OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D01794

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.81/3
9 October 1970

ORIGINAL: ENGLISH

Regional Workshop on Clay Building Materials Industries in Africa

Tunis, 6 - 12 December 1970

PROGRESS, ACCELERATION AND STANDARDISATION 1/

by

H.W.H. West

British Ceramic Research Association
United Kingdom

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the author, without re-editing.

id.70-5601

S U M M A R Y

The economic situation of developing countries in Africa is considered and their present output of bricks and postulated outputs for 1980 compared with Great Britain as a country with a fully developed brick and tile industry. There is considerable potential demand for bricks and tiles as the countries develop, and ways in which the industries may be expanded are suggested.

Productivity is examined first in relation to the situation in Great Britain when more labour intensive processes were used, and man-power requirements for various types of production given. Simple improvements are described and amended man-power requirements listed. Modern, highly mechanised plants can have productive labour costs of less than 1 man-hour per thousand bricks. The capital costs of new works are discussed and the increase in these costs and decrease in labour costs is demonstrated over the period 1955-1968. The proportion of the total running costs debitable to each part of the process is given and compared with costs derived from data suggested by the United Nations Economic Commission for Africa.

Research and development facilities for a central research facility and for works laboratories are considered together with the distribution of effort, a possible research programme, and the development of new products. Quality control tests and charts are described. Reference is given to apparatus and methods for various testing procedures.

National standards are important to the development of the industry and the requirements for a standards organisation are discussed. The principles of modular co-ordination are outlined and it is concluded that the initiation of a system of standards is an opportunity to ensure that they are all related on a modularly co-ordinated basis.

While in the early years of the development of a brick and tile industry emphasis may be placed on production technology, as the products improve and the buildings become more sophisticated there is a need for research into performance in use, and the establishment of advisory facilities for the consumer.

CONTENTS

CAPTIONS OF FIGURES

1. THE ESTABLISHMENT AND DEVELOPMENT OF A BRICK AND TILE INDUSTRY

The necessity for a brick and tile industry arises from the need to provide cheap building materials from which permanent durable dwellings can be made. A demand in short to improve the housing conditions of the people over that prevailing in mud huts or crude timber shelters. While adobe (bricks en banco or poto poto) may be adequate a fired-clay brick is better and in combination with clay roofing and floor tiles enables damp-proof and vermin-proof dwellings and store houses to be constructed.

Other building materials may similarly provide good shelter, for example concrete blocks. Since cement is manufactured in large central factories it, or the blocks, has to be transported to where the dwellings are needed and this may make the product too expensive for general use. However where breeze blocks are readily available they may be less expensive than bricks for a given area of wall. Table 1 gives comparative figures for some African countries(1)

TABLE 1

Price in $US of bricks and blocks only for $1 m^2$ of 20 cm. thick wall (1965)

	Ghana	Ivory Coast	Mali	Nigeria	Togo	Niger	Upper Volta
Breeze Blocks							
Solid	3.1-4.5	3.0	-	-		8.5-14.2	8.5-14.2
Hollow	2.1-3.6	2.2-2.7	2.6-3.6	-		7.8-10.8	7.8-10.8
Bricks							
Solid	-	5.7	5.8	9.8		-	6.2
Perforated	3.2-4.0	1.9-4.0	2.2-2.3	2.3-3.0	0.7	2.4-2.6	2.8-3.9

Clay bricks can be made wherever suitable raw material and fuel occur, and clays suitable for brick making occur widely. At worst river alluvium may be used, so that in practice most village communities could set up a small local brickworks. Indeed this may be necessary since bricks and tiles are heavy and the cost of transport accordingly high. The United Nations Economic Commission for Africa has noted(1) that the average cost of bricks in Africa is $18 per ton and the transport cost about 6c per ton per kilometre so that at a distance of 300 km from the brickworks the price is doubled. While large brickworks may be set up to serve centres of population, it is not to be expected that the bricks will be transported far and small craft workshops have a vital role to play.

