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WOODEN LOAD BEARING BUILDING COMPONENT PRODUCTION IN DEVELOPING COUNTRIES.

AN ANALYSIS OF ALTERNATIVES [1].

by

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CONTENTS

WOODEN LOAD BEARING BUILDING COMPONENT PRODUCTION IN DEVELOPING COUNTRIES

AN ANALYSIS OF ALTERNATIVES

SUMMARY

1 Wood is a renewable natural resource which is in good supply in a high proportion of the developing countries, and fortunately, in many instances, these countries tend to support more desirable and higher strength species of hardwoods than the softwoods of the developed temperate regions. Many developing nations have resources of plantation softwoods which are also eminently suited or structural components, if processed correctly.

2 Sawing and drying techniques and quality control leave a great deal to be desired in many developing countries, and to achieve the full benefits of all of the modern techniques for the structural usage of sawn wood, sawing, drying, stress grading and preservation techniques will need to be upgraded in virtually all developing nations.

3 Properly sawn, dried, stress graded and preserved tropical hardwoods and softwoods are excellent material for the construction of structural building components, and the use of light weight timber trusses using spiked metal connector plates has had an enormously favourable effect on the economics of construction, with the particular advantage in the case of trusses that green sawn wood can be used.

4 In addition, sawn wood is a low energy material as compared with steel, bricks, aluminium and concrete and with the tripling of oil costs, the use of indigenous wood resources as a structural replacement for steel is becoming of increasing economic importance.

5 This paper outlines the range of structural timber building components which may find application in developing nations and discusses factors influencing the choice of particular components, the equipment used for their production and gives some consideration to economic and technological factors which lead in turn to presenting the parameters which lead to the selection of a particular process.

6 The paper illustrates that light weight timber trusses, solid poles and piles, and both sawn and laminated beams, built up plywood nailed box beams and prefabricated wall and floor panels all have a role to play in meeting the need for economic building components in developing countries.

SECTION 1 INTRODUCTION

7 Structural building components by definition are load bearing.

8 This background paper will broadly consider the following wooden components:

(a) Structural solid wood piles, poles and beams either round or squared
(b) Structural wall units and panels
(c) Structural wooden flooring and floor panels
(d) Built up nailed and glue nailed wooden beams and plywood box beams
(e) Glue laminated beams
(f) Light weight timber trusses.

9 In each case, the product is first described and then the various alternative processes and equipment used are considered.

10 Quality control and costing is briefly discussed but in regard to the latter, practice varies widely throughout the developing world and subsequent discussion will enable specific comparison to be drawn between various areas. Marketing consideration will be discussed in relation to all products in the final section of the Paper.

SECTION II

11 (a) Structural Usage of Wood as Poles and Piles

Since Mankind started his trend towards urbanisation during the Stone Age, some 20,000 years ago, wood as a readily available local material has been used structurally in the round form for the construction of shelter and as a means of construction simple log bridges (see photograph of simple elevated pole and beam house with thatched roof - New Guinea).

New Guinea Pole & Beam Elevated Floor House with Thatched Roof

12 Extraction of such piles and poles involved felling by stone axe and transport by elephant, manpower and water ways, and resistant species were determined through experience alone.

13 Today, pressure treated poles and piles still play an important part in construction and are widely used structurally as load bearing elements and in bridge

construction as beams.

14 Improved felling and logging techniques and time proven methods of fastening such as the use of Ring Connectors and Shear Plates still makes this type of construction economically viable, particularly in regions where transport facilities are poor and where the wood substitutes for steel or concrete which is imported and which requires a high energy usage.

15 Felling can be either by axe, handsaw or chainsaw and logging can still be carried out using animal and manpower, the use of water ways or the use of mechanical equipment and the squaring or flattening of ends of round beams can still be achieved using the broad axe or with portable slab mills using a chainsaw as the cutting medium.

16 Bolted ring connected or plain joints are achieved using hand or powered augurs with appropriate grooving tools. Road bridges using this type of construction can still be built for approximately one half the cost of an equivalent steel structure in many areas.

(b) Structural Wall Units and Panels

17 In housing programmes where any degree of standardisation can be achieved, overall efficiency and cost reductions can be achieved by the use of factory fabricated or on site fabricated wall frames or wall panels.

18 At a recent Pan Asian Conference in Singapore, Ir. Saijidi of the Indonesian Government Department of Housing described numerous experimental ventures in this area in Indonesia, and one of the developing world's largest prefabricator companies in Petaling Jaya, Malaysia, a smaller group in Nairobi, Kenya, a well-developed group in Brazil, and hundreds of other similar companies, together with many Government Departments in Africa, Asia and

South America have successfuly used similar systems.

19 In all instances, simple jigs are used to fabricate timber frames generally using 38mm x 75mm (or thereabouts) studs at 60cm centres with or without plywood sheathing on one face.

20 Hand nailing is the general rule, but in isolated instances, air nailing or stapling guns are in use. However, most Authorities show a strong and probably correct preference for cheap, locally-made nails rather than the more expensive proprietary pre-assembled clips of nails or staples so commonly used in the developed nations.

21 The wood used in such panels and frames is generally green sawn hardwood or softwood and all joints are butt jointed without "housing" or mortising, and end nailing using 4.5mm x 75mm diamond head nails through the top and bottom plates is preferred in hardwood.

22 This is the present common practice and in the view of many executives of the companies and departments concerned is still the most economical method where the operatives concerned are earning $U.S. 25.00 per month or less.

23 However, in some of the developing nations, inflation has clearly demonstrated that a degree of mechanisation is now warranted, paving the way for the introduction of intermediate and higher levels of technology.

24 At the top of the technology tree is equipment of the type offered by a company in the U.K. where Numerically controlled equipment masterminds and produces up to nearly 500 metres of wall frame per eight hour shift with a minimum of labour.

25 An old established American Company produces similar but heavier and more expensive equipment possibly better suited to hardwoods, but such production equipment, capable of producing wall frames for 20 small to medium houses per eight hours can cost in excess of $U.S.160,000.00 including

36 This can then be compared with the process using the same jig with a simple American style hand-propelled gantry of the type already referred to, using air-operated guns.

37 Finally, the possibility exists in a limited number of cases to look at the elaborate, expensive, Numerically controlled wall panel machines from the U.S.A. of which there are a number of suppliers or the alternative Numerically controlled machine from the U.K.

