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16790

Distr.
RESTRICTED

IO/R.70
3 May 1988

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

TECHNICAL ASSISTANCE FOR THE IMPROVEMENT OF THE PRODUCTION OF CONCRETE PYLONS FOR HIGH-VOLTAGE POWER TRANSMISSION LINES

UC/UD/COS/87/066

COSTA RICA

Technical report: Improvement and up-grading of the design, manufacture and erection of reinforced and prestressed concrete pylons for high-voltage power transmission lines*

Prepared for the Government of Costa Rica
by the United Nations Industrial Development Organization

Based on the work of Mr. G. Fogarasi, expert in reinforced and precase concrete

Backstopping officer: B. Der Petrossian, Chemical Industries Branch

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Explanatory notes

The value of the Costarrican colon during the period of the mission: 1 US$= 73.20 to 74.20 Costarrican Colón.

Definition of abbreviations used in the report:

UNDP : United Nations Development Program, San José, Costa Rica.
I.C.E.: Instituto Costarricense de Electricidad
P.C. : Productos de Concreto, S.A., San José, Costa Rica
PRENAC: Pretensados Nacionales S.A., San José, Costa Rica
ESCOSA: Estructuras de Concreto, S.A., Cartago, Costa Rica
PCI : Prestressed Concrete Institute, Chicago, Ill., USA
FIP : Federation Internationale de la Précontrainte, London, England
BVM : Beton- es Vasbetonipari Muvek (Concrete and Reinforced Concrete Works, Hungary
PFEIFFER:Pfeiffer Maschinenfabrik, Federal Republic Germany
ETI : Epitestudomanyi Intezet (Institute for Building Science), Hungary
r.c.: reinforced concrete
p.c.: prestressed concrete

Note: SI system is accepted in Costa Rica, however some former units are frequently used, such as

1 kg = appx. 10 N,
1 kg/cm² = appx. 0.1 N/mm²
1 psi = appx. 0.07 N/mm²

Abstract

Title of project: Improvement and upgrading of the design, manufacture and erection of reinforced and prestressed concrete pylons for high voltage power transmission lines.

Number of project: UC/UD/COS/87/066/11-51/J 13419

Duration of the activity: 33 days (18 days in Duty station

San José and the rest home-based work

Objectives of the activity:

Survey and collection of information on existing and potential design capabilities and production technologies of p.c. poles for high voltage transmission lines in the country. Definition of problems and shortcomings, demonstration of ways and means of the improvement of production. Providing information on the up to date technologies in prefabrication of p.c. poles and preparation of a preliminary proposal of a pilot plant. Preparation of the training programme and factory visits in Hungary for two months for the Costarrican engineers.

Main conclusions and recommendations:

Prestressed concrete poles for transmission or distribution lines are produced by three companies: PC, PRENAC and ICE all together in 5 plants. Improvement in details and prefabrication of other types of structural elements are recommended.

Recommendations were made to the Costarrican Governement for setting up a new project for the development of the industrialized construction (R.1), for organizing a training program for civil engineers in design, manufacturing and erection of prefabricated structures (R.2) nd to set up a multipurpose shiftable pilot plant for the prefabricatin of prestressed concrete poles and other types of prestressed and reinforced concrete structures (R.3).

Recommendations were made to ICE to investigate the feasibility of Vierendeel type p.c. poles (R.4), to study a large series of documentations written or collected by the expert and given to ICE on site (R.5, R.6, R.7), different programmes for the visit of ICE experts in Hungary (R.8, R.9, R.10, R.11).

Recommendations were made to prefabricating companies in problems of safety measures (R.13, R.14 and R16), of improving the quality of the elements (R.12, R.15, R.17, R.18).

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I. Activities and output

INTRODUCTION

The main objective of the project is the improvement and upgrading of the design, manufacture and erection of prestressed concrete pylons for high voltage power transmission lines.

The mission reported is the first part of the project which is followed by the training programme and factory visits of two Costarrican engineers in Hungary organized on site by the Hungarian Institute ETI.

The duration of the activity: 33 days, with 18 days in Duty station San José, Costa Rica and the rest home-based work.

The original objectives of the activity according to the job description were:

1. Undertake necessary survey and collect technical information on existing design capabilities and production technologies of concrete pylons for high voltage transmission lines in the country.

2. Evaluate the collected information and define the problems and shortcomings in the design and production of concrete pylons.

3. By means of visiting the production plant, lecturing and having consultations with local technical staff, demonstrate ways and means how the quality and quantity and of the production could be improved taking into consideration the availability, quality and handling methods of raw material and existing equipment and manpower.

4. Pay a short visit to some other plants, manufacturing other types of concrete products in and around San José, particularly those which are capable of manufacturing prestressed concrete elements and establish a comparison between the technological advancements of these plants, and the plant which is producing only concrete pylons for high voltage transmission lines. These visits and accompanied assessment would lead to a better evaluation of the technologies and capacities available in the country in precast concrete industry.

5. Advise and provide information for the authorities of ICE on the recent developments and up to date technologies existing in most developed countries in the concrete pylon manufacturing technology particularly the prestressing technologies for these pylons.

6. Prepare a preliminary proposal/lay-out and design of a pilot plant, including all necessary equipment for prestressing, concrete production, curing, storing, and all facilities required for manufacturing concrete pylons with high standard and quality. The draft proposal should take into account the capacities and optimum utilization of existing facilities and should provide a cost estimate as well.

7. In close co-operation with the Hungarian Institute for Building Science prepare a training programme and factory visits in Hungary for two months for the Costarrican engineers.

8. The expert is expected to prepare a final technical report setting out the findings of his consultation mission and also a set of recommendations and a programme to the Government for further actions which might be taken in order to improve the technical capabilities.
   This report should be submitted to UNIDO

The detailed programme prepared by I.C.E. before the arrival of the expert was in accordance with the original objectives listed above, but it concentrates to the manufacture (prefabrication).

The objectives slightly modified by I.C.E. were attained taking into account the duration of the activity.
On the base of the findings further proposals are made in the following recommendations.

RECOMMENDATIONS

R.1 Recommendation to the Government of Costa Rica

Investigation of the possibilities of seting up a new project in the frame of the UNDP activities in Costa Rica on a cost sharing base for the development, training and promotion of the industrialized construction and system building based on prefabricated prestressed or reinforced concrete elements in all fields of housing; industrial, agricultural and public building; public works and utilities; bridge, road, railroad, tunnel, electrical and hydraulic construction.
The need of such a project is obvious at the one hand for the demand of a rapid and low-cost construction, on the other hand because of the substantially higher prices of imported srteel structures.
In some special areas where complete building systems have been already introduced (such as electric poles, pipes, some standard single and multi storey building systems) excelent results can be found in Costa Rica.
In other areas the lack of training programs in design, prefabrication, erection, quality control, marketing, safety measures, terms of acceptance, modular co-ordination, standardization and of the technological transfer hinders the further development.

R 2 Recommendation to the government of Costa Rica

Delivering an extra lecture of high interest in the Colegio Federado de Ingenieros y Arquitectos, over the frame of the project activity on prefabricated structures and their manufacturing technologies the expert recommends to organize a training programme for civil and structural engineers and architects. This programme should be realized in the frame of the UNDP activities in Costa Rica on a cost sharing base in the following subjects:

Design of prefabricated elements and complete structures with special enphasis
- on the requirement of prefabrication,
- on the analysis and detailing of prefabricated elements,
- on the seismic requirements
- on the corrosion protection and durability,
- on th stability of structures during erection and in final phase.

Quality control, tolerances, terms of acceptance.
Marketing in prefabrication and construction.
Modular coordinatior and standardization in the construction.
Safety measures in prefabrication and erection.

The optimal duration of that programme would be appx. three months with home based works for preparation of unexpensive illustrated technical books in Spanish language and with training in the form of evening courses on site.

R.3 Recommendation to the government and ICE

Investigation of the feasibility and effectivity of setting up a multipurpose shiftable pilot plant for the prefabrication prestressed concrete poles. The same plant can be used for the prefabrication of other type of p.c. and r.c. elements, such as railroad sleepers, columns, beams, joists, lintels, floor and wall slabs fences, smaller bridge elements, driven piles, elements for foundation and hydraulic construction, etc.
Prefabrication of that types of pols as well as of all other elements mentioned above can be studied during the visits of the Costarrican experts in Hungary.

R:4 Recommendation to ICE

Investigation of the feasibility of the introduction of Vierendeel type p.c. poles in Costa Rica. These poles have rectangular cross sections and transversal holes according to fig. 5 and 6. The moment bearing capacity in the main direction is appx. the double of that of the perpendicular direction. Therefore the designer can determine the most advantageous position of the poles both in portal structures and in case of single poles used in straight lines, angle points, connection (tap) points, end points, etc.
Design, prefabrication and erection of these type of poles can be studied during the visit of the Costarrican experts in Hungary.

R.5 Recommendation to ICE

Study of some recent developments of prefabrication technologies for the manufacture of prestressed concrete poles.
In the frame of a direct promotion the expert gave on site one example of Volume I the following materials:

		page
1.	Vibration technology of the German Pfeiffer system for the production of prestressed concrete poles	2/02
2.	Spinning/centrifugating/technology of the German Pfeiffer system for the production of prestressed spun concrete poles	2/15
3.	Spinning/centrifugating/technology of the Czecho-Slowakian Elecktrovod Senec for the production of spun concrete poles	2/19
4.	Reinforced concrete poles in Poland	2/26

5.	Prestressed concrete poles in New Zealand	2/28
6.	Vibration technologies of the Hungarian BVM system for the production of Vierendeel type prestressed concrete poles	2/30
7.	Construction of power lines for transmission and distribution by use of spun concrete poles, by Erich Bacsa, Zurich, Switzerland	2/31
8.	Prestressed Concrete Poles: State of the Art by Thomas E. Rodgers Prestressed Concrete Institute, Journal, Sept-Oct 1984, pp 52-lol.	2/38
9.	Precast concrete technologies for developing countries by G.Fogarasi	
10.	BVM brochures	
11.	Zublin brochures	
12.	Pfeiffer brochures	

The same tchnologies were introduced and illustrated with slides in the lectures of the expert delivered during the mission.

R.6 Recommendation to ICE

Study of the Hungarian electrical network system for 20 and 35 kV with the aim of the improvement of the distribution line system of 34.5 kV of ICE.
In the frame of a direct promotion the expert gave on site one example of Volume II the following materials:

The VA'T-H2 Hungarian electrical network sytem for 20 and 35 kV (Abstract with illustrations in English).