Mortar materials are also necessary. Cement production requires large capital resources, but wherever limestone or calcium carbonate in any form occurs lime-burning will enable adequate sand-lime mortars to be made. Even dry walling or bonding with mud may be better than no shelter, but in considering the establishment of a brick and tile industry it is presupposed that conventional brickwork will result.

This requires skilled bricklayers. While simple structures are readily put together from bricks by amateur craftsmen, the development of a viable brick industry demands the concomitant development of a building construction industry and government action may be necessary to train bricklayers. Indeed it is not to be expected that a brick industry will arise spontaneously and certainly large brick factories to serve the major cities will be set up on a national basis rather than by individual entrepreneurs.

The rate at which a brick industry develops depends upon the total industrial climate. In agricultural communities growth of the brick industry seems to be slow and there is a tendency for it to remain a scattered collection of local craft workshops. The development of roads is necessary before the larger works can come into being to serve a bigger area and it seems to be industrialisation bringing higher wages which leads to a general demand for better dwellings and hence for the products of the brick industry. During the period 1821-1912 in Great Britain, that is the time of the industrial revolution, brick production rose at the average rate of 3%, but during the period 1921 to 1938 which was the time of greatly increased demand for private houses, the great speculative building boom, - production rose at the average rate of about 5%.

The U.K. may be regarded as approaching the ultimate in demand for clay building materials. It is a small country heavily populated - 90% of the population of over 50 million is concentrated in about 60,000 square miles of

England and Wales. The maximum demand for new dwellings has been put at 500,000/year or roughly 1% of the population although this figure has never been attained. For a house of 1000 sq. ft. floor area (about 100 sq. metres) assuming all the walls are constructed of bricks 15000 will be needed together with c.4000 plain roofing tiles. The maximum annual production required for housing alone is thus 7,500 million bricks and 2000 million plain roofing tiles. Housing comprises 70% of the total market for bricks so that the maximum demand for all purposes might be about 11000 million per year. This is 200 bricks per head of the population. The highest total production of bricks ever was in 1964 when it was 7954 millions or 145 per head of the 55 million population (1969 census). Production is now depressed due to economic factors and in 1969 was 6734 million or 122 per head.

Table 2 E.C.A.(1) collected data for 25 African countries in 1965 and Table 2 shows this with their projections for 1980. If Libya is excluded then the maximum production of bricks per head in 1980 is only just over 20. In Great Britain the production was 75 bricks per capita in 1830, it rose to about 90 per capita in 1840 and remained constant until 1921, when the rate increased so that by 1938 it was 138 per head.

Clearly there is considerable potential demand to be satisfied as these countries develop. The problem is how to satisfy it without extensive capital investment and purchase of imported machines.

Three stages of production should be distinguished conveniently delineated by the outputs 5 tons per day, 50 tons per day and 300 tons per day. 5 tons per day is a small rural workshop, the next stage up from one man making bricks on his own. The process is hand-making with possibly some simple preparation machinery driven first by animal power. The aim should be to encourage the spread of this kind of craft brickmaking together with lime burning for mortar and bricklaying.

Plants with outputs of 300 tons per day are factories located at centres of population and requiring adequate reserves of raw material and all the facilities of urban civilisation, power supply, fuel, and a source of trained

TABLE 2 DATA FOR 25 AFRICAN COUNTRIES FOR 1965 WITH PROJECTIONS TO 1980 (After Horvath)[1]

