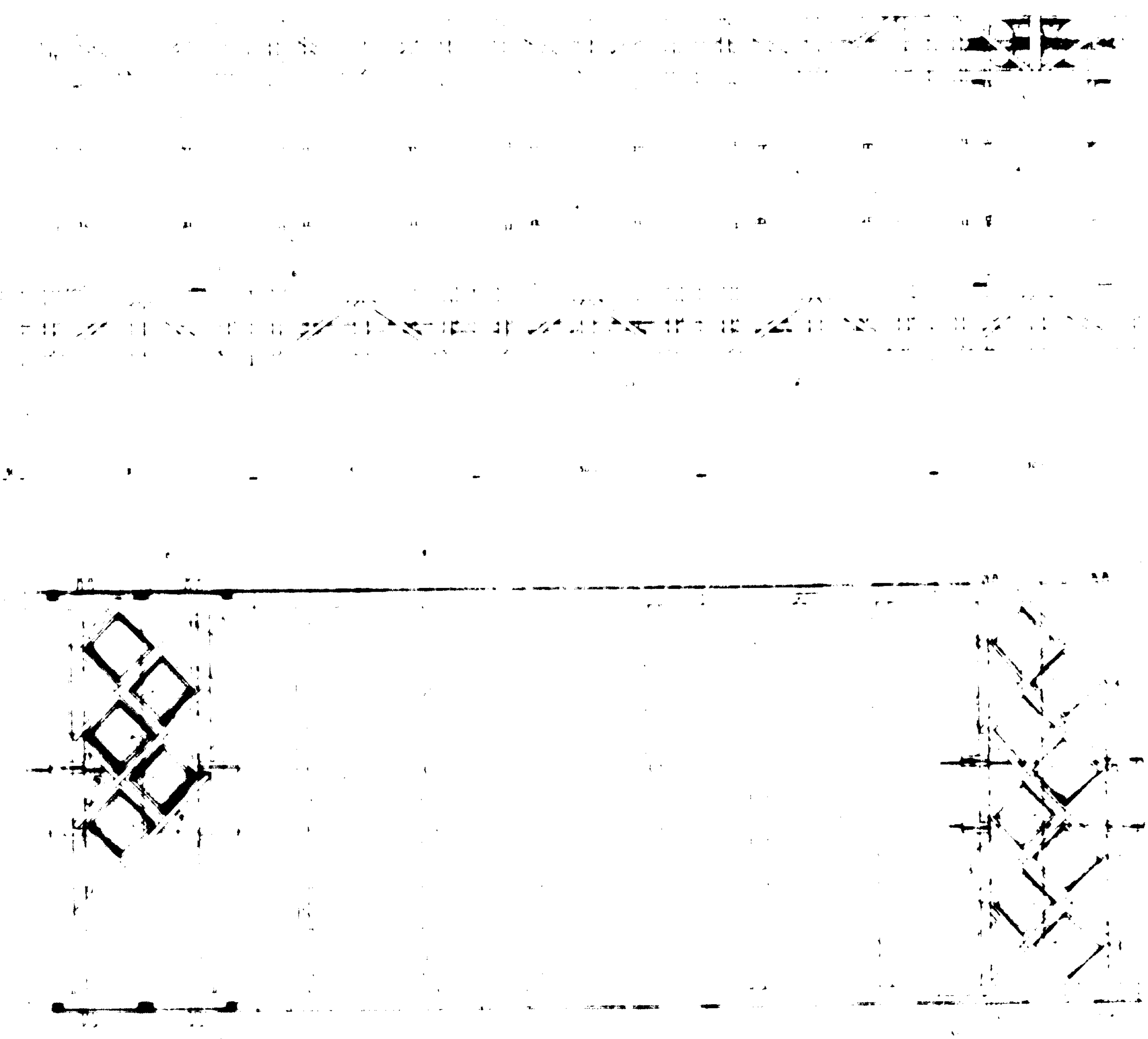
ELECTRICAL INDUSTRY TESTING

AND

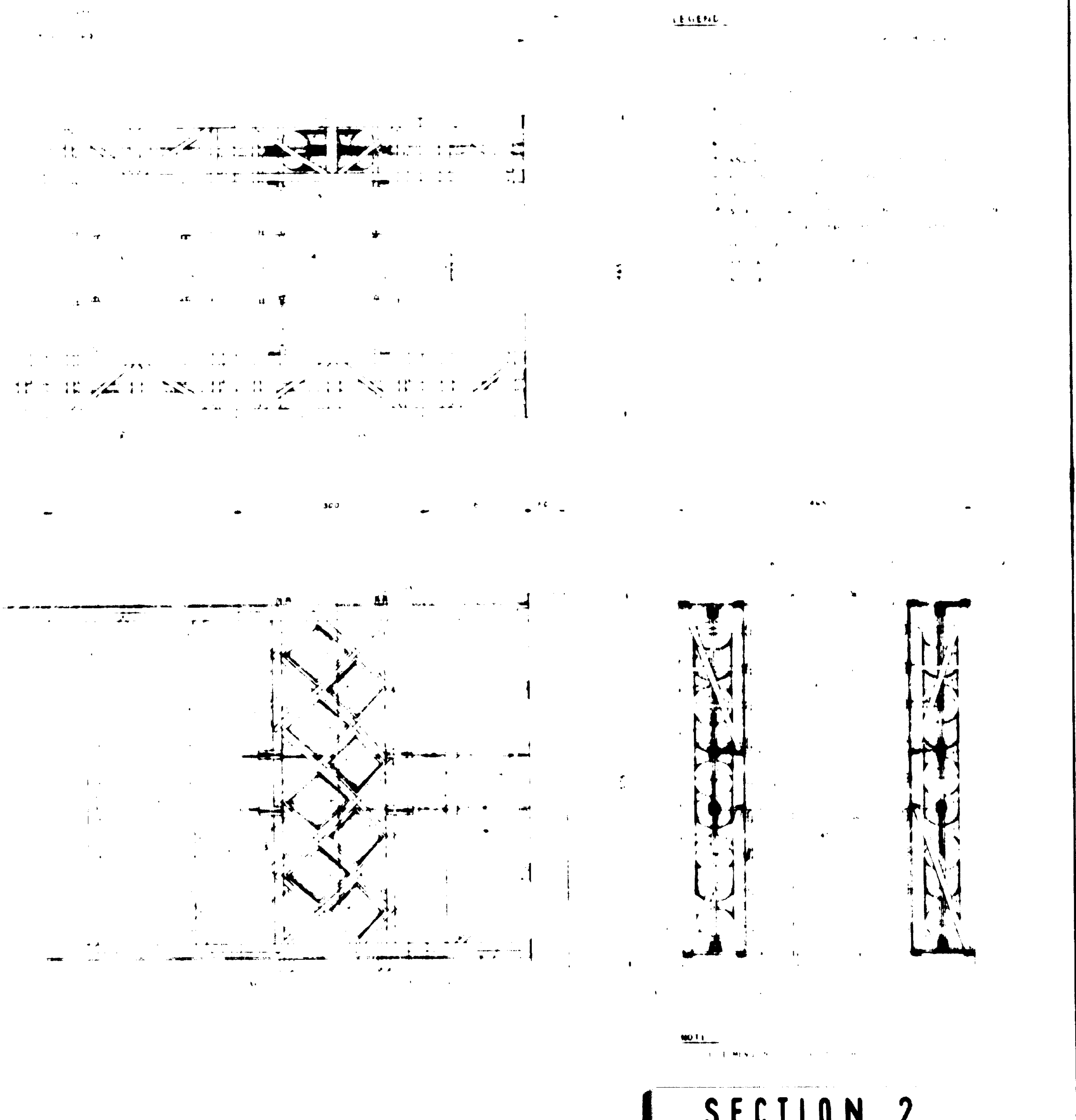
EXPERIMENTATION CENTRE

MADRID SPAIN

TOWER OF ... CONTROL CONDENSERS