38 In addition, I am advised that a number of intermediate technology machines have been developed in Europe.

(c) Structural Wood Flooring and Floor Panels

39 (i) The advent of structural plywood and chipboard or panel board or hardboard generally about 17.5mm in maximum thickness has enormously speeded up the laying of floors on floor joists at 60cm centres. Such plywood or board with tongued and grooved edges can be regarded as a structural building component and should be investigated as one option for flooring systems.

40 Special equipment used in the production of such flooring is quite normal to both industries except that the trim saws used in finishing the sheets carry additional cutters to provide the tongue and groove.

41 Equipment for this operation is available from specialist companies in Japan, U.S.A. and Germany, Finland and elsewhere.

42 (ii) Similarly, hollow core extruded panels suitably veneered are being used as structural floor panels in a number of countries and this product is used, often veneered with hardboard, as a load bearing wall panel.

43 (iii) Cheapest of the load bearing floor panels in the developing countries up to recent times, is the nailed or glue nailed sandwich panel using 38mm x 75mm hardwood stringers dressed on two edges at 45cm centres with 7.5mm plywood or hardboard nailed to both sides.

44 No special equipment is needed to produce such simple panels other than simple jigs, simple power or hand saws, hammers or air-operated stapling guns.

45 Such panels are relatively light and have good insulating properties and can be used either as load bearing floor or wall panels.

46 However, the advent of structural ply and board sheets will tend to alter the relative economics of these alternatives.

47 Finally, the cost of plywood is now being adversely affected by rising glue and energy costs and it is possible that hardboard, which used wood lignin as its bonding agent could displace plywood as a structural material, particularly now that techniques have evolved to "waterproof" hardboard.

48 (d) Built Up Nailed and Glue Nailed Wooden Beams and Box Beams

(i) Nail Laminated Beams and Trusses

Thin planks on edge can readily be hand nailed or nailed with hand held guns, or laminated by nailing machines with nails in a predetermined pattern into beams of adequate strength for strutural purposes.

49 Papers on this subject have been published by E. George Sterr in the U.S.A., Dalgleish in Australia, N. Venkalya in India, N.J. Masani in India and many others, and the prime technology lies in the structural design, and in the selection of nail types which can include annular or helical nails where available. Excellent design

information relevant particularly to hardwood can be found within "The Timber Design Handbook" by Pearson, Kloot and Boyd and also within the Australian Timber Design Code C.A.65.

50 Nail laminated beams can be fabricated from green, unseasoned, sawn wood and can be fabricated to achieve large section and long length.

51 However, the economics of such beams is unfavourable in wood rich countries and they find principal acceptance in areas where wood is in short supply, or where timber sections are small both in dimension and length, and labour costs are low.

52 When seasonsed wood is substituted for green wood, improved performance results with lower initial deflection and reduced long-term "creep". Performance can be further improved with "glue nailing" in which the dressed laminates are coated with either casein, melamine or an U.F. glue using a hand roller applicator prior to nailing.

53 Papers are also available on the technology and costing of this technique from the U.S. Forest Product Laboratory in Madison, Wisconsin, U.S.A. and many other sources and hence it would be superfluous to discuss this process in depth in this Paper.

54 Again, however, to summarise, nail laminating is used and shows cost advantages in regions of low labour cost with a scarcity of long length, large dimension sawn wood.

55 Likewise, trusses can be made using nailed joints with or without gussets which can in turn be plywood, hardboard, or perforated steel plates, usually of 1mm thickness.

56 Such trusses are usually not economic, however, where labour costs exceed $50.00 per month and have largely been supplanted.

57 (ii) Plywood or Hardboard Composite Beams

Sophisticated equipment has operated successfully for many years in the U.S.A., the U.K., Scandinavia and in Europe for the mass production of composite beams.

58 In one particular European process. dressed, seasoned finger jointed wood flanges in continuous lengths have a groove routed on the inside face to form a sinusoidal path and into this groove a continuous ribbon of plywood is fed to form the web of the beam.

59 Glue which is fed into the groove is continuously cured by a R.F. heating process at speeds in excess of 10 metres per minute.

60 The beams are then cut to the required length. Another process in the U.S. uses heavier - 17.5mm straight webs with veed edges glued by R.F. equipment into a matching vee groove.

61 Where heavy plywood prices are cheaper, as in the U.S., the continuous straight web process is more economical than the sinusoidal web process.

62 As kiln drying to carefully controlled moisture content conditions and accurate sizing and grooving to fine tolerances is vital in both of these types, it is felt that it would be premature to introudce these processes into many of the developing nations at the present juncture. However, a number of the developing nations such as Brazil, Ghana, Malaysia and the Philippines could no doubt handle this production due to the advanced state of their timber industries.

63 It is felt, however, that a pre-requisite of the introduction of any such advanced technology is a very

careful study of the problems if any of both drying, machining and gluing the wood species concerned and an equally careful market survey would be necessary. Adequate quality control procedures are a pre-requisite for success in this type of production.

64 (iii) Nail Laminated Plywood or Hardboard Box Beams

Of more relevance to most developing countries are perhaps plywood or hardboard box beams.

Basically, this component consists of dry or green top and bottom members joined by two thin plywood or hardboard webs to form a box section, with vertical wood members placed at designated intervals.

65 When green sawn wood is used for the top and bottom chords, flat head nails only are used on a predetermined pattern.

66 It should be noted that hardwood sturctural nail patterns differ from those used in softwoods and data and designs on hardwood based box beams are available from the C.S.I.R.O. in Melbourne, Australia, as well as from (inter alia) Forest Research Institutions in Dehra Dunn, India, Los Baños in the Philippines and Kepong in Malaysia.

67 Of particular relevance is "The Timber Engineering Code C.A.65" available from the Australian Standards Association which provides a wealth of information on structural hardwood design practice.

68 Similarly, the widely known "Timber Design Handbook" by Pearson, Kloot and Boyd published in Australia gives a good base for internationally accepted design practice with emphasis on hardwoods, and good coverage is given in both to the entire scope of this Paper, so far as the technical aspects of load bearing components are concerned.

69 As with nail laminated beams, when box beams are made with seasoned chords, the webs can be glue nailed to the chords to achieve greater stiffness and to minimise "creep".