R.7 Recommendation to ICE

Study of the Hungarian technologies for prefabrication of p.c. poles.
In the frame of a direct promotion the expert forwards in Annex IV the following materials:
"Hungarian technologies for prefabrication of transmission poles".

R.8 Recommendation to ICE

Study of the most important standards and guide lines for the design of high voltage electrical networks and prestressed concrete poles.
In the frame of a direct promotion the expert gave on site one example of Volume III the copies of the following materials.

1. Guide Specification for Prestressed Concrete Poles
   Prestressed Concrete Institute Journal, May-June 1982, Chicago, p. 19 to 29

2. Guide for Design of Prestressed Concrete Poles
Prestressed Concrete Institute Journal, May-June 1983, Chicago, p. 23 to 87

3. Response of spun cast Concrete Poles to Vehicle Impact
Prestressed Concrete Institute Journal, Jan-Feb 1986, Chicago, p 62 to 82

4. MSZ 151/1-86. Overhead lines for power transmission. Installation prescriptions for high voltage overhead transmission lines
Hungarian Standard /in Hungarian/. pp. 23

5. MSZ 151/3-73. Overhead lines for power transmission. Supports /poles/.
Hungarian Standard /in Hungarian/ pp. 18

6. MSZ 151/4-68. Overhead lines for power transmission. Support /pole/ foundation.
Hungarian Standard /in Hungarian/ pp.8

7. Reinforced and prestressed concrete line poles. Poles of low load bearing.
MSZ 4781/2/87. Hungarian Standard/in Hungarian/ pp.6

8. MSZ 15020-86. Design of load bearing structures of buildings. General requirements.
Hungarian standard/in Hungarian/ pp. 5

9. MSZ 15021/1-86. Design of load bearing structures of buildings. Design loads for buildings.
Hungarian standard/in Hungarian/ pp. 30

10. MSZ 15021/2-86. Design of load bearing structures of buildings. Requierements for rigidity.
Hungarian standard/in Hungarian/ pp. 4

11. MSZ 15022/1-86. Design of load bearing structures of buildings. Reinforced concrete structures.
Hungarian standard/in Hungarian/ pp. 50

12. MSZ 15022/2-86. Design of load bearing structures of buildings. Prestressed concreto structures.
Hungarian standard /in Hungarian/ pp. 9

13. MSZ 15022/3-86. Design of load bearing structures of buildings. Prefabricated concrete, reinforced and prestressed concrete structures.
Hungarian Standard /in Hungarian/ pp. 12

14. Construction of high voltage aerial networks over nominal voltage of 1 kV, December 1985.
DIN VDE 0210. German Standard/in German/. pp. 46

R.9 Recommendation to ICE

Improvement of the terms of acceptance of concrete poles on a quality and tolerance control base. In case of demand a brief training in quality control is available in the frame of the visit of ICE experts in Hungary.

R.10 Recommendation to ICE

Visiting prefabrication factories manufacturing p.c. poles. In case of demand the two Hungarian factories producing p.c. poles can be visited during the visit of Costarrican experts to Hungary.

R.11 Recommendation to ICE

Study of the design methods of prestressed concrete poles and supporting structures. If the Hungarian Institute ETI can assure the terms a consultation with Hungarian consulting offices EROTERV, EPINVEST, ETI, BVM, etc. is advisable in the problems of ultimate and crack control design. Furthermore a consultation in design of high voltage transmission poles and portal structures is also advisable (e.g. with Bacsa Consulting Zurich, who has a filiate in Vienna too).

R 12. Recommendation to ICE and to the precasting plants

The optimal lifting points of p.c. poles for stripping, lifting, handling and erection should be selected on a base of the optimal equalization of positive and negative bending moments.
The forwarded PCI materials contain valuable data for the calculation of the optimal handling points.

R 13. Recommendation to the fabricating companies

Some prefabricating companies don't use efficient safety caps, covers or shields which protect the workers against striking steel tendon parts if breakage occurs or against striking parts of anchorage chucks and grips if slippage ocurrs. Further safety measures can be studied in Chapter 13 of the book Prestressed Concrete Technology written by the author.

R 14. Recommendation to the prefabricating companies

In some prefabricating companies a lot of assembling work is done over totally tensioned prestressed tendons. In those cases a two phase tensioning is advisable, where these works can be done over partially (30 to 50%) tensioned tendons.

R 15. Recommendation to prefabricating companies

At the end of some poles longitudinal splitting cracks could be found along the tendons, which are dangerous of points of view of slip, corrosion and durability. These splitting cracks can be eliminated normally by placing an independent small external stirrup of small diameter (3 to 4 mm) in 3 to 5 rings around the tendons at the end of the pole.
Concrete cover should be controled.

R 16. Recommendation to prefabricating companies

Having seen an interesting self developed stirrup winding machine equipped with a good safety switch it has to be noted that the use of a wire conducting cone mounted shiftable on a horizontal axle and also connected to the safety switch is advisable for safety reasons.

R 17. Recommendation to prefabricating companies

In all of the Costarrican vibrating technologies the use of the top mould of half-circular cross section did not result adequate surface of pole on the upper half. Therefore the final shape of the upper half surface of the pole is done by hand-patching. This demand at the one hand tremendous man power, on the other hand in certain cases transversal cracks could be found becasuse of the differential shrinkage of the patch-mortar and of the real vibrated concrete.
If the constructyion of the top mould can not be improved it is advisable the investigation of the introduction of a polygonal cross section (e.g. of 9 angles), where only 1 of 9 sides should be smoothed by a simple throweler.

R 18. Recommendation to ICE

For further information it is advisable to contact Prestressed Concrete Institute, USA, (President: Mr. David W. Hanson, President of FABCON Inc., 6111 West Highway 13, Savage, Minnesota, 55378 USA, Tel: 612-890-4444).
The prescription for PCI Journal, purchase of the metrical version of PCI Design Handbook, etc. is recommended.

TECHNICAL REPORT

I. ACTIVITIES AND OUTPUT

A. Duties and objectives of the activity

Duties and objectives according to the related job description dated of 04.09.1987 were as follows:

The expert will be assigned to the "Instituto Costarricense de Electricidad" (ICE) and will specifically be expected to:

1. Undertake necessary survey and collect technical information on existing design capabilities and production technologies of concrete pylons for high voltage transmission lines in the country.

2. Evaluate the collected information and define the problems and shortcomings in the design and production of concrete pylons.

3. By means of visiting the production plant, lecturing and having consultations with local technical staff, demonstrate ways and means how the quality and quantity and of the production could be improved taking into consideration the availability, quality and handling methods of raw material and existing equipment and manpower.

4. Pay a short visit to some other plants, manufacturing other types of concrete products in and around San José, particularly those which are capable of manufacturing prestressed concrete elements and establish a comparison between the technological advancements of these plants, and the plant which is producing only concrete pylons for high voltage transmission lines. These visits and accompanied assessment would lead to a better evaluation of the technologies and capacities available in the country in precast concrete industry.

5. Advise and provide information for the authorities of ICE on the recent developments and up to date technologies existing in most developed countries in the concrete pylon manufacturing technology particularly the prestressing technologies for these pylons.

6. Prepare a preliminary proposal/lay-out and design of a pilot plant, including all necessary equipment for prestressing, concrete production, curing, storing, and all facilities required for manufacturing concrete pylons with high standard and quality. The draft proposal should take into account the capacities and optimum utilization of existing facilities and should provide a cost estimate as well.

7. In close co-operation with the Hungarian Institute for Building Science prepare a training programme and factory visits in Hungary for two months for the Costarrican engineers.

8. The expert is expected to prepare a final technical report setting out the findings of his consultation mission and also a set of recommendations and a programme to the Government for further actions which might be taken in order to improve the technical capabilities.
This report should be submitted to UNIDO

B. Program of the technical activity

The program of the technical activity organized by ICE according to the Project Document of UNIDO was as follows:

Monday, 22.02.88, Central Building of ICE.
Exposition the requirements of ICE for design of prefabricated p.c. poles.
Description of existing p.c. prefabricating plants in and around San José.

Tuesday, 23.02.88
Visit to the Patarrá p.c. pole plant of Productos de Concreto (see Nº 2 of Annex I).

Wednesday, 24.02.88
Visit to the p.c. pole manufacturing plant of ICE in Cebadilla, Alajuela.

Thursday, 25.02.88
Visit to the p.c. prefabrication plant of ESCOSA in Cartago (see Nº 3 of Annex I).

Friday, 26.02.88, Central Building of ICE
Discussion of the results of the previous visits.

Monday, 29.02.88, Central Building of ICE
Explanation and discussion on the existing design capabilities in Costa Rica, as well as the possibilities in assistance.

Tuesday, 1.03.88
Visit to the plant for prefabrication of p.c. poles of PRENAC in San Francisco, San José.

Wednesday, 2.03.88, Central Building of ICE
Lecture of the expert and discussion on the state of the art of the development of prefabricating technologies of p.c. poles delivered to the engineers of ICE.

Thursday, to Friday, 03. to 04.03.88, Central Building of ICE
Preparation of a preliminary proposal for a pilot plant for the manufacturing of prefabricated p.c. poles.

Thursday, 03.03.88, 7 pm Colegio Federado de Ingenieros, San Pedro, San José.
Lecture of the expert on the state of the art of the prefabricating technologies of different p.c. structures.

Monday, 07.03.88 Central Building of ICE
Preparation of scope of the training programme and of the factory visits in Hungary for the Costarrican engineers.

Tuesday, 08.03.88, UNDP Office, Los Yoses
Evaluation of the results and preparation of further tasks of the project.

II. FINDINGS AND RESULTS OF THE ACTIVITIES

1. Basic materials of poles and other supports

The decisive point of the selection of the proper types and materials of the supports of the electrical systems is that Costa Rica has no metallurgy and no own steel production.
The high costs of imported steel structures forced the introduction of prefabrication of reinforced and prestressed concrete structures in all fields of construction.
Cement is produced in Costa Rica in good qualities and quantities also for export.
Aggregates for concrete are produced by local quarries in different qualities. The material of aggregates is allways some sort of eruptive stone crushed and classified in the quarries. E.g. ESCOSA uses three fractions: one of river sand and two fractions of crushed stones of maximal diameters of 7 and 20 mm respectively. The superfluous fine particles, such as clay and silk were washed out from the river sand during wet classification, while those of the others seem to be intact.
No detailed information were available on a comprehensive investigation of the aggregates. In case of need a consultation with the experts of ETI, Hungary on a possible investigation of samples of aggregates taken on random selection is advisable.