G.N.P. = Gross National Product
n.d. = Not determined

	POPULATION MILLIONS		G.N.P. MILLION $		G.N.P. per Capita $		Production of bricks thousands		Consumption of bricks per capita	
	1965	1980	1965	1980	1965	1980	1965	1980	1965	1980
DAHOMEY	2.35	3.35	163	344	69	103	571	9714	0.24	2.90
GAMBIA	0.32	0.49	23	54	71	110	-	2286	-	4.67
GHANA	7.74	12.13	1565	3487	202	287	1000	66654	0.13	5.51
GUINEA	3.48	5.03	252	562	72	112	6343	23427	1.82	4.66
IVORY COAST	3.83	5.38	953	2446	249	455	857	61426	0.22	11.42
LIBERIA	1.05	1.24	263	725	250	585	2971	8571	2.83	6.91
MALI	4.58	6.48	327	657	71	101	3428	7428	0.75	1.15
MAURITANIA	0.74	0.89	142	340	192	382	-	2286	-	2.57
NIGER	3.27	4.67	296	708	90	152	1029	12235	0.32	2.63
NIGERIA	58.0	91.0	4272	10060	74	110	7143	135993	0.12	1.49
SENEGAL	3.47	4.63	700	1560	202	337	4000	37427	1.15	8.08
SIERRA LEONE	2.71	3.66	228	593	84	162	-	17142	-	4.68
TOGO	1.64	2.37	143	332	67	140	5143	8000	3.14	3.38
UPPER VOLTA	4.78	6.41	224	662	47	103	1800	10285	0.38	1.60
ALGERIA	11.30	18.30	2170	4910	192	268	91424	265704	8.09	11.24
LIBYA	1.60	2.50	940	4200	590	1680	9428	171420	5.89	68.57
MOROCCO	12.60	20.0	2270	4900	180	245	27427	137140	2.18	6.86
TUNISIA	4.30	6.80	820	2150	190	316	32284	137140	7.51	20.17
SUDAN	12.50	20.70	1170	2640	94	128	n.d.	131422	-	6.35
CAMEROUNS	5.0	7.23	634	1707	125	233	5714	27427	1.14	3.79
TCHAD	3.25	4.19	213	673	64	158	5143	31427	1.58	7.50
BRAZZAVILLE CONGO	0.86	1.11	139	373	154	332	2857	6285	3.32	5.66
KINSHASA CONGO	15.10	22.04	1200	2967	78	131	6285	130000	0.42	5.90
CENTRAL AFRICAN REPUBLIC	1.31	1.84	143	453	108	243	2286	9142	1.75	4.97
GABON	0.46	0.59	193	516	413	873	n.d.	4857	-	8.23
TOTALS FOR 25 COUNTRIES	166.24	253.03	19443	48020			217133	495075		
MEAN					158	310			2.15	
RANGE					47-590	101-1680			0.12-8.09	1.15-68.57

For comparison the GNP for Great Britain in 1969 was £38,617 million and the population 55.534 millions. Thus the GNP per capita was £696 or $1672.

operatives, fitters and electricians. Such a plant may well be a combined unit supplying a range of clay products, bricks, tiles and sewer pipes and the investment required is such that it is likely to receive government support.

For bricks the plant might be soft mud or extrusion, but if it is to produce several products it will be the latter. The machinery should still be simple with the minimum of mechanical handling equipment. Natural drying will be supplemented with heat and ventilation in the rains to allow the plant to be non-seasonal. A continuous kiln will be used though a tunnel kiln may not be necessary.

The intermediate sized plant of 50 to 60 tons per day gives an output of 100,000 per week and is the size which formed the standard unit in the industrialisation of the British brick industry. It is commercially small enough for one man as owner manager and in Great Britain such plants were frequently set up by builders to provide materials for their own work.

The likely sequence of development seems to be that one or more factories will be set up in the major cities to provide a higher quality of ware including specialised products which are required in relatively small quantities. This is likely to require government financial support and at the same time the government should actively encourage the development of a network of rural community workshops and the training of bricklayers. As fired clay products become increasingly available and the demand rises so it may be anticipated that business men will take the opportunity of setting up the intermediate scale factories wherever a large enough market exists or can be seen potentially to exist.

This combination of a few works and a scattered hand-made industry has already emerged in some African countries. Table 3 after Horvath[(1)] shows the position in 1968. This table refers only to known works fired bricks and is almost certainly therefore conservative. It seems not to include brick en banco.