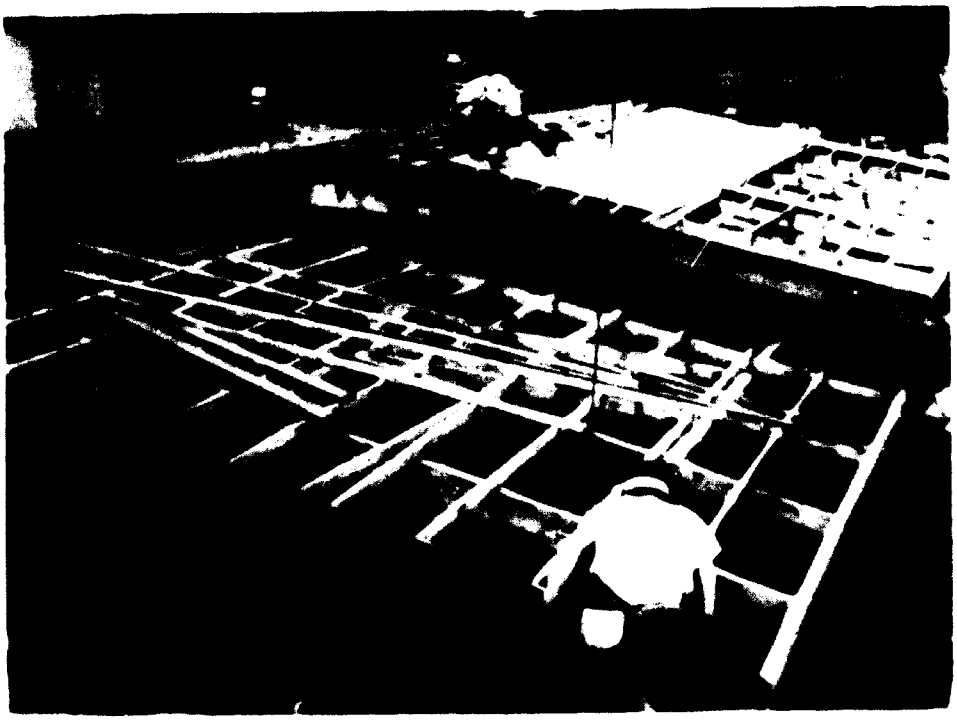
70 Finally, box beams can be put on to a production basis either with nails, glue nailing or gluing alone. In the latter case, quality control becomes a necessity. Accurate sizing and careful control of moisture contect, glue mixing and application, lay up time and pressing procedures all dictate a degree of sophistication not always present in the wood industries of the developing countries.

71 Again, this is a question of case by case assessment based on locally available species, facilities, and labour skills.

72 Under carefully supervised conditions and with adequate facilties, glued box beams are cheaper than when nailed, but experience in some developing areas indicates that local labour shortcomings and lack of appropriate equipment often accompanied by difficult climatic conditions, can cause disastrously high rejection rates of glued components.

73 This comment applies equally to the manufacture of "Glue-Lam" beams and glued plywood gussetted trusses in many developing areas.

74 On the other hand, plywood production is often handled successfully in the same areas because intrinsic quality controls are inbuilt into a comprehensive plywood plant which is usually purchased under a commissioning contract.



Glue Nailed Plywood Box Beams - Japan

75 (e) Glue Laminated Beams

Glue laminated timber beams can have important economic significance in countries where tree sizes are small and the species can be readily dried and glued.

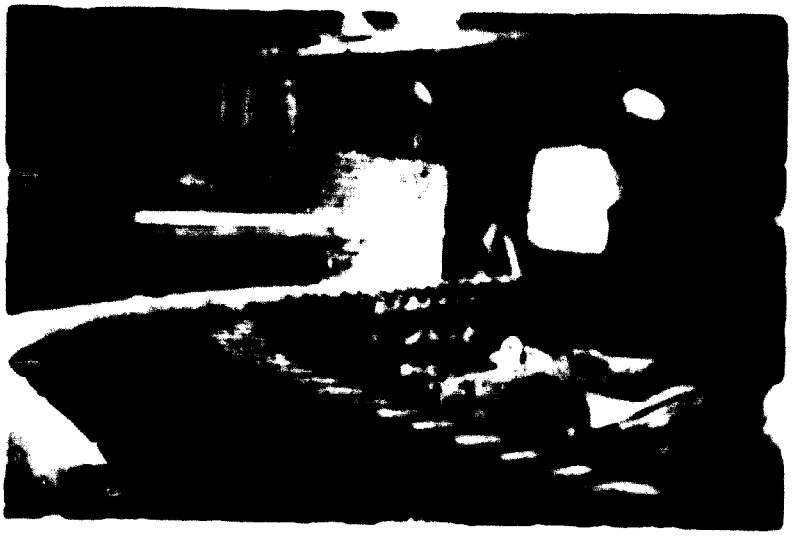
76 The absence of a basic steel industry can also contribute to a favourable economic advantage for glue laminated beams. For instance, in one African country using the available small sizes and relatively short lengths of softwood available

it has been shown that it is quite economic to laminate these small sections into 50m x 150m beams, approximately 11 metres long for roofing low cost row houses and in this area, it appears that stock lamination has a viable future.

77 On the other hand, a venture into custom lamination in a South East Asian developing country failed largely because of quality control problems, whilst in the Philippines, a small but successful non-structural laminating venture is thriving.

78 Assuming that readily glueable, kiln dried and properly sized wood sections are available at the right moisture content, equipment needed to establish a laminating plant of relatively low capacity can be installed for as little as $U.S.3,000.00.