2. State of the art of the high voltage transmission system of 138 kV and 230 kV

The electrical system of Costa Rica consists of

a. High voltage transmission system of 138 kV and 230 kV,
b. Low voltage distribution system of 34.5 kV and 13.8 kV,

Until 1984 the supports of the high voltage transmission system were made exclusively of steel lattice towers imported from different countries, mostly from Italy and Brasil, a few from Spain and México. The elements of the towers were imported in form of galvanized steel angles cut to measure and drilled for bolt connections. Local contractors erected the towers according to the design of the suppliers.
The price of the imported steel structure of one tower was 3 000 US$ (increasing now). Spans of towers were 450 to 500 m.

In 1984 a short section of a 138 kV transmission line called "La Caja Alajuela" was erected on single timber supports of a length of 21 and 23 meters. The conductors were mounted on three levels of rigid horizontal type insulators to minimize the expenses of the right of way. Timber were imported from the United States for a price of 900 US$ each. Spans of timber poles were appx. 100 m.

With the aim of substituting the import materials ICE begun the design of the Colorado-Santa Rita (Guanacaste province) transmission line of 138 kV in 1984.
The project was finished in 1985. The standard supports of the line were H type structures made of a pair of <u>prestressed concrete poles</u>, a top horizontal steel lattice structure and a diagonal bracing according to fig. 1.
Design of the structures was based on own experience having some sort of American literature and assistance. A combination of US provisions and company requirements were used in the design.

The total length of the line was 30 Km with an average span of 275 to 300 m. 132 p.c. poles were used for the erection of 66 H type portal structures, whereas 34 supports were constructed of steel lattice towers because of very large spans or transportation difficulties. The total construction cost of the line was appx. 50 p.c. of that of made completely with steel towers.

The prestressed concrete poles of a total length of 18 m had a square section varying from 320 x 320 mm to 200 x 200 mm according to fig. 2. The poles were pretensioned with 4 pcs of 1/2 in (12.7 mm) diameter seven wire strands. 4 pcs of longitudinal deformed bars of 3/8 in, were the supplementary reinforcement of the pole in a length of 9 m. The poles were produced by Productos de Concreto S.A. on a self developed vibrating technology in self-stressed steel molds with removable conical steel cores. (See photos 1 to 7 in Annex I). According to the [illegible] of ICE the poles were not cracked and met the requirement of grade of concrete 350 kg/cm² (35 MPa), however terms of acceptance are not clear. The weight of the pole was 1920 kg.

The ultimate moment bearing capacity of the poles was Mu = 8.00 m (appx. 80 kNm) measured on a level of 2 m from the bottom. This equals to an ultimate horizontal top tension (load bearing capacity) of

$$F_{uht} = \frac{8.00\ m}{16\ m} = 500\ kg\ (appx.\ 5\ KN)$$

which corresponds to an allowed top (design) horizontal load bearing capacity of appx. 200 kg (appx. 2.0 KN) calculating with a safety factor 1.67, a supercharge factor of 1.15 and taking into consideration the wind load on the entire pole.

This low value of top horizontal load bearing capacity was compensated in transversal direction by bracing the poles into frame and in longitudinal direction by the application of two pairs of inclined anchoring stays for every third support. On the other hand the designers of ICE took very low temperature differences into consideration in the design

(10 ºC difference). Ice load doesn't exist in Costa Rica. Breaking of conductors was not taken into consideration. The decisive period of the design was that the weight of the pole can not be over 2 000 kg for transportation and erection reasons. Large scale experiments and a failure test on a life size H type portal structure stayed with a pair of inclined anchoring cable in both direction were made to verify the analitical results.
The Colorado-Santa Rita line is in service for 3 years and no problems were presented in spite of the use of the very slender p.c. poles and the empirical design.

Based on the favorable experiences the realization of further transmission lines of 230 kV are planed in a total length of 108 Km until 1993. The length of the Miravalles-Arenal section is 32 Km, that of the Miravalles-Liberia section is 36 Km, while the length of the Siquirres-Guápiles line is 40 Km
The typical arrangement of a so called HV type portal support is shown in fig. 3.
The design loads calculated of real loads are as follows:

V1 = 115 x 1,0 x 1,67 = 200 kg (2 kN) horizontal top
V2 = 337 x 1,0 x 1,67 = 563 kg (5,63 kN) horizontal on 3 isolators
P1 = 102 x 1,15 x 1,67 = 200 kg (2 kN) vertical top
P2 = 406 x 1,15 x 1,67 = 780 kg (7,80 kN) vertical on 3 isolators

Calculating with an average span of 300 m, two poles per support and a construction time of 3 years, the annual demand of high voltage p.c. poles is 108 Km: 0,3 Km x 2 pcs : 3 years = 240 poles per year in present prices 220 x 20 000 = 4 400 000 ¢ per year.

3. State of the art of the low voltage distribution system

The low voltage distribution system of Costa Rica consists of the 34.5 kV and the 13.8 kV system. The 13.8 kV system will be replaced entirely by the 34.5 kV system. The main contractor of the erection of that type of lines is the ICE, however some other local electrification institutions, like ESPH-Heredia, CNFL-San José, Coope Guanacaste, JASEC, Cartago and Coope San Carlos are doing the same work in smaller extent.

For the supports of the low voltage distribution system either single timber poles, or single prestressed concrete poles are used recently. Steel poles are not used for that purpose any more because of the high price of the imported steel structures.

In angle or connecting points of the lines inclined cable stays are used for balancing the poles. Cable stays are anchored in the earth by reinforced concrete blocks of different masses. Other solutions, like stronger single poles, twin poles or portals are not used for that purpose.

Timber poles in length of 7.62, 10.67, 12.19 and 13.71 m are produced for ICE in Turrialba, Cartago. However in the last years only 1 500 to 2 000 timber poles were produced annually in Turrialba, because of small drying capacity. For local co-operatives timber poles are locally produced in small quantities. Raising timber prices yields to the consequence that timber poles are more expensive than prestressed concrete poles recently.

Prestressed concrete poles are produced in the form of hollow core (tapered) conical elements of a circular ring cross section. According to the "Normas de Construcción, ICE, Sept. 1983" 10 types of p.c. poles are standardized for distribution lines (see fig. 4). In type poles of lengths in 8, 9, 10, 11, 12, 13 and 15 m have an external top diameter of 13 cm. IP type poles of lengths in 11,13 and 15 m have an external top diameter of 16 cm.

4. Prefabricating technologies of the manufacture of p.c. poles

In the frame of the programme organized by ICE 3 pole technology has been visited.

Productos de Concreto (PC) is the main manufactures of p.c. poles. In the last year (1987) PC produces in 3 plants: the following distribution poles:

700 pcs of 8 m
6 300 pcs of 10 m
1 800 pcs of 11 m
1 200 pcs of 12 m
300 pcs of 13 m length

10 300 pcs in total

The distribution poles are manufactured in short self-stressing moulds with removable cores by a self developed vibrating technology.
Sequences of the production are shown in Photos 1 to 7 in Annex II. The level of mechanization is low, bending of spiral stirrup, patching of the whole top half-circular surface and the removal of cores are made by hand.
Compacting is made by one single vibrator moved along the top mould in steps.
In 3 plants on 65 moulds the total capacity in one shift is:

$$65 \times 250 = 16.250 \text{ pcs per year}$$

The productivity is 16.250 pcs: ----workers = pc per worker in one year.

The prefabrication of the slender transmission poles of 18 m long in a self developed self stressed mould in a relative good quality was an outstanding

ICE Prefabrication plant in Cebadilla

The equipments of the plant were bought in 1976 from unknown resources. The plant installed at first in the year of 1980 in Corobici, Guanacaste and wasshifted in 1985 to Cebadilla.
The plant consists of two lines of long bed technology for 2 x 4 pcs of 11 m length. 4 pcs of elements are produced each day with an annual production of

4 x 250 = 1000 pcs

Having 6 workders the productivity of the plant is

1000 pcs: 6 workers = 167 pcs per worker

Details of the long line technology are shown in Photos 9 to 17. There is no steam curing in the line, sprinkling pipes can assure the required release strength of concrete in a 2 days period.

Pretensados Nacionales SA, PRENAC, San Francisco, San José

PRENAC owns a spining (centrifugating) technology purchased form the Western German PFEIFFER company 23 years ago.
In 12 moulds 6 workers manufacture poles up to 15 m.
The spining equipment is long enough for poles of 20 m or even longer. The moulds consists of two half moulds; and in the length they are bolted together of 3 m long mould units, but mould sections of 1 and 2 m length are also available. From these sections presently moulds of a maximal length of 17 m can be assembled, but in case of a rational series of 200 pcs per year they are ready to manufacture longer moulds [illegible] They have already exported moulds to Salvador on a price of 900 USD per m.
Grade of concrete 5000 or 6000 (= 35 and 42 MPa resp.).
Two sets of moulds are used, on of 130 mm, the other of 160 mm external top diameter. Change of diameter at the length is 15 mm per m in diameter.
8 to 12 pieces of wires of 6 mm diameter are used, imported from Japan, South Korea or Brasil on a recent price of 900 USD/tones. Sometimes strands are used too.
The price of poles is in average 1 200 C per m, which is 3times higher than the 4 000 C price of a PC pole of a length of PC. Driven piles of the same geometry are also produced on the technology.

The productivity of this plant is 3000:6 = 500 poles per 1 worker in one year, the best in Costa Rica.
PRENAC sales its products to the other local and co-operative electrical companies undertaking also in case of demand the erection in custom-dug foundation hole. They erect by own trailers equipped with 4 tone crane.

5. Prefabricating technologies for manufacturing other types of elements

Productos de Concreto SA manufactures pipes, p.c. joists, fences, T and TT units, solid floor slabs and an own developed 3 to 4 storey high flat wall slab with foundation and bracket-edges.
PRENAC produces all types of vibrated and spun concrete pipes up to the diameter of 2.90 m, as well as TT units and driven piles.
Estructuras de Concreto SA, ESCOSA has a new prefabrication plant with very high investment and highly mechanized openable stationaryk moulds.
The capital and the technologies are both Italian.

In the craned hall of industrial product elements of a standard single storey hall structure of 12, 15, 18 and 20 m span are produced. The manufacture of the main girders, the gutter elements, the purlins and the foundation elements are shown in Photos 19 to 23 of Annex II. In the large craned hall p.c. beams and r.c. columns of a multi storey earthquake proof structure are produced on long line fixed bed technologies shown in Photos 24 and 25 of Annex II. P.C. hollow core slabs of 8, 12 and 16 cm are manufactured by a long line slip mould machine made in Italy, but very similar to the German slip mould machines. The 1 shift capacity of ESCOSA is fully lasted.