Table 3

OUTPUT OF BRICKWORKS IN NORTH, WEST AND CENTRAL AFRICA 1968

Country	Number of Brickworks	Output of bricks tons/yr	Hand made output tons/yr	Total output known tons/yr	Notes
Algeria	52	610,000	n.d.	610,000	Plus 160,000 t/yr tiles
Libya	-		15000		
Morocco	15	120,000	60000	180,000	
Tunisia	50	220,000	n.d.	220,000	
Sudan	-	-	n.d.	n.d.	Omdurman brickworks under construction 53000 t/yr.
Ivory Coast	2	27,000		27,000	Abidjan brickworks under construction 25000 t/yr
Dahomey	-	-	2000	2,000	
Gambia	-	-	-	-	
Ghana	16	74,000			Includes Malami brickwork 23000t/yr & 15 mobile b/wor
Guinea	4	82,000			3 brickworks projected
Upper Volta	2	14,000			
Liberia	2	10,000			
Mali	1	12,000			
Mauretania	-	-	-	-	
Niger	2	26,000			
Nigeria	2	36,000			
Senegal	3	12,000	4000	16,000	
Sierra Leone	-	-	-	-	
Togo	-	-	18000	18,000	
Camerouns	1	25,000	n.d.	25,000	New factory under construction at [illegible] with capacity 25,000 t/yr
Brazzaville Congo	2	16,000			
Kinshasa Congo	2	32,000			
Gabon	-	-	n.d.		Handmade only
C.A.R.	1	10,000			
Tchad	2	45,000	n.d.	45,000	Including a project for mobile brickworks of 12,000 t/yr.

n.d. = not determined

The concept of mobile brickworks is interesting. While this must be a relatively expensive method of production it provides a means of disseminating an awareness of the virtues of a higher quality product, and of producing more widely products other than the solid brick, for example, perforated bricks and hollow blocks. In order to promote the manufacture and use of better quality, longer lasting products, however, another type of infrastructure is needed, that of exploration for raw materials, research and development in heavy clay technology, national standards and testing facilities to ensure compliance. Only when such a structure has been built up can a brick and tile industry be said to be fully established and only then will clay products become the universal, plentiful and inexpensive building units that they are in the developed countries and the general level of housing raised accordingly.

2. PRODUCTIVITY AND PRODUCTION EFFICIENCY

In developing countries there is usually no shortage of labour, but rather a shortage of capital to purchase mechanical plant. Nevertheless the best use should be made of the brickmaking resources whether human or machine and it may be instructive to consider European experience in the mechanisation of brickmaking processes.

The comparative index of productivity is the labour cost in man-hours per thousand bricks, (m.h./1000) for other clayware units man-hours per ton. (m.h./t.). The tables are based on a 40-hour week except that "Firing" is taken as three men working a total of 168 hours. The labour is divided into "Productive" - these processes directly associated with manufacture - and "non-productive" which includes all other labour, e.g. maintenance and transport. In general the data given are for productive labour only.

2.1 Basic processes

In this section the data are representative of the manual version of the process, so that while machinery is used for making etc. the amount of handling equipment is minimal. They are broadly representative of the practice in England in the days of relatively cheap labour before 1950.

In the seasonal operation of a hand-made yard, clay is dug and weathered over the winter, in spring making begins and the bricks are hack-dried in the sun and fired in clamps. Five men produce about 10,000 bricks a week, during the making season. The winter operations which comprise digging and curfing, removing overburden, maintenance and loading from stock have not been included in the table so that actual labour requirement may be almost twice that shown.

TABLE 4

Labour for handmaking (Seasonal)
(Output 10,000/week)

Process	Men	Hrs. per week	m.h./1000
Preparing and wheeling clay, and sand	1	40	4
Making (1000/man/day) and wheeling and hacking	2	80	8
Skintling, wheeling and setting, drawing and loading	2	80	8
Totals	5	200	20

The soft mud process using the standard three-mould Berry machine with a target output of 1000/hr. shows little improvement (Table 5)

TABLE 5

Labour for single Berry plant
(Output 40,000/week)

Process		Men	Hrs. per week	m.h./1000
Digging and curfing		3	120	3
Wheeling clay and sand		3	120	3
Making (1 machine)	Temperer	1	40	1
	Berry	4	160	4
Wheeling, hacking and skintling in sheds		3	120	3
Preparing clamps and wheeling and setting		3	120	3
Drawing and loading		2	80	2
Totals		19	760	19

For a much larger output of soft mud bricks using the Lancaster machine with automatic loading of tunnel dryer cars and a tunnel kiln, the labour requirements are much reduced. (Table 6).