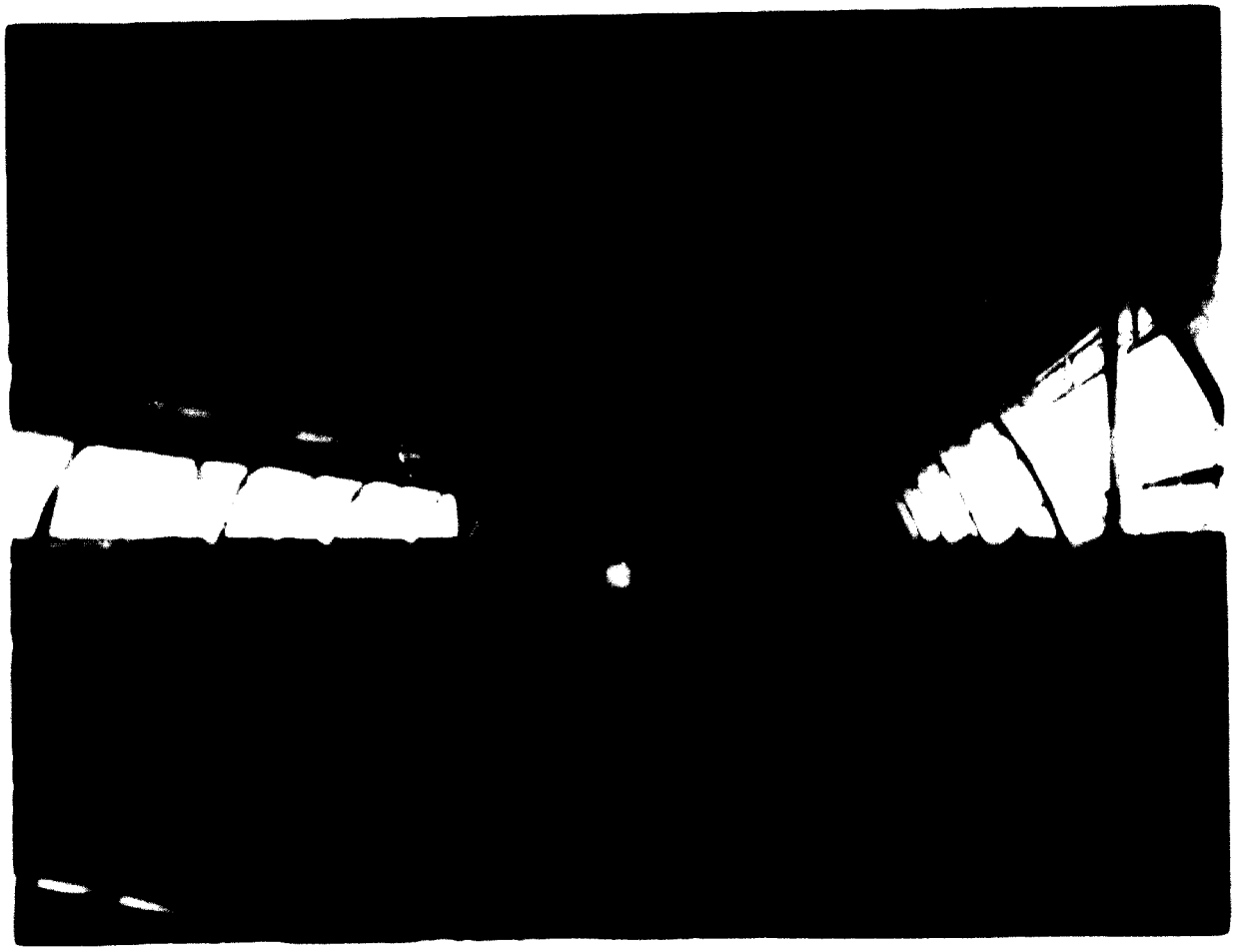
79 Basically, this equipment consists of cutting and joining devices for scarf joints, glue mixing and spreading equipment and a forming and clamping jig where glue spread sections are "laid up" to the appropriate profile and held by clamps until the glue joints are sufficiently cured to remove the beam (see photograph of fabrication of curved portals, glue laminated beam, jig and clamps).



Glue Laminated Beam, Jig and Clamps

80 Glue laminated timber beams are ideal for Auditoriums and Halls and are often both attractive and economic for bulk storage buildings and factories, where corrosion resistance and low maintainence are important.

81 Most importantly, the fire rating and performance of heavy glue laminated beams is considerably better than that of a steel structure of equal structural strength and it is aesthetically superior (see photograph open knee type portal - public hall or auditorium).

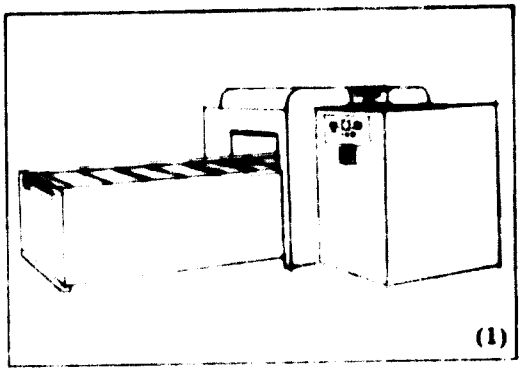


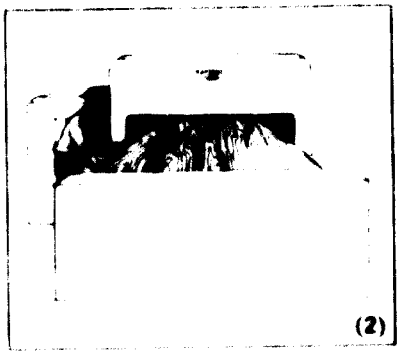
Public Hall or Auditorium

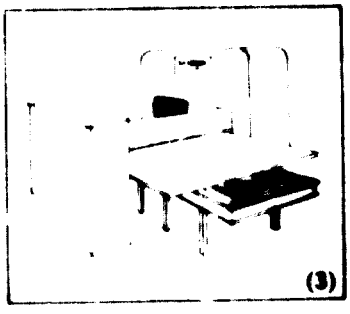
82 Structural "Glue-Lam" factory floor panels, finger joints and core stock too can be readily automatically produced in continuous presses using high frequency generators to ensure rapid curing of the glue lines. Again, the need for glueable species, first quality machining and proper kiln drying techniques are a necessity and such equipment as depicted below (line drawing no. 4) gives a broad indication of six different types of high production R.F. machines available. Such machines are expensive and require maintenance staff with electronic skills. Additionally, the possibility of interference with radio and T.V. reception by this equipment, which is often rated up to 30KW, exists and must be guarded against.

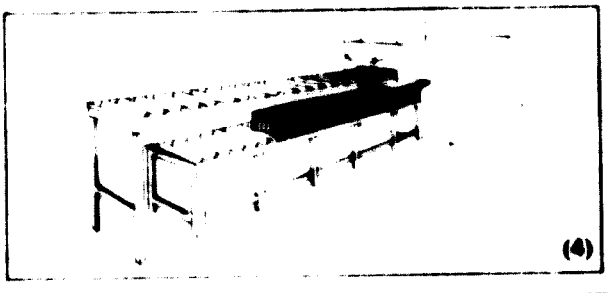
83 Costs of such machines start at $U.S.40,000.00 and can be as high as $U.S.150,000.00 and specialised, skilled maintenance staff are essential.