The success of new investigations shows the very advantageous position of prefabricated concrete structures against the extremely expensive imported steel structures.
On the other hand only structures belonging to completely standardized system can be sold because of lack of training in design and erection of precast concrete structures.

6. Design capabilities

All the transmission lines and most of the distribution lines of Costa Rica are designed by ICE. In the frame of the design of the lines the spans and the real loads are determined by the Transmission Design Office of ICE. Design loads are calculated on the base of a security factor of 1.67 and an overload factor of 1.15 and 1.0 respectively based on a home standard of ICE.

The geometry of the supporting structures of the transmission lines are designed according to minimal electrical distances required by the National Electric Safety Code (NESC) of USA adapted by ICE. Preliminary analysis of the supporting portal structures are made by traditional methods, while for the final analysis the American SAP computer program is used. A new program for microcomputers is in the phase of introduction.

The design of the prestressed concrete transmission and distribution poles are made by the prefabricating companies. ICE gives all the loads as well as the moments, shear, compression and tension on the levels of the cross beam, of the bracings and on the ground level. The design and analysis of the poles should be improved according to the internationally accepted level.

Terms of acceptance for poles are elaborated and given precastors by ICE, but these need also further improvements.

Both in the civil and the mechanical area of design department of ICE well prepared and equipped civil and mechanical engineers of high level degrees ar working. The home development of the transmission line portal structures and the poles justify the high level of their education as well as and their innovative capabilities.
A part of the informations the engineers of ICE asked for was elaborated by the expert in the frame of home-based work (see R.4 and R.7). Others can be supplied during the visit of two Costarrican engineers in Hungary in form of training programs and factory visits (see R.8 and R.10).
Though some sort of prefabrication is in the program of the civil engineering faculty of the local technical university, the subject is general and no use in practice.
Design of p.c. poles is made by prefabricating companies limited only to the ultimate control of the main cross section.

7. Transportation and erection

The 18 m long poles were transported from the prefabrication plant of Patarrá, San José to the construction campin Parranca, Puntarenas (130 km) by PC on his own trailers of appx. length of 15 m in groups of six.
ICE transported groups of 3 poles on lighter trailers to the erection sites. Poles were erected by small cranes erected on tracks. For this reason the weight of the poles can not than 2 tones.

8. Pole demands of ICE

The average demand of ICE in low voltage distribution poles for the years of 1988 to 1993 is appx. 11000 poles annually.
The average demand of ICE in high voltage transmission poles for the years of 1989 to 1993 is appx. 200 poles annually.

The existing capacities of the prefabrication plants in and around San José can satisfy this demand, but an upgrading of the existing capacities is necessary.

III UTILIZATION OF THE RESULTS OF THE ACTIVITY

The results of the activity are summarized in the Recommendations.

Some of these results like that of listed in R.5, R.6 R.7 and R.8 are ready for utilization in the forms of many hundred pages of written or printed information, different national standards, guide lines and examples for the manual and computer analysis of poles, photos and descriptions of the most developed technologies, drawings and abstracts of standard documentations of electrical lines, etc.

Other results of the activity such as those recommendations summarized in R.12, R.13, R.14, R.15, R.16 and R.17 were directly adviced to the prefabricators during the visit of the expert, so they already use if they wish.

Some of them, like that of under R.14 has been already prove and introduced in at least one plant.

Some results yielding in recommendations R.2, R.3, R.4, R.8, R.10 and R.11 relate to the training programme of two Costarrican engineers in Hungary and will be utilized during that programme.

Most of the results were interpreted in the form of two lectures delivered to the experts of ICE and to the prefabricating engineers according to the programne.

IV. CONCLUSIONS

Prestressed concrete poles for transmission or distribution lines are produced by three companies: PC, PRENAC and ICE all together in 5 plants. PC has 3 short bed vibrating technologies ICE a long bed vibrating technology while PRENAC a spinning technology. The level of mechanization is very different, the lower the mecanization -the lower the prices. The manufacture of the slender 18 m long p.c. poles with very simple equipments was an excellent solutions for some quality problems and safety shortages are summarized in points R.11 to R.16 of the Recommendations.

The productivity of the p.c. pole technological lines varies between 170 to 500 poles per worker annually, which takes 15 to 45% of the productivity of the p.c. pole technology of BVM, Hungary (1100 poles per worker annually).

Other types of p.c. and r.c. elemtns are mainly produced by ESCOSA and PC. ESCOSA has put high investments into the technologies. Some of its technologies are versatile (long bed system) the others single purpose moulds made on high level of mechanization.

According to the request of UNIDO and ICE design and list of equipment of a multipurpose plant has been elaborated by the expert (see Fig. 7 and connecting table).

ANNEX I

SENIOR COUNTERPART STAFF

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ICE plant for the manufacture of p.c. poles, Cebadilla,
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Bruno Guandalini, Resident Represesntative
Soren Aarslev, JPO
Juerg Meichle, Oficial de Programas (53-39-20)

ANNEX II - PHOTOS

PATARRA PLANT OF "PRODUCTOS DE CONCRETO, S.A."

Photo 1. View of the line for prefabrication of p.c. poles in the Patarrá plant of PCSA.

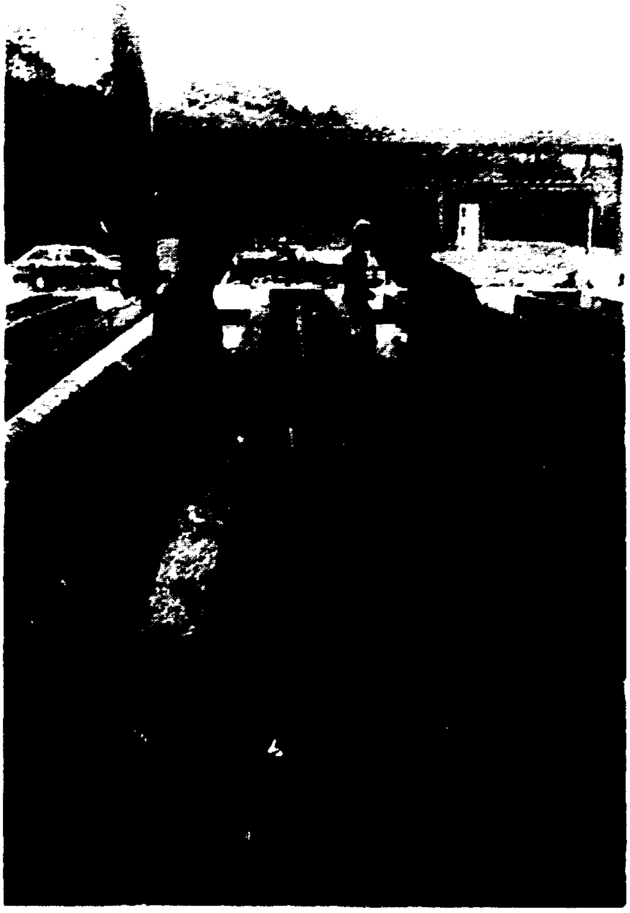


Photo 2. Fixing of hole forming dowels into the steel mould, core former and spiral stirrups already placed. Lines in the background serve for prefabrication of solid floor and multistorey wallslabs, as well as of columns and beams.

Photo 3. Self-stressing steel mould on concrete footings ready to cast in the Patarrá plant of PCSA. Core former and top mould already fixed, strands stressed and anchored against the mould.

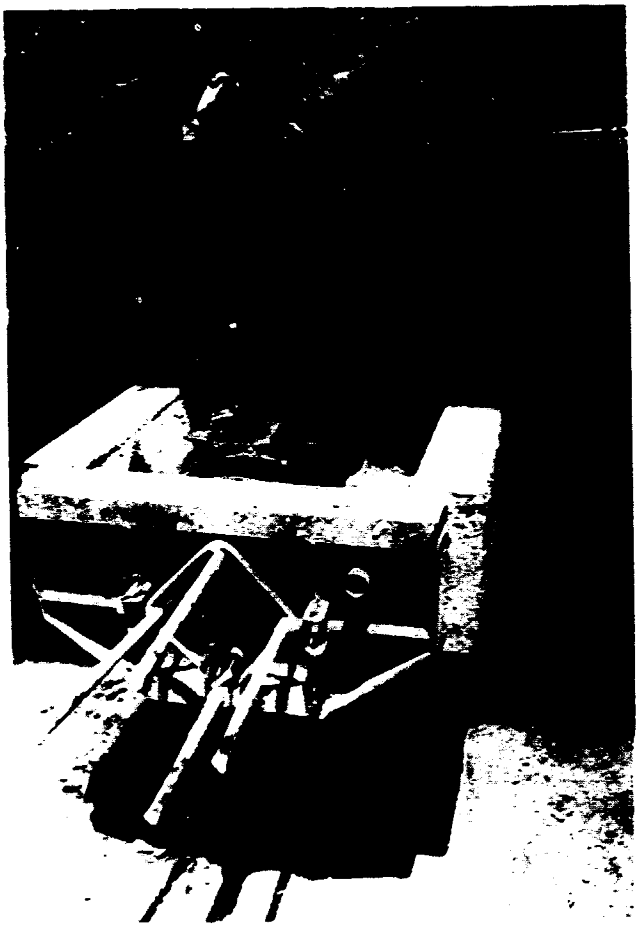


Photo 4. Vibrator mounted onto the top mould.

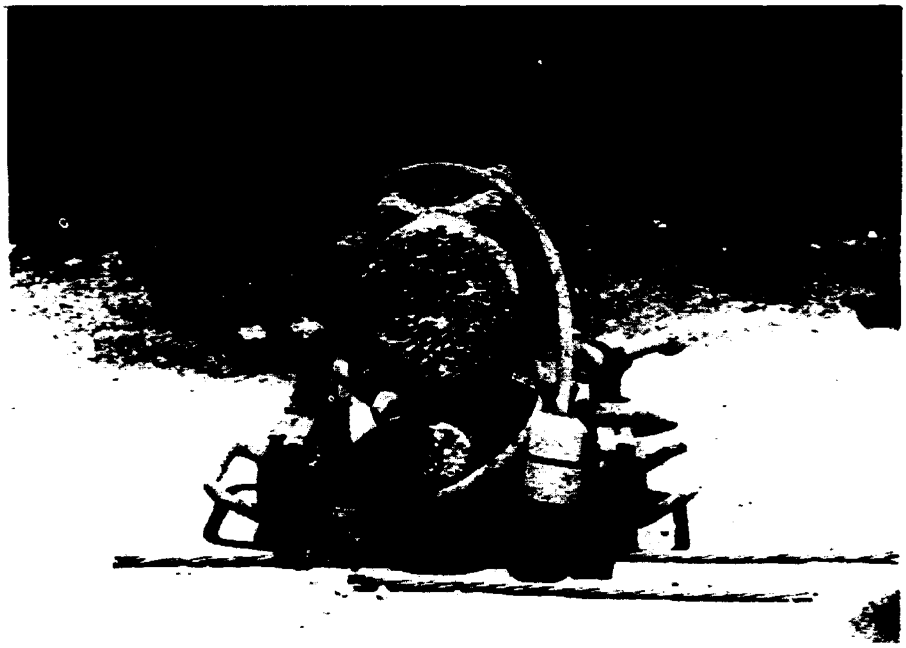


Photo 5. View of top vibrator used in the Patarra plant of PCSA

Photo 6. The first half meter of the core is removed just after casting by a chain wrench seen in the bottom right corner. After that removal is made by hand.