TABLE 6

Labour for a Lancaster Plant
(Output: 300,000/wk)

Process	Men	Hours/wk	m.h./1000
Mechanical digging and processing in wash-backs	4	160	0.53
Making	6	240	0.80
Drying	4	160	0.53
Setting	18	720	2.40
Firing	3	168	0.56
Drawing and sorting	15	600	2.00
Totals	50	2048	6.82

There are many variants of the extrusion process. In Table 7 a simple form with hand-winning and hot floor drying is compared with mechanised winning and tunnel dryers, and hollow block production using chamber dryers.

TABLE 7

Labour for extrusion of bricks and hollow blocks
(Output 100,000 bricks or brick-equivalents/wk)

	Bricks Hot Floor		Bricks Tunnel Dryor		Hollow Blocks Chamber Dryer	
	Men	m.h./1000	Men	m.h./1000	Men	m.h./1000 brick eq.
Hand winning and haulage	15	6.0	-	-	-	-
Excavator and haulage	-	-	2	0.6	2	0.8
Wet Pan	1	0.4	1	0.4	1	0.4
Extruder	2	0.8	2	0.8	2	0.8
Wheeling to hot floors and putting down	5	2.0	-	-	-	-
Taking up and wheeling to kiln	3	1.2	-	-	-	-
Tunnel or chamber dryer	-	-	5	2.0	8	3.2
Setting	3	1.2	3	1.2	2	0.8
Firing	3	1.7	3	1.7	3	1.7
Drawing	3	1.2	3	1.2	2	0.8
Totals	35	14.5	19	8.1	20	8.5

It will be remembered that in these processes the minimum of mechanical handling is postulated. Thus in the tunnel dryer system 2 men castle bricks onto the cars, 2 men push in full cars and assist in pulling dry ones out while one other man returns empties. In the chamber dryer system 2 men at the pug place pallets on the ascender, there is a finger car to the dryers and another from the dryer to the descender where 2 men place the pallets in carousel cars. 2 men wheel cars to the kiln and 2 men return pallets and clean up. Only 2 setters and 2 drawers are required because the larger size of hollow blocks allows more brick-equivalents to be handled.

The stiff-plastic process using the double press is very similar in labour content to the better forms of extrusion. Although there is no drying operation the dry grinding process takes more labour. (Table 8).

TABLE 8

Labour for stiff-plastic making
(Output: 100,000/wk)

Process	Men	m.h./1000
Excavator and haulage	2	0.8
Dry pan	1	0.4
Screen and dust floor	1	0.4
Tempering	1	0.4
Taking off double press	2	0.8
Cleaning up and press relief	1	0.4
Wheeling and setting	5	2.0
Firing	3	1.7
Drawing and loading	3	1.2
Totals	19	8.1

The basic process of semi-dry press manufacture uses 3 presses each with an output of 1000/hr. Table 9 shows that the process is more economical of labour than any except the high output soft mud process, but it will be seen in the next section that considerable improvement is possible in the extrusion process.

TABLE 9

Labour for semi-dry press plant
(Output: 120,000/wk)

Process	Men	m.h./1000
Excavator and haulage	2	0.7
Dry pan	1	0.3
Screen and dust floor	2	0.7
Taking off presses	3	1.0
Cleaning up and press relief	2	0.7
Wheeling and setting	6	2.0
Firing	3	1.0
Drawing	3	1.0
Totals	22	7.7*

Table 10 In Table 10 the manufacture of standard roofing tiles is shown with a comparison between hand- and machine-made and plain tiles and single lap tiles. The latter provide the maximum roof cover for the minimum cost, since 60% of the roof has only single thickness cover. Plain tiles on the other hand overlap so that 80% of the roof has treble thickness and the rest double thickness of cover.