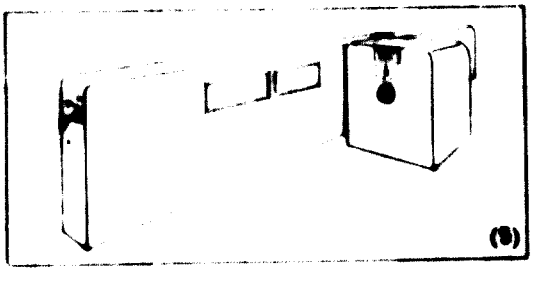
84 Humidity and temperature control become a pre-requisite in any extreme climate in which gluing operations are undertaken. Whilst many equatorial climates are suited to gluing operations, extreme problems can be encountered in very hot, low humidity regions in particular, unless some climatic control is introduced.

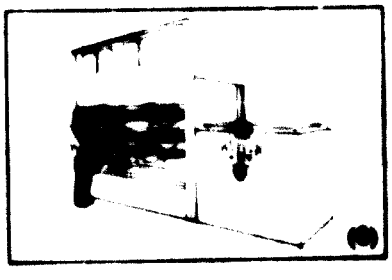












(1) EDGE GLUING PRESS, a versatile machine for producing panels and a variety of edge glued products.

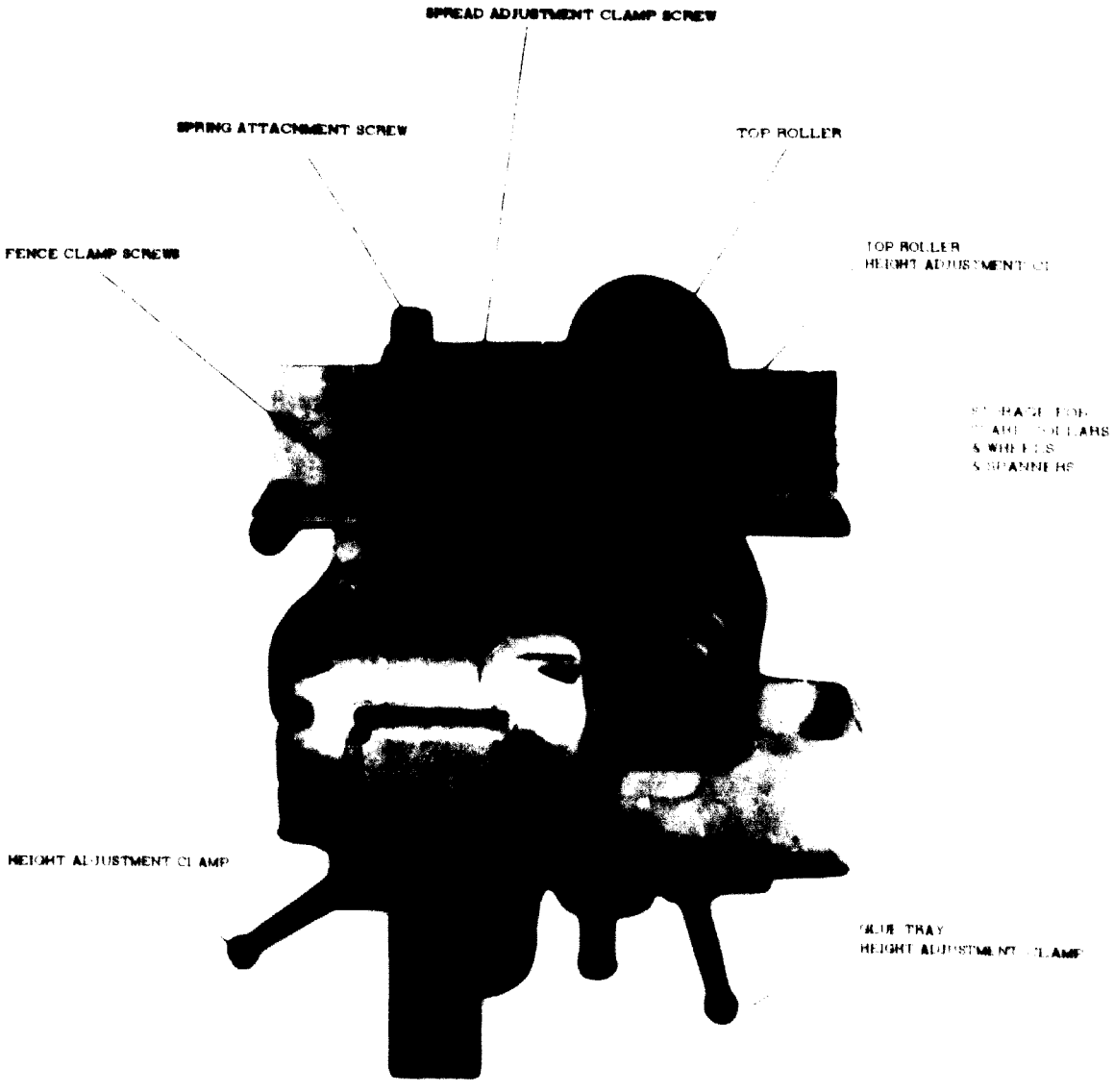
(2) PLYWOOD FINGER JOINTS & SCARF JOINTS may be cured on a combined plywood machine.

(3) PARTICLE BOARD PRODUCTS are butt glued in continuous forms on the Model CC.

(4) GLU-LAM BEAMS are cured on a special machine which is made for producing large laminated beams.

(5) FINGER JOINT CURING OVEN a continuous feed machine for high production finger joint operations.

(6) NUMEROUS specialty machines, edge banding, panel on frame, curved plywood and many other products are available.



Low Cost Glue Spreader

85 (f) Light Weight Timber Trusses

Light weight timber trusses of the gang-nail type, using green or dry hardwood or softwood jointed by spiked metal connector plates, with either columnar or triangular teeth, have found widespread acceptance throughout the Western world in the housing, commercial, industrial and rural building fields. See Report "Production Techniques for the Use of Wood in Housing under Conditions Prevailing in Developing Countries", pages 30 and 31, UNIDO Study Group November 1969 ID/10 Jan.1971 and "Selection of Equipment for Assembling Wood Structures and Frames Using Metal Connectors" UNIDO Paper ID/WG.151/31 13 November 1973.

86 Most of the connector systems have been developed in the Northern Hemisphere and hence tend to have focussed on the jointing of softwoods.

87 Unfortunately, therefore, virtually all of the Northern Hemisphere connectors with one or two notable exceptions are unsuited for use in tropical hardwoods, which predominate in the developing countries.

88 This unsuitability rests on questions of tooth length and hence column strength of the teeth, teeth spacing and net section of the parent plate, bearing in mind the strength of the wood itself and in particular the tensile strength, hardness and stiffness of the steel from which the connectors are made.