Photo 7. The cores removed from the moulds are transported longitudinally by a truck to the next casting position.

Photo 8. Longline pretensioning for the prefabrication of p.c. floor joists

PLANT OF ICE FOR PREFABRICATION OF P.C. POLES IN CEBADILLA, ALAJUELA

Photo 9. View of the long line fixed bed technology for prefabrication of p.c. poles in Cebadilla (2 lines for 2 x 4 poles of a length of 11 m)

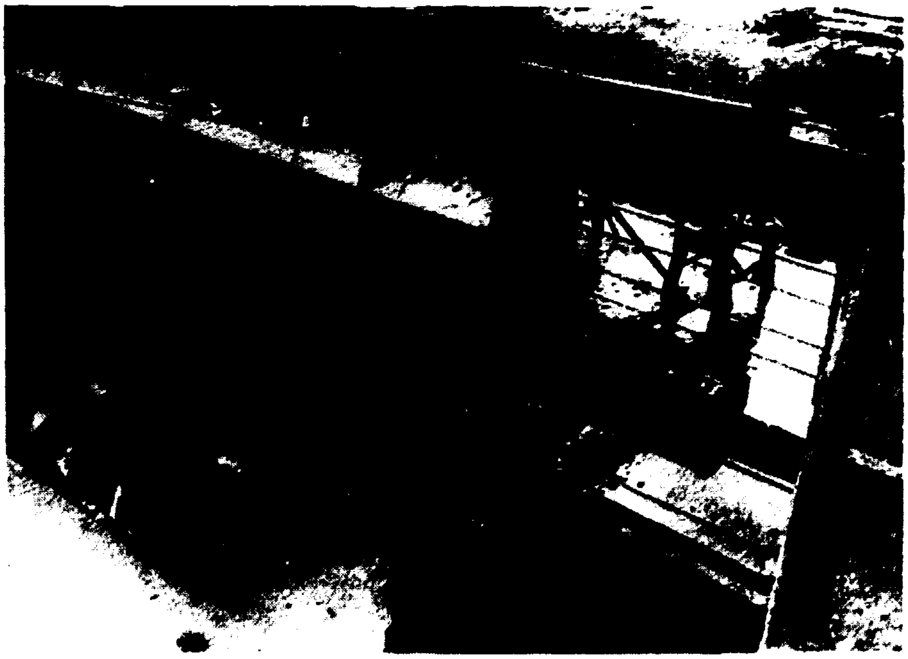


Photo 10. Detail of the end of the first mould after position of the core and pulling-in the strands.

Photo 11. Stressing jack in operation, strands are stressed against the anchor posts of the underground abutments.

Photo 12. Winding machines for the manufacture of spiral stirrups of changing diameters

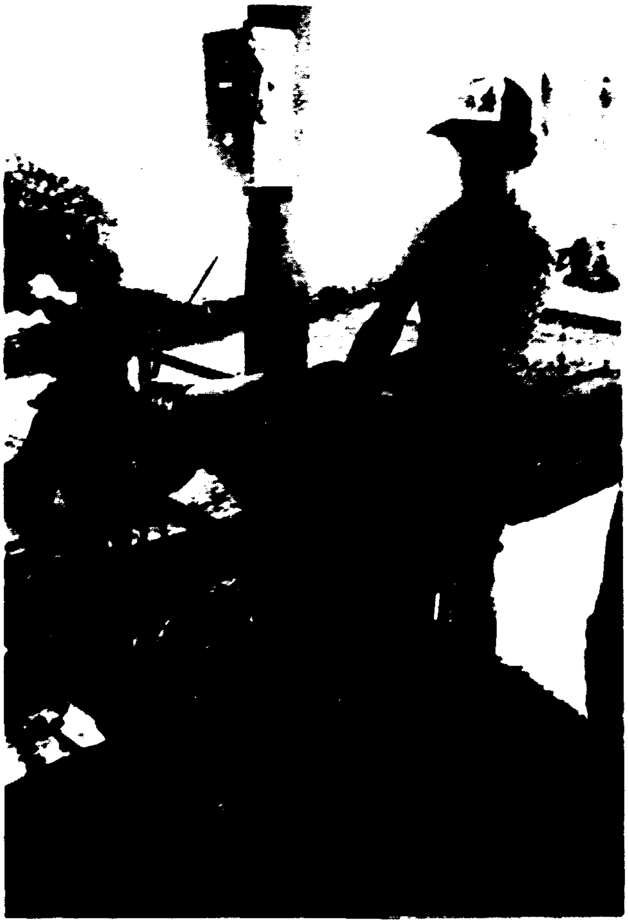


Photo 13. Detail of the line with the second mould in the phase of spacing the stirrups after stressing

Photo 14. End of the last mould with vibrator fixed on it, in the

Photo 15. End view of the first mould with the partially removed core. Appx. 1 m of the core is pulled out immediately after casting by a chain-tightener.

Photo 16. Middle of the line with detail of top mould in foreground and partially removed cores in the background.

Photo 17. Detail of the medium part of the line with partially removed cores and sprinkling pipes over the partially dismoulded poles. The only curing of the poles is a 40 to 48 hour sprinkling.

Photo 18. Ing. Manuel E. Cabezas (ICE), Ing. Ulises Odio (ICE), Dr. Ing. Gyula Fogarasi (UNIDO) and plant manager.

PREFABRICATION OF OTHER TYPES OF P.C. AND R.C. ELEMENTS IN THE CARTAGO PLANT OF ESCOSA

Photo 19. Battery mould for precasting of 5 pieces of p.c. roof girders of a standard length of 15 m in the Cartago Plant of ESCOSA. In the background battery mould for precasting of r.c. columns can be seen.

Photo 20. Moulds with removable cores for precasting of r.c. gutter elements.

Photo 21. Adjustable battery mould for precasting of r.c. roof purlins.

Photo 22. Moulds open diagonally for precasting of r.c. foundations.

Photo 23. Casting in the foundation moulds in the Cartago Plant of ESCOSA.

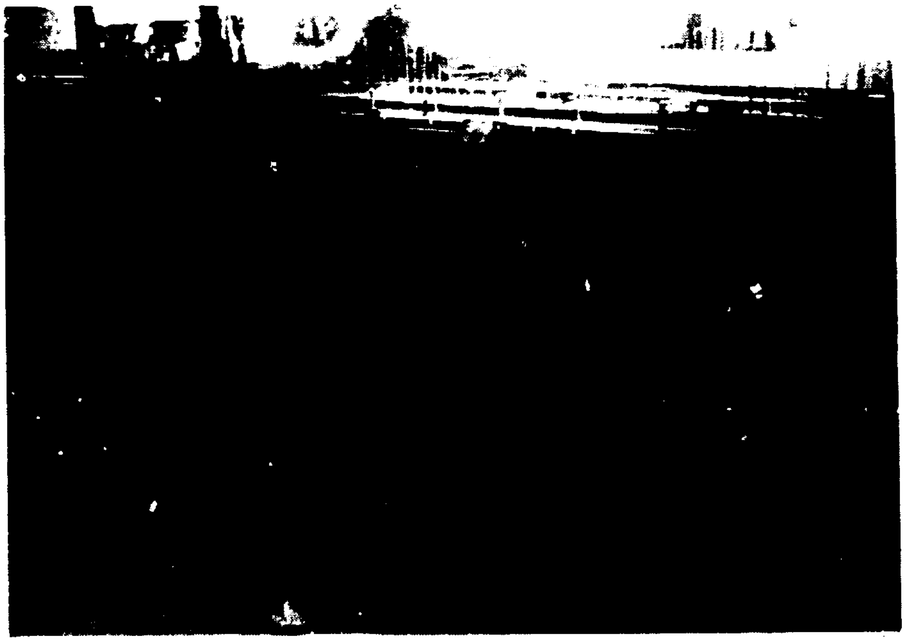


Photo 24. End detail of the long line fixed bed system for precasting of p.c. beams of multi storey buildings.