SECTION 1

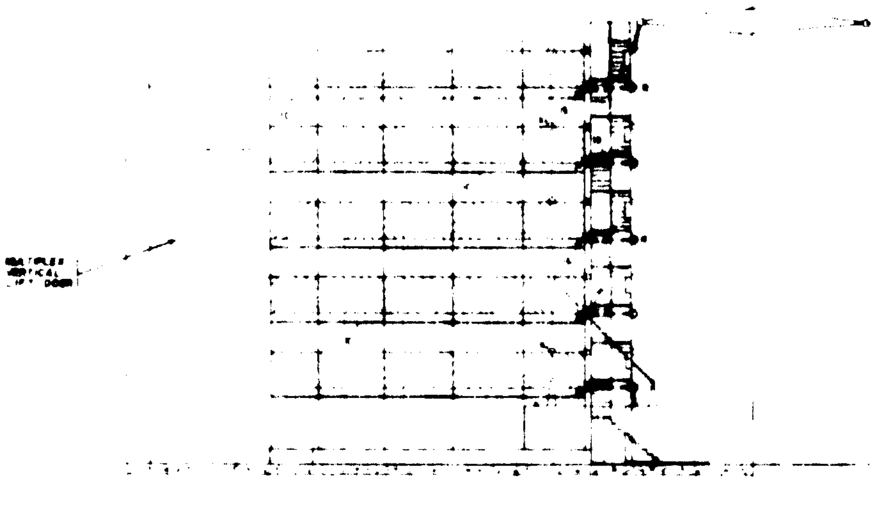


SECTION 2

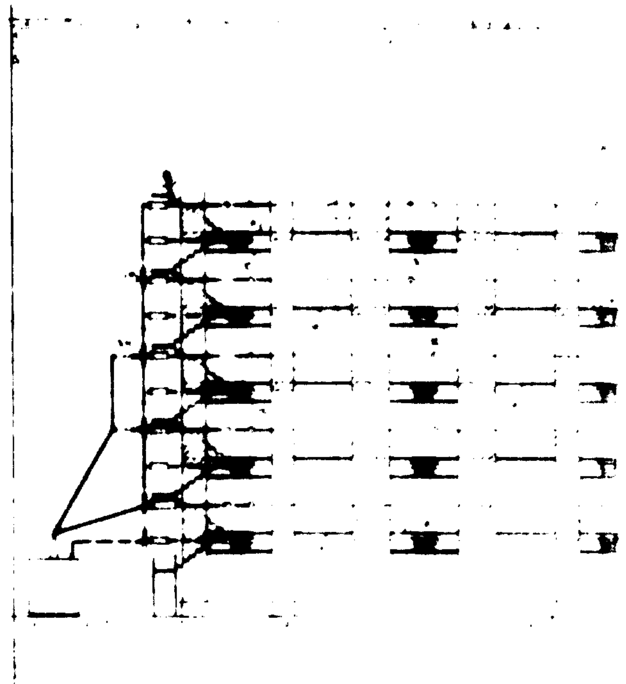
ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