89 Additionally, connectors for use in tropical hardwoods or green softwoods should be heavily galvanised and made from semi-high tensile steel with parallel-sided teeth spaced in such a fashion to ensure that splitting does not occur. The tooth length should also be sufficiently short to ensure adequate column strength, thereby preventing the tooth from turning over or buckling when being pressed into the hardwood.

90 SECTION III - METHOD OF MANUFACTURE OF TRUSSES

Posts of green or dry wood cut to the appropriate end detail are securely locked into a quick-setting jig and the spiked metal connector plates are placed in their correct position on either side of the joint.

91 Hydraulic pressure is then used to squeeze the connector home simultaneously from both sides, thereby completing each joint in a matter of seconds.

92 With recent types of equipment, the whole truss can be made in as little as 75 seconds and despite low labour costs in many developing countries, it has been conclusively demonstrated through some years of experience in the Philippines, Malaysia, Mexico and certain parts of Africa and many other developing regions, that light weight timber trusses of this type are considerably cheaper than trusses made using bolted or nailed joints.

93 One of the primary advantages of this type of truss is that the finished truss itself is frequently only 4cm thick and up to 60 trusses can readily be carried on the back of a normal motor lorry.

94 Bolted or nailed trusses of similar strength are usually 12cm thick except in the case of plywood gussetted trusses and hence, only 20 trusses can be carried on the same vehicle.

95 With interest rate ranging up to 20% in the developing nations, speed of construction is becoming a controlling factor and the use of light weight spiked metal connector plate trusses can save up to four days in a typical mass housing project, which takes an average of 60 days to erect.

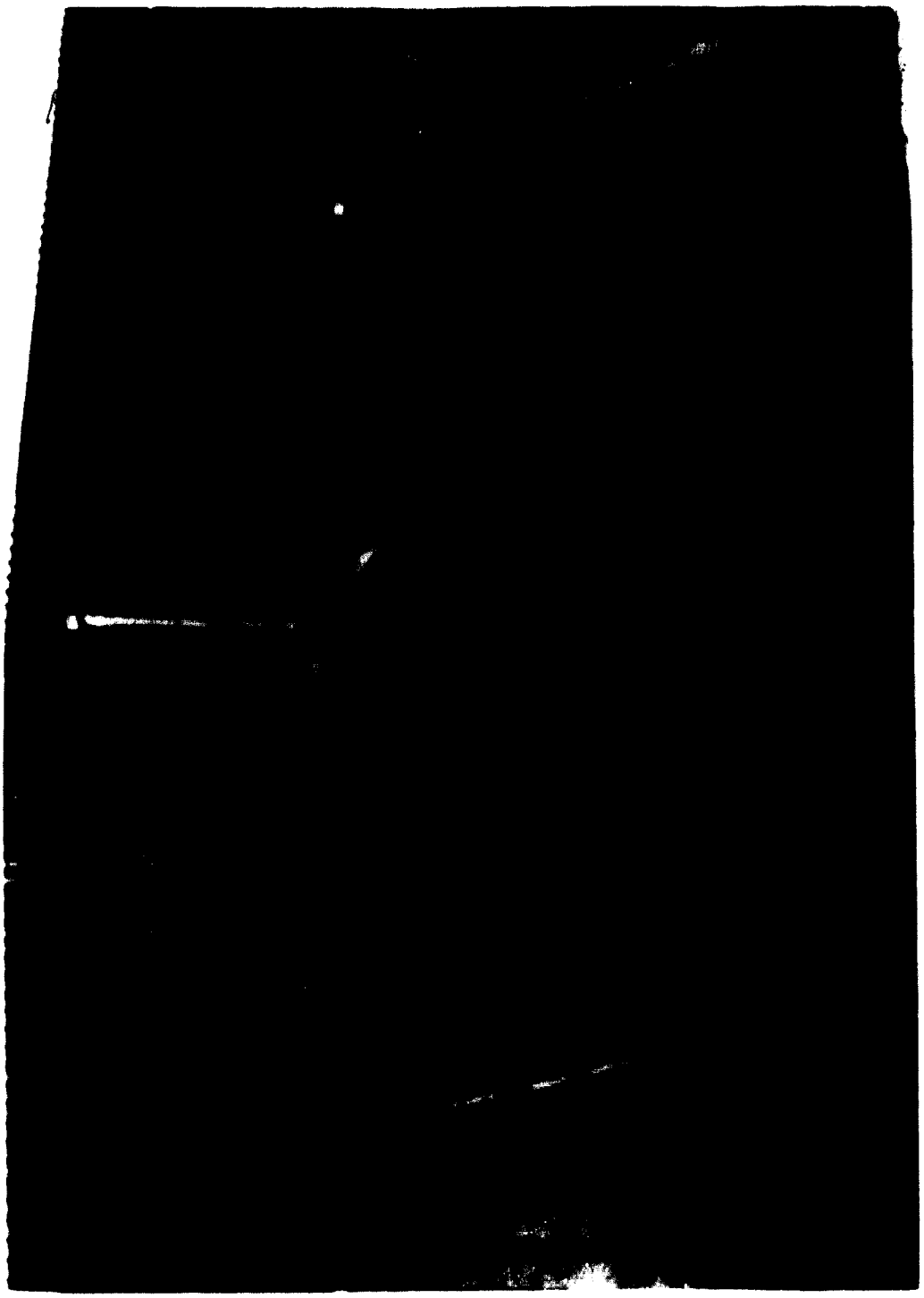
96 The interest reduction alone achieved through a time saving of 6.6% on each house can be readily shown as sufficient reason to utilise trusses in their housing

projects and it is for this reason that the National Housing Corporation of the Philippines, the Housing Department of the Government of Indonesia and many other such authorities have specified and are using trusses of this type.

97 The cheapest equipment suitable for the manufacture of trusses in the developing nations is the air-operated impact press.

98 The plant referred to is capable of making in the order of 100 trusses per eight hour shift with three operatives and the number of trusses on a three room mass housing project is 11 trusses, so that it will be seen this equipment can cope for a programme involving the construction of nine houses per day, at a total expenditure of approximately $U.S.22,000.00, and the average cost of trusses made in such a plant in a developing country such as Africa as at the 30th September, 1974, would be approximately $U.S.12.00 per 8 metre truss.

99 It is suggested, for additional information at this stage, that a careful study be made of the UNIDO Papers already referred to above.