2.2 Improved processes

It is not difficult to make immediate improvement to the processes described above by the installation of simple mechanical handling aids. However the cost of this has to be weighed against the cost of the labour displaced. A convenient yard stick is three year's wages for the man displaced, so that in Great Britain now it is worth spending £3000 to replace one man. Other countries will clearly show different amounts using the same formula and in developing countries with very low wage rates it may be impossible to show a gain in this way. It should be noted, however, that the mechanisation of brickmaking leads also to better quality and less waste and this should be taken into account.

Simple work studies may enable the tempo of a hand process to be increased without capital investment. It has been noted (2) that increasing the drawing and sorting rate from 1000/hr. to 1500/hr. will reduce the cost from 10/-/1000

*In all the tables the m.h./1000 is correct for the totals; the addition of individual items does not necessarily agree in the last place of decimals.

TABLE 10

Labour for roofing-tile manufacture

PROCESS	PLAIN TILES				SINGLE LAP TILES			
	Hand made 80 tons/wk		Extruded 250 tons/wk		Hand made 80 tons/wk		Extruded bats pressed 250 tons/wk	
	men	mh/ton	men	mh/ton	men	mh/ton	men	mh/ton
Hand winning and haulage including weathering	6	3.0	-	-	6	3.0	-	-
Excavator winning and weathering rope haulage	-	-	4	0.6	-	-	4	0.6
Wet pan	1	0.5	1	0.2	1	0.5	1	0.2
Clot production	1	0.5	1	0.2	1	0.5	1	0.2
Souring	1	0.5	-	-	1	0.5	-	-
Barrowing clots to makers	1	0.5	-	-	1	0.5	-	-
Making	-	-	4	0.7	-	-	8	1.3
Hand moulding and setting in racks	10	5.0	-	-	16	8.0	-	-
Drying on racks	1	0.5	-	-	3	1.5	-	-
Placing pallets in ascender	-	-	-	-	-	-	2	0.3
Wheeling to dryer	-	-	6	1.0	-	-	1	0.2
Cambering and chequering	-	-	6	1.0	-	-	-	-
Loading and wheeling	2	1.0	4	0.7	2	1.0	4	0.6
Setting	2	1.0	4	0.6	2	1.0	4	0.6
Firing- Continuous	-	-	3	0.7	-	-	-	-
or Intermittent	4	2.8	-	-	4	2.8	9	2.0
Drawing and Sorting	2	1.0	4	0.6	2	1.0	4	0.6
Wheeling and stacking	1	0.5	3	0.5	1	0.5	3	0.5
Loading	1	0.5	3	0.5	1	0.5	3	0.5
TOTALS:	33	17.3	43	7.1	41	21.3	44	7.6

to 8/-/1000 even if the men are given an incentive bonus to raise their pay from 10/-/hr. to 12/-/hr. This is a saving of £300 per man per year. Similarly changes in layout to avoid unnecessary handling may be equally productive, and the provision of cat walks may enable one man to oversee several items of plant.

Perhaps the greatest single aid to productivity is the establishment and maintenance of the correct output. This is determined by the output of the critical machine - the one at which, because of its method or economics of operation, the minimum variation is possible. It will often be a press, or an automatic setting machine. Whatever it is the works should be designed in multiples of its output and a constant flow of material maintained to it. Fluctuations should be reduced by suitable hoppers for raw materials and magazine conveyors for products. The rated output of a machine is its normal output when working continuously. The aim should be to maintain consistently the target output which is 10% less than this and is intended to take account of waste at all stages of the process, and should not be regarded as an allowance for idle time.

Mechanical loading of pallets onto dryer cars or stacking of green bricks is assumed. Fork-lift trucks are used for transport and where practicable fork-lift setting and drawing yields savings. Oil or gas are preferred as fuels because of the labour cost in handling coal.

By using simple handling devices and choosing outputs to suit the plant considerable improvements can be made in the labour requirements of the basic processes given above. This is shown in Table 11, and the effect of output is shown under the extrusion process where the labour requirement for a plant designed for 160,000 per week has also been calculated at 100,000 per week.