TOWER OF INDUCTANCE COILS

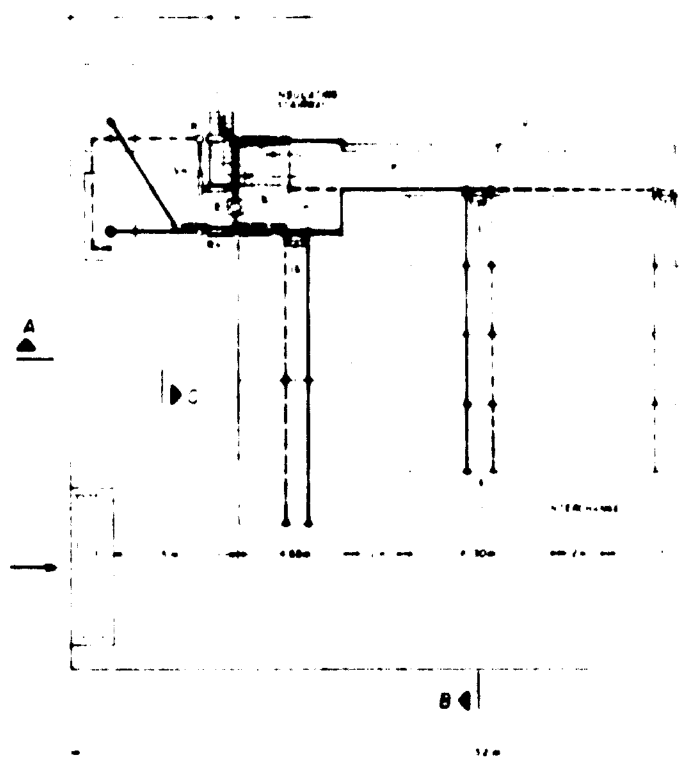
1015



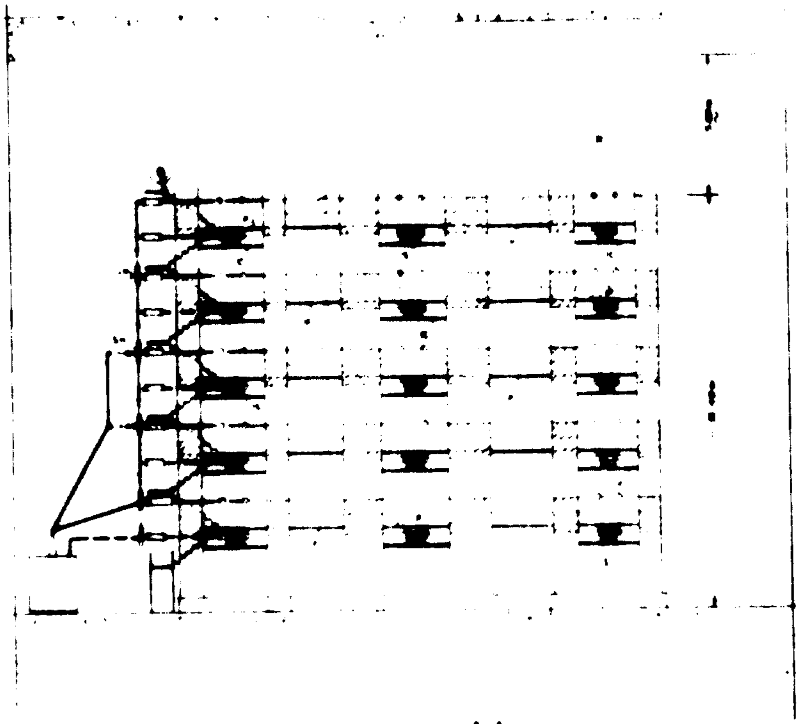
Section B-B



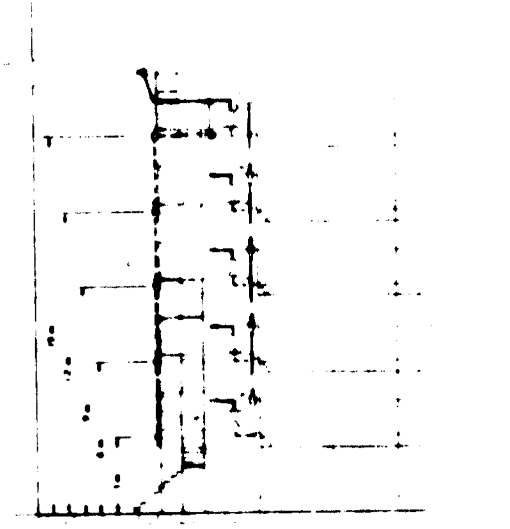
Section A-A



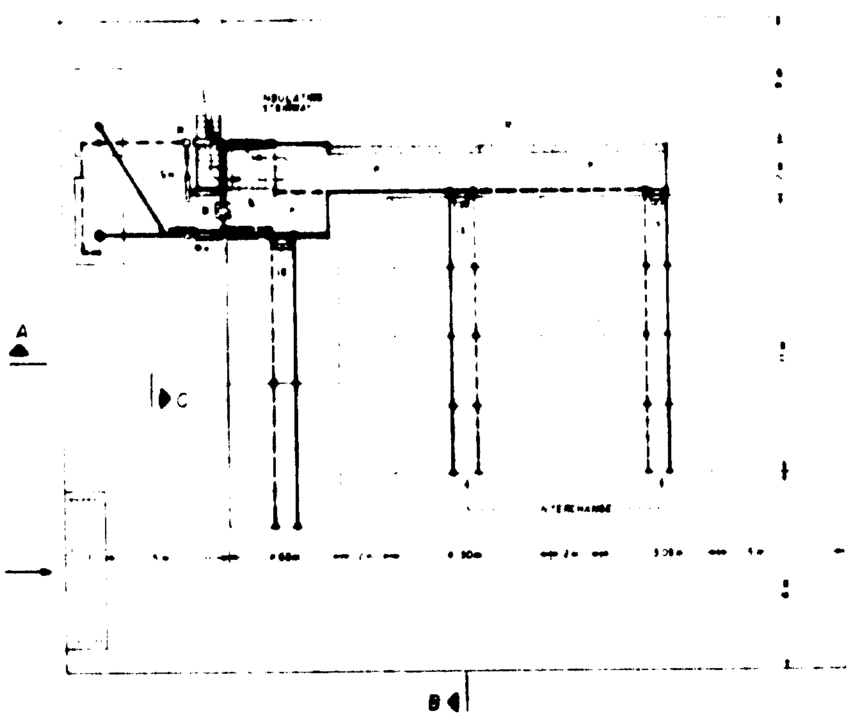
SECTION 1



Section A-A



Section C-C



SECTION 2

ELECTRICAL INDUSTRY TESTING
AND
EXPERIMENTATION CENTRE
MADRID SPAIN

MULTISTAGE SYNTHETIC CIRCUIT
GENERAL LAYOUT

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche

B-055

83.04.05

AD 83.01