Air Operated Impact Press

100 SECTION IV - TESTING OF STRUCTURAL WOODEN LOAD BEARING BUILDING COMPONENTS

There is a well-established procedure for the testing of glue laminated beams and light weight timber trusses and adequate knowledge of such procedure is available within the Forestry Departments and allied research units of the Governments of most developing nations and therefore, it is not proposed to deal with these procedures in this Paper.

101 SECTION V - MARKETING OF STRUCTURAL WOODEN LOAD BEARING BUILDING COMPONENTS

Products of this type face considerable initial resistance in gaining acceptance from building and lending authorities, architects and consulting engineers, and approving authorities such as council, municipalities, Standards Associations and so on, and the initial marketing strategy, therefore, must have a very high engineering content, designed to demonstrate the structural adequacy and long life of the product concerned and the fact that it has been fully researched and that the designs have been carried out in line with accepted and proven practice.

102 Inevitably, therefore, the first stage of marketing such products in a developing nation is to provide samples, test results and proof of performance to all relevant parties.

103 Once this has been done, the initial resistance quickly melts and there is very soon a widespread body of enthusiastic protagonists for the new types of components and the construction advantages gained from their use.

104 In marketing structural building components, it is, of course, vital that the prices be set at economic levels and that adequate training and information is provided to carpenters and construction authorities alike so that the components are used in accordance with their design assumptions.

105 Here I would in particular refer to such vital questions as adequate bracing of buildings and roof trusses, of the maintenance of proper camber and the appropriate quality control procedure to ensure the structural adequacy of the finished product.

106 The third pre-requisite for marketing is to ensure the availability of the product which, in turn, necessitates a proper transport infrastructure to enable the components to be transported from their central point of manufacture to the various building sites.

107 Beyond this point, normal marketing procedures only apply and therefore, this becomes a question of making the advantages of components very clear and these can be summarised as under:

. On site theft is reduced and usually eliminated.

. A vast reduction in time, for instance, in the case of trusses by conventional methods, a roof structure normally takes four days on a typical house, whereas the same roof can be erected with gang-nail type trusses in under two hours and this factor additionally reduces wet weather delays in construction.

. Using components considerably reduces on site waste and consequently time spent in cleaning up the construction site of such waste.

. Components are in general strong and more accurate than on site construction and usually give greater flexibility of design, probably due to the fact that trusses give complete freedom so far as interior layout is concerned.

108 CONCLUSION

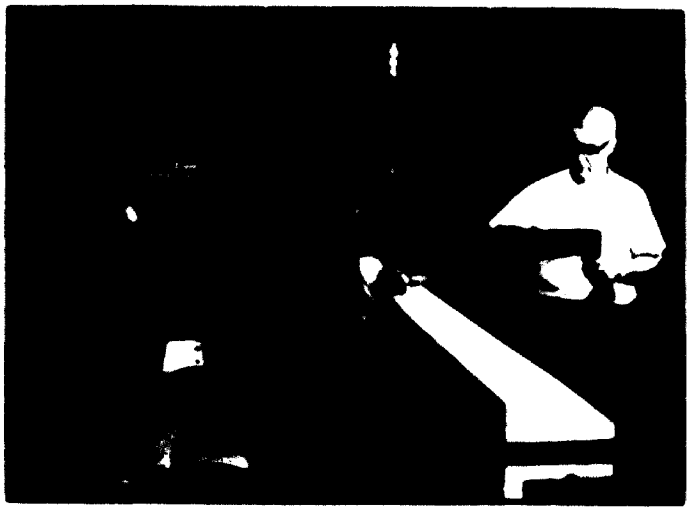
The enormous backlog of housing which exists throughout the developing countries will necessitate the introduction of the widespread use of components to meet existing housing needs let alone the various increases in housing needed to provide for the inevitable doubling of population in the developing nations during the next 25 years.

109 The quadrupled cost of oil in its own right will demand an increase in the use of indigenous "low energy" materials and the reduction in use of imported "high energy" materials. There is a strong argument for the substitution of wooden building components and in particular, light weight wooden trusses for steel trusses in commercial, industrial and agricultural buildings.

110 A study recently carried out by the University of Nairobi in Kenya showed that light weight timber trusses of the gang-nail type, made from locally available wood, cost under half of the cost of steel trusses of equal load bearing capacity, fabricated locally using skilled African labour.

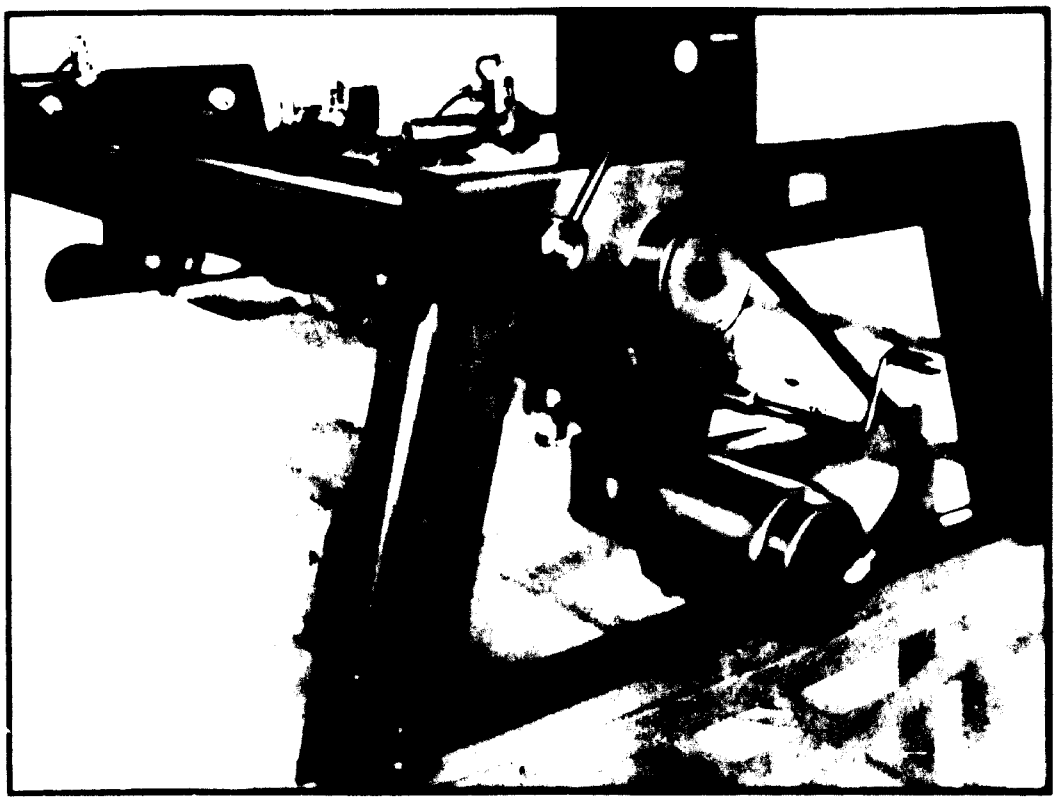
111 In view of the fact that the basic steel has to be imported and the high cost differences involved, it will become obvious that a large potential exists for the substitution of wooden trusses for steel trusses in such countries.