TABLE 11

LABOUR REQUIREMENTS FOR IMPROVED PROCESSES

		Target output/week	Total men	mh/1000
Hand made		100,000	33	14.1
Soft mud	Berry plant clamp-fired	148,000	22	5.8
	Aberson plant clamp-fired	200,000	19	3.8
	Aberson plant kiln fired	540,000	48	3.6
Extruded	Under-aired, Hoffmann fired	160,000	17	4.6
	Plant as above	100,000	13	5.7
	Stiff de-aired, tunnel kiln fired	160,000	15	4.1
Stiff plastic	Hand set and drawn	188,000	20	4.5
	Fork-lift set and drawn	198,000	12	2.8
Semi-dry pressed	Hand set	260,000	23	3.7
	Fork-lift set and drawn	260,000	17	2.8

Mechanisation involves changes in the detail of the process, but in addition one kind of product may be replaced by another. The replacement of the stiff plastic process by stiff extrusion is shown in Table 12,(3) first where the same two small continuous kilns were used, and then a new plant with a tunnel kiln. The last column shows that fork-lift setting and drawing in flat-arched Hoffmanns is even more economical of labour.

Some data on non-productive labour are given in this table. As presses are replaced by extrusion the amount of maintenance required falls, but first the tunnel kiln and then the introduction of fork-lift trucks raises it again. Labourers, however, are reduced as mechanical aids come in.

2.3 Highly mechanised plants

Since World War II there has been a massive improvement in productivity in brick plants in developed countries. In 1947 the National Brick Advisory Council in Great Britain provided target labour figures for the various processes, and in 1958 the British Ceramic Research Association revised

TABLE 12

EFFECT ON LABOUR REQUIREMENTS OF CHANGING THE PRODUCT AND THE PROCESS

Output/week	A 240,000 Stiff Plastic 1954	B 240,000 Wirecut 1964	C 400,000 Wirecut Tunnel Kiln 1964	D 720,000 Wirecut Flat arched Hoffmanns (?)
Parts of process	m.h./th.	m.h./th.	m.h./th.	m.h./th.
Winning & Haulage	1.33	0.74	0.52	0.63
Making	4.80	0.80	0.48	0.49
Drying	-	0.40	0.24	0.28
Setting, Firing & Drawing	7.78	5.66	2.96	2.28
Total Productive Labour	13.91	7.60	4.20	3.68
Maintenance	2.08	0.40	0.96	1.04
Labourers	1.04	1.00	0.60	0.63
Office & Canteen	0.83	0.60	0.36	0.49
Total non-Productive Labour	3.95	2.00	1.92	2.16
Total Labour	17.86	9.60	6.12	5.84

these on the basis of their work on the reorganisation of existing brickworks. (Table 13)

TABLE 13

Productive Labour m.h./1000

Process	N.B.A.C. recommendations 1947	B.C.R.A. recommendations 1958
Wirecut	6.7 - 9.8	4.5 - 5.4
Stiff Plastic	7.5 - 8.7	3.1 - 4.8
Semi-dry Pressed	6.1 - 8.9	3.4 - 4.4

Table 14 The values quoted put the stiff-plastic and semi-dry press processes in a good light, but considerable development has taken place in the wirecut process since then, and this is shown in Table 14 where the process is broken down for a number of factories built since 1962, and compared with the earlier recommendations.

Productivity should be considered not only in terms of labour requirements but also by the quality of the product. Modern tunnel kiln plants regularly produce 94-97% first quality ware with only 0.0 to 0.4% waste and the rest sold as seconds. In U.S.A. the whole production may be loaded without sorting.

Such a works is the one-high plant of General Shale at Knoxville, Tennessee.(4) The output of 630,000 bricks per week is achieved with only 4 men on each shift in the making plant. There is a "swing" shift of 4 men for shift changeover, and winning and dry grinding labour has to be added to arrive at the total productive labour figure of 1.4 m.h./1000. On each shift one man is a supervisor and each of the three men is wholly responsible for one section of the plant, extrusion and setting machine