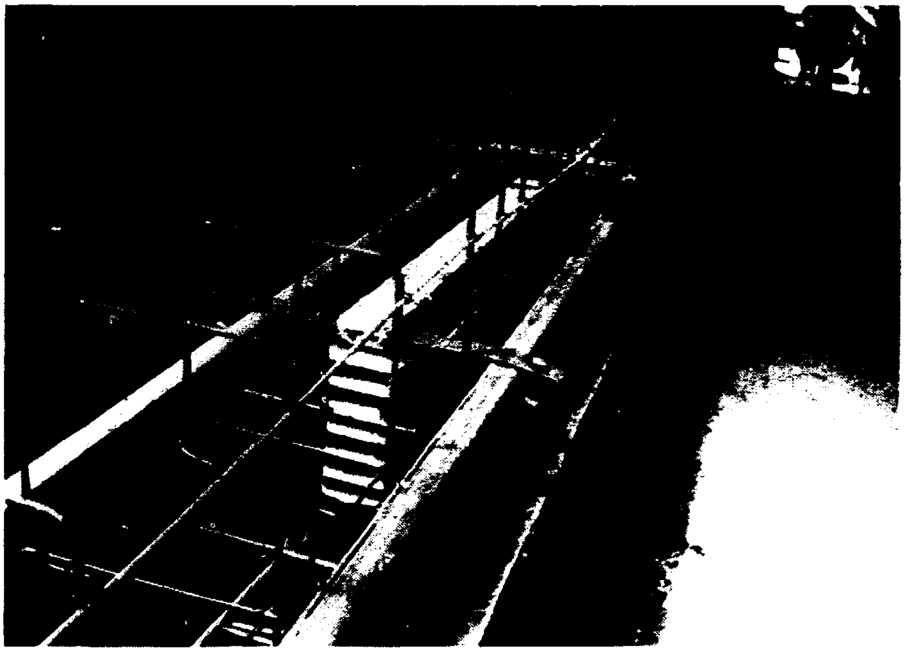
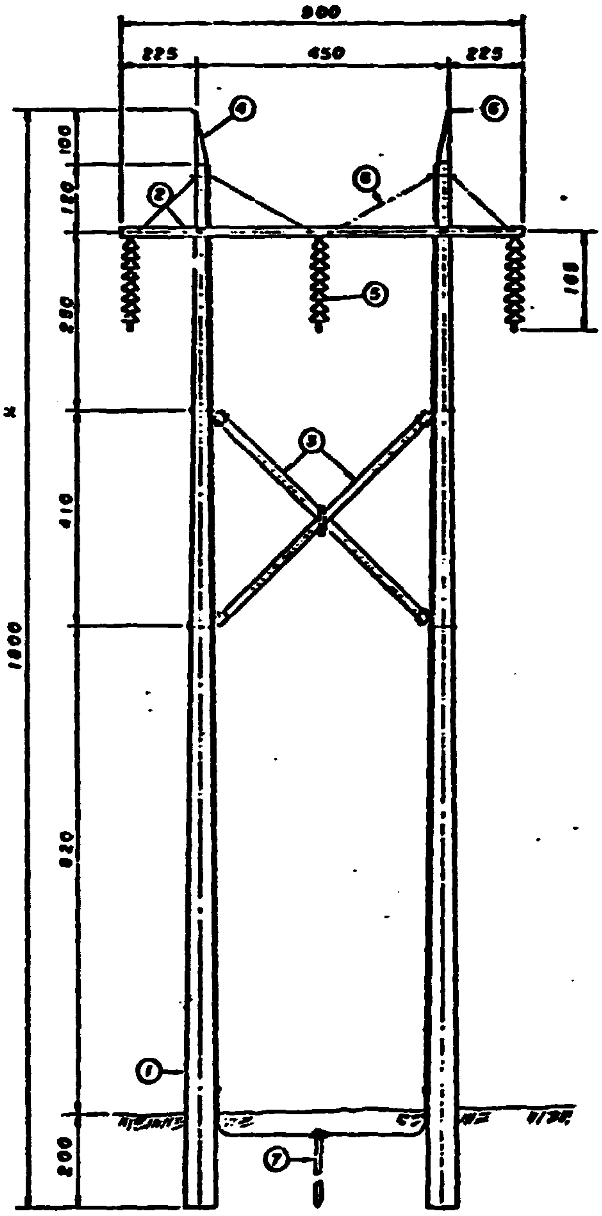


Photo 25. End details of the moulds of p.c. beams for multi storey buildings. By the use of a core the ends of the beams have a U form hollow. These hollows and the top of the beam are cast on site after placing of proper reinforcement connecting the beams to the columns assuring a monolithic effect against earthquake.

ANNEX III - FIGURES



NOTA:

- DIMENSIONES EN CENTIMETROS, SALVO OTRA INDICACION.

ITEM	CANT.	DESCRIPCION
1	2	POSTE DE 18 mts. CONCRETO, ACERO O MADERA
2	2	CRUCERO DE MADERA DE 7,5 x 20 x 900 cm
3	2	RIOSTRA DE MADERA DE 10 x 15 x 600
4	2	BAYONETA DE 150 cm DE ANGULAR DE 100 x 100 mm x 6 mm espesor
5	3	CADENA DE AISLADORES DE 11 UNIDADES, PREFORMADO Y CONDUCTOR.
6	2	CONJUNTO DE SUSPENSION HILO DE GUARDA
7		PUESTA A TIERRA
8		CABLE DE ACERO Ø = 9mm

L.T. COLORADO - SANTA RITA

138 KV CONDUCTOR M.C.M. 394,6 A.A.A.C.

Fig.1 H type supporting structure consisting of two prestressed concrete poles for the colorado-Santa Rita transmission line of 138 kV

FIGURA Nº 1

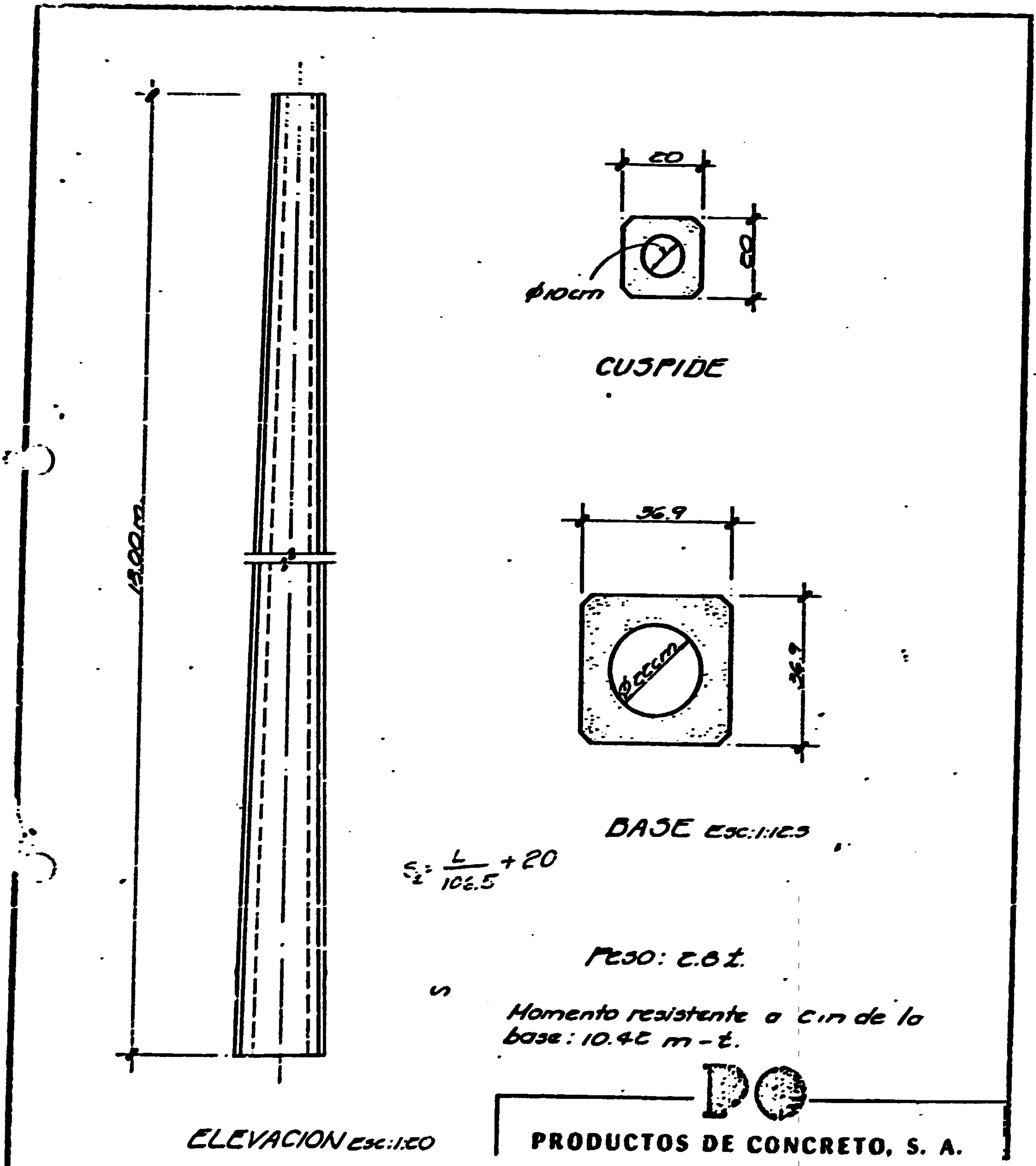


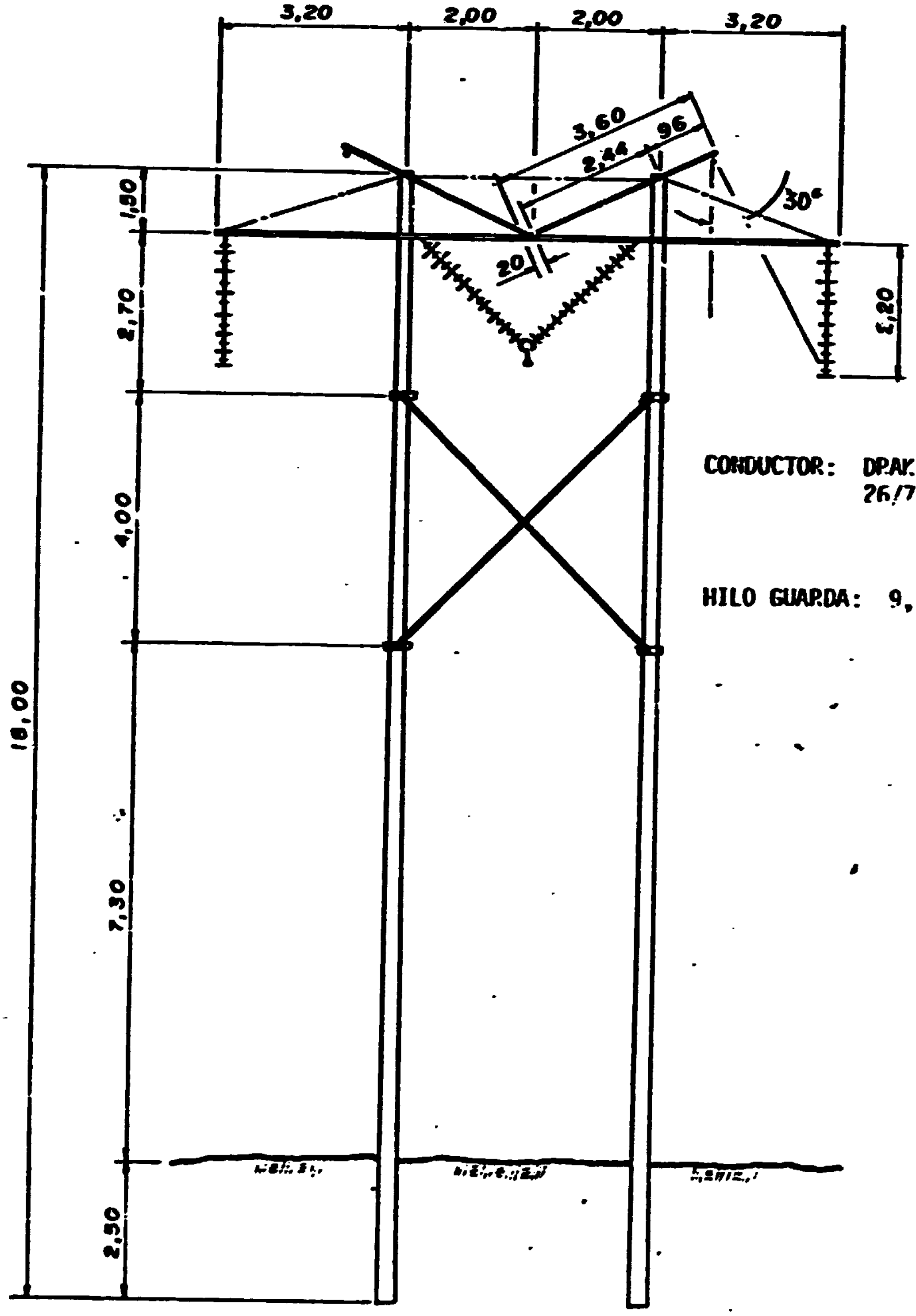
Fig. 2 18 m long prestressed concrete poles used for the Colorado-Santa Rita transmission line

DISEÑO: WCS
DIBUJO: MLB
REVISO:

Nº FECHA REVISIONES

FECHA: Feb 82
ESCALA: Ind
PROYECTO

GEOMETRIA ESTRUCTURA HV



CONDUCTOR: DRAKE 795 MCM
26/7 ACSR

HILO GUARDA: 9,51 mm Ø

Fig. 3 HV type supporting structure consisting of two prestressed concrete poles for the Miravalles-Arenal and Miravalles-Liberia transmission lines of 230 kV

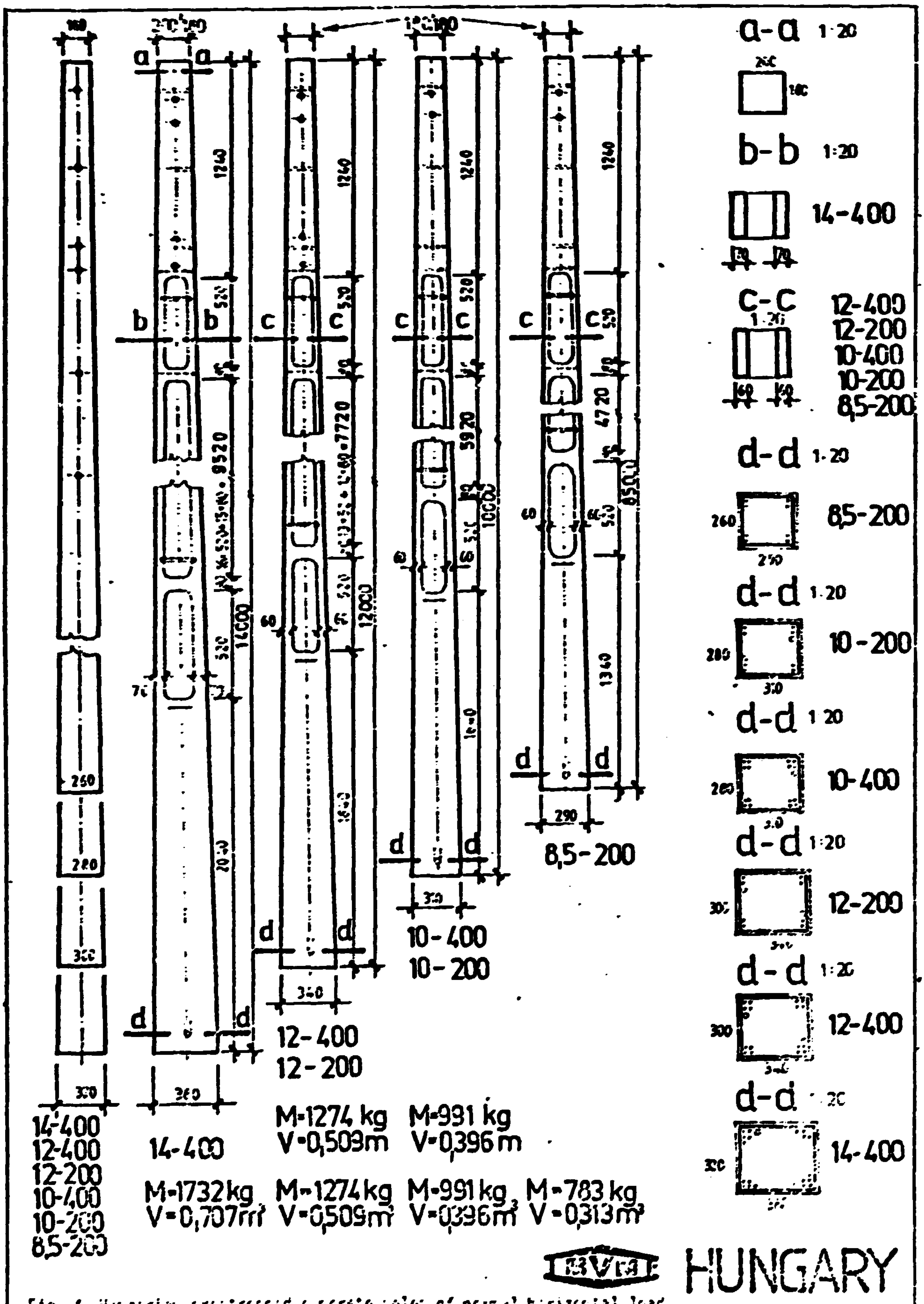
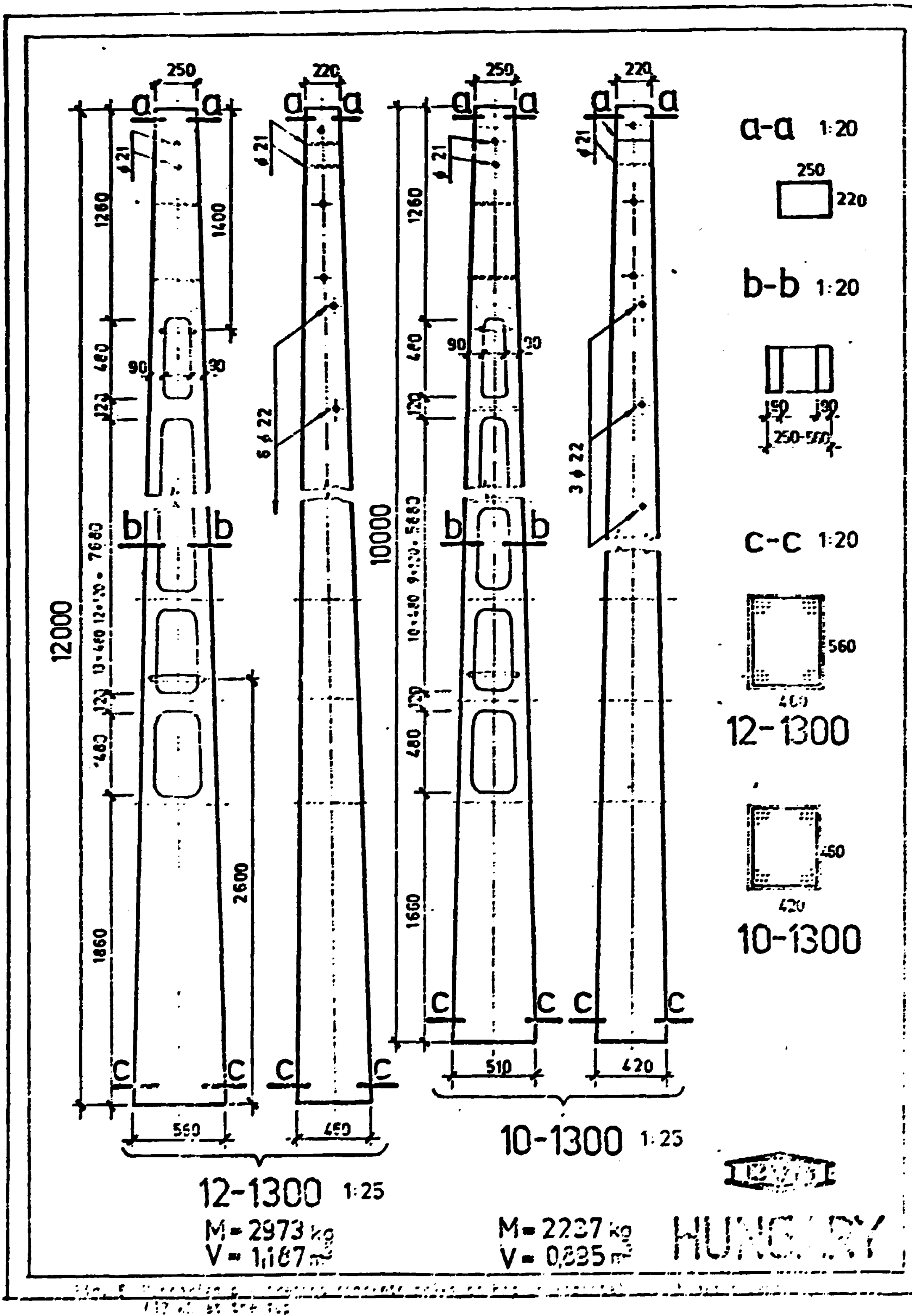
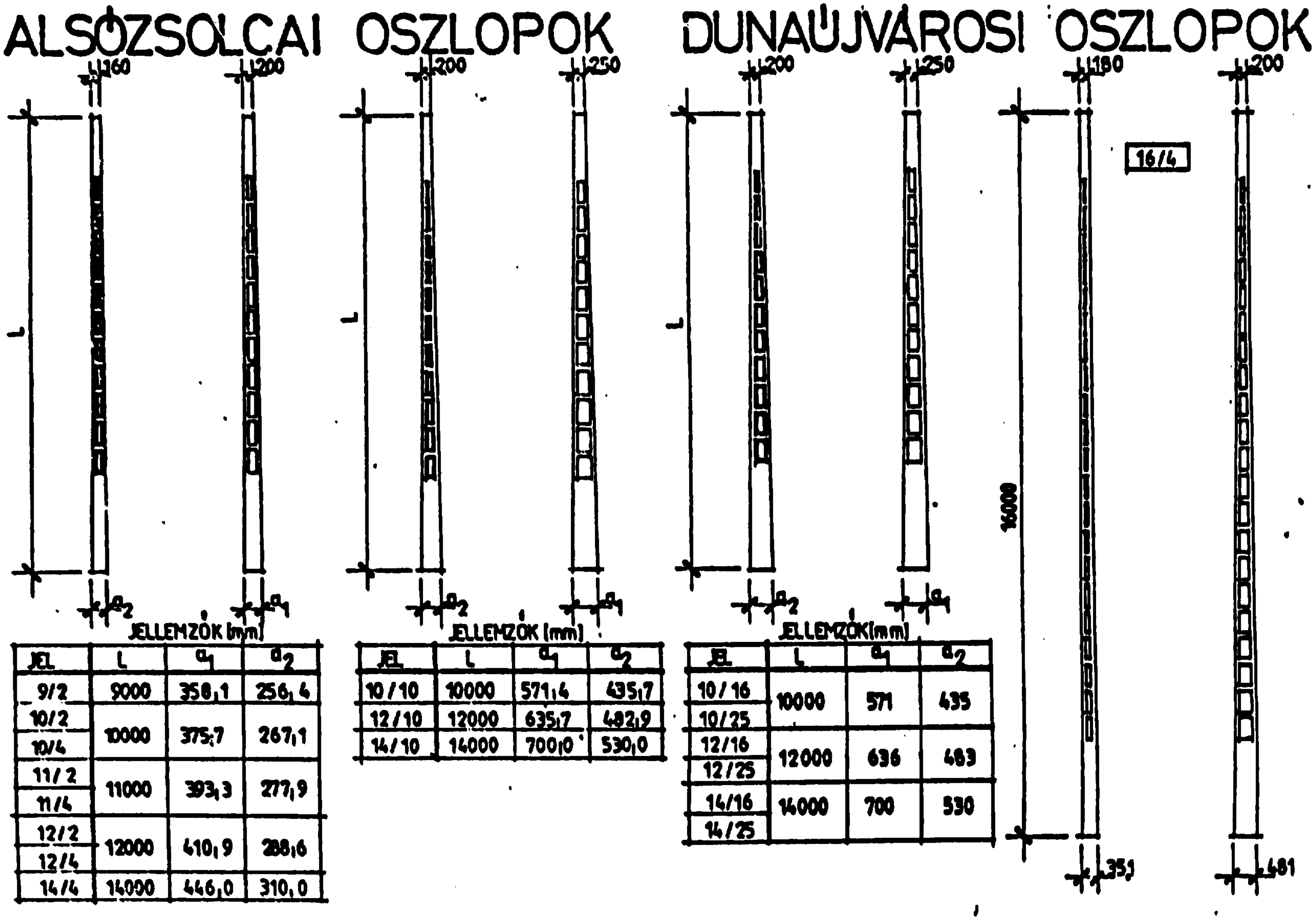


Fig. 8 Hungarian prestressed concrete poles of normal horizontal load carrying capacity [illegible]


250
220
250
220
a
a
b
b
c
c
ϕ 21
6 ϕ 22
3 ϕ 22
1280
1400
480
90
30
120
12000
10000
7680
13 • 480 12 • 120
10 • 480 9 • 120 • 5680
2600
1660
560
460
510
420
a-a 1:20
b-b 1:20
c-c 1:20
250-500
400
560
12-1300
420
460
10-1300
12-1300 1:25
M = 2973 kg
V = 1,187 m³
10-1300 1:25
M = 2237 kg
V = 0,835 m³
HUNGARY

[illegible]



JELLEMZÓK (mm)

JEL	L	a_1	a_2
9/2	9000	358,1	256,4
10/2	10000	375,7	267,1
10/4			
11/2	11000	393,3	277,9
11/4			
12/2	12000	410,9	288,6
12/4			
14/4	14000	446,0	310,0

JELLEMZÓK (mm)

JEL	L	a_1	a_2
10/10	10000	571,4	435,7
12/10	12000	635,7	482,9
14/10	14000	700,0	530,0

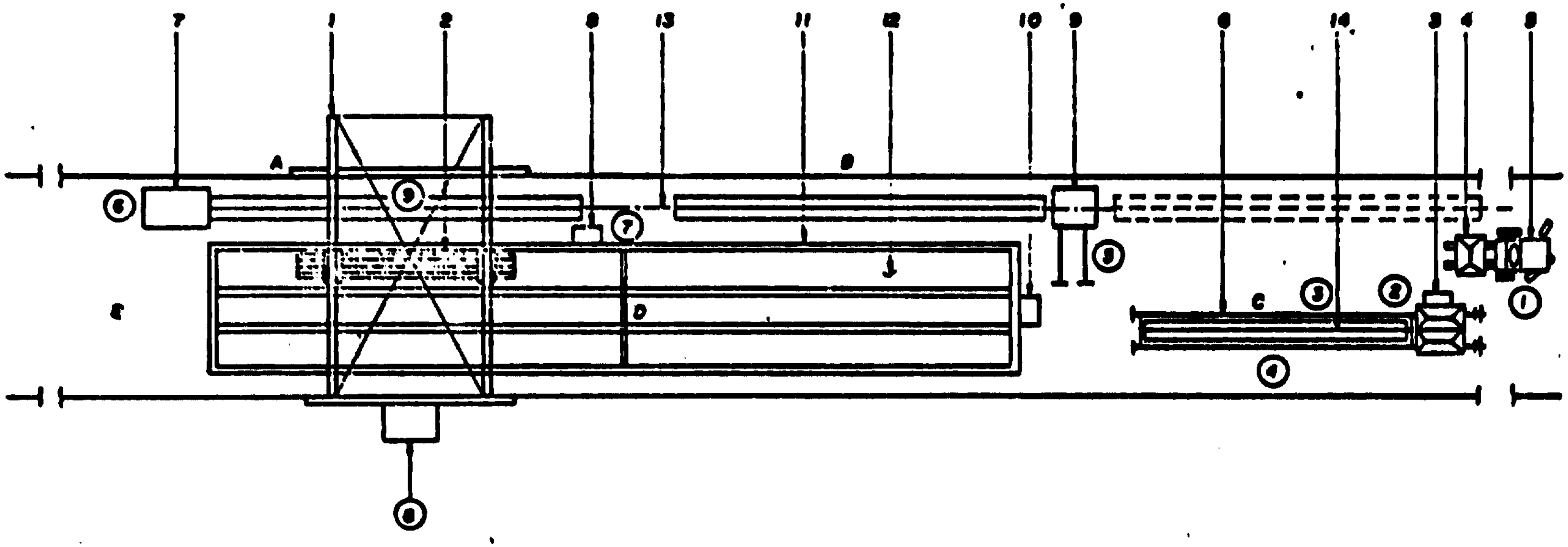
JELLEMZÓK (mm)

JEL	L	a_1	a_2
10/16	10000	571	435
10/25			
12/16	12000	636	483
12/25			
14/16	14000	700	530
14/25			

Fig. 6 New types of Hungarian prestressed concrete poles

Dr Gyula Fogarasi
UNIDO expert

SAN JOSE, COSTA RICA, 01-03-1988



NOTE:

Figures 1 to 14 relate to the equipments and moulds listed in the "List of equipments"

SYMBOLS:

A	Stripping-Wiring
B	Tensioning
C	Forming-Casting
D	Steam curing
E	Preliminary stocking

A,B,C,...	Working places.
1,2,3,...	Equipments
①②③	Manpower

LAYOUT OF THE MAIN LINE OF THE BVM MULTIPURPOSE COMBINE TECHNOLOGY FOR THE BASIC ARRANGEMENT OF MANUFACTURING P.C. POLES

Fig. 7

A III/8

BVM CONCRETE AND REINFORCED CONCRETE WORKS HUNGARY, BUDAPEST, H-1117 BUDAFOKI UT 209

LIST OF EQUIPMENTS

FOR THE MAIN TECHNOLOGICAL LINE OF THE MULTIPURPOSE COMBINE PREFABRICATION TECHNOLOGY FOR TRANSMISSION POLES PAGE:

ACCORDING TO THE DRAWING No B-1736

Informative

Item	Denomination of the equipments	Pcs of equipments	Packaging number	Packaging measures per packaging units	Mass without packaging per pack	Mass without packaging total	Mass of pack. per unit	Mass with pack. per pack	Mass with pack. total	Ex works prices without pack.	Ex works prices with pack.	Notes
			pcs	mm	kg	kg	kg	kg	kg	USD	USD	
1.	Manufacturing combine 2x8 to Gyártókombájn	1	2 2	11000x1600x1500 1000x1000x1500	11.000 1.800	[illegible]	2000 300	1[illegible].000 2.100	28200	65.000	69.000	
2.	Automatic spreader beam Automata himba	1	1	6000x1600x1200	2.000	2000	800	2.800	2800	9.000	10.000	
3.	Concreting gantry /selfpropell Betonterítő kocsi /önjáró/	1	1 2	4000x3000x2000 1000x1000x1200	3.000 500	4000	— .250	3.000 750	4500	15.000	17.000	
4.	Container for concrete supply Betonszállító konténer	2	2	1000x1500x1000	1.000	2000	—	1.000	2000	4.400	4.400	
5.	Fork lift truck Emelővillás targonca	1										local supply
6.	Hollow forming compacting equip Üregképző-tömörítő-kitoló ber.	1	1 1 2	13000x 600x1200 1200x1200x1000 1500x1000x 600	8.000 1.000 1.500	12000	1000 400 200	9.000 1.400 1.700	13800	34.500	37.000	
7.	Stripping equipment Kitoló berendezés	1	1 1	2000x1800x1000 1000x1000x1000	5.000 1.200	6200	800 500	5.800 1.700	7500	14.400	16.400	
8.	Stress releasing equipment Feszültségoldó berendezés	1	1	1000x 800 x 800	600	600	200	800	800	1.800	2.000	
9.	Tensioning equipment Feszítőberendezés	1	1 1	2200x1500x1000 1000x1000x1000	4.000 1.000	5000	[illegible]00 500	5.500 1.500	7000	17.500	19.500	
10.	Steam generator and distributor Gőzfejlesztő és elvezető ber.	1										local supply
11.	Insulated curing basins Gőzérlelőkád	6										local supply
12.	Insulated curing cover Gőzérlelőkád hőszigetelt fedő	6										local supply
13.	Drag conveyor for moulds Sablonvonszolópálya	1	1 1	3000x1000x 700 1000x1000x1000	3.000 1.200	4200	1000 400	4.000 1.600	5600	20.000	22.000	
14.	Moulds Sablonok	14	14	1225x1000x 370	3.500	[illegible]	—	3.500	[illegible]	147.000	147.000	
	TOTAL WEIGHT AND PRICE, RESP.					[illegible] kg			121.20[illegible] kg		[illegible]	