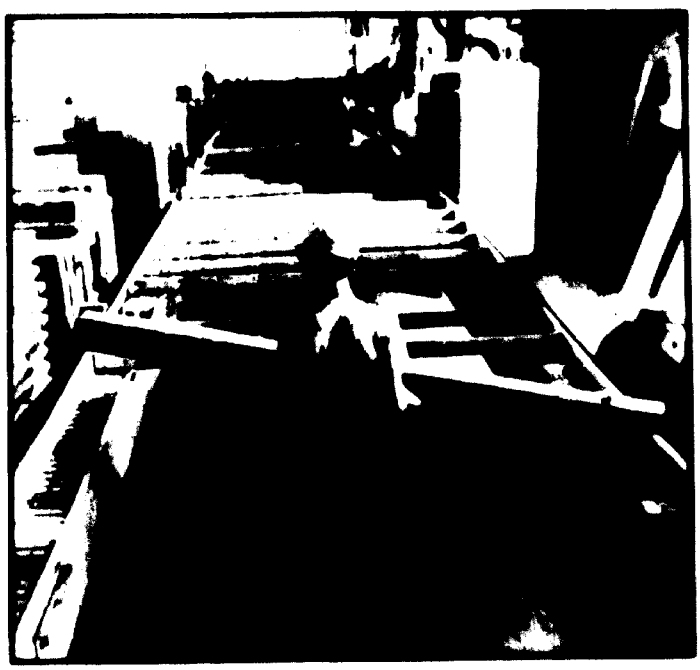
112 The high cost of money, combined with the urgent need for housing, will also ensure the increased usage of wooden load bearing building components in the developing countries in the future.



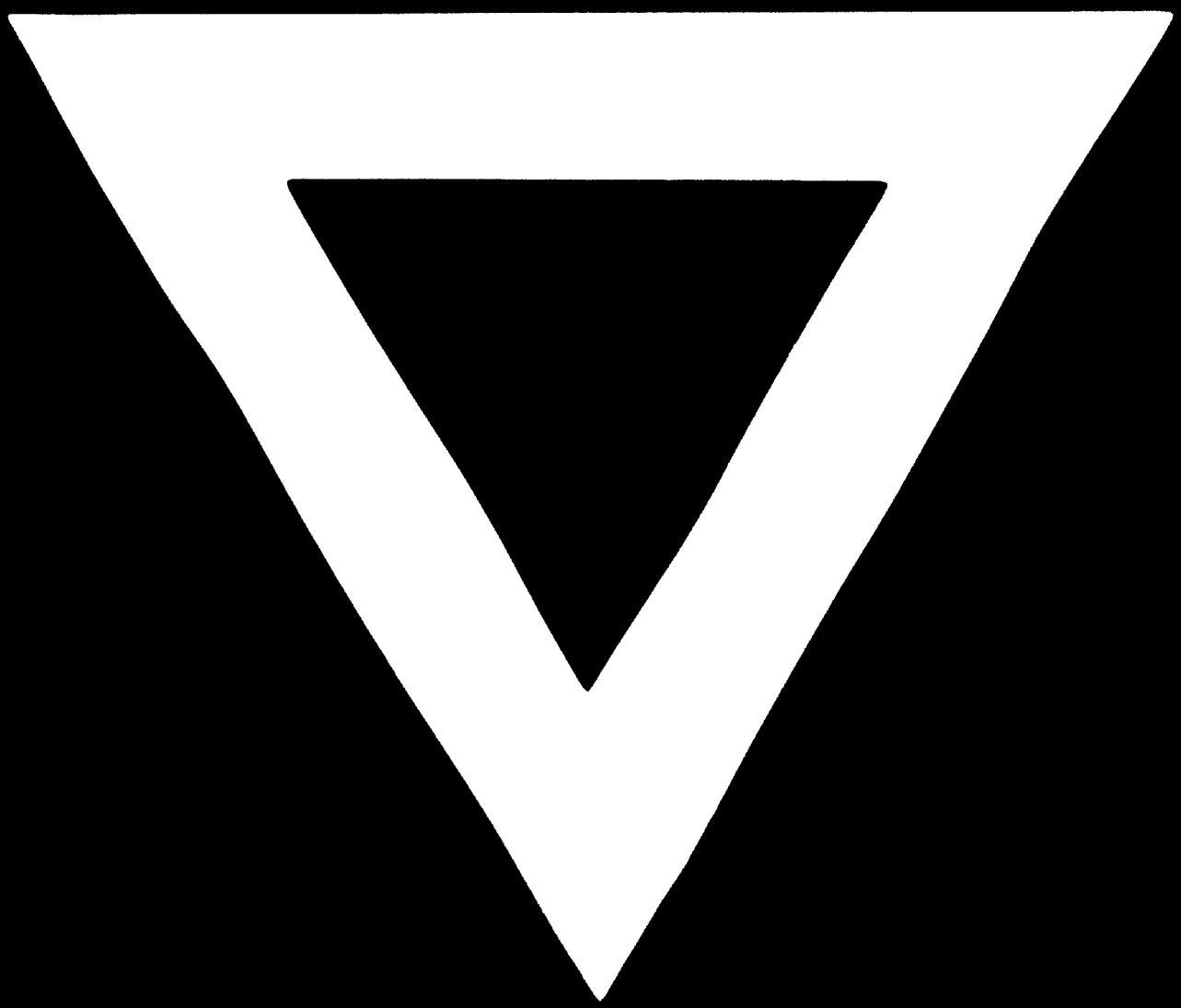
"AUTO-NAILER"
High speed U.S. nail laminating machine which drives up to 5" long threaded nails at a rate of up to 90 nails per minute.

IRIAD - low volume, low cost, wall framing machine suited for the manufacture of wall frames, using semi-skilled labour. Nail heads are suitable for softwoods only.





HEFTCO(U.S.) - high volume wall framing machine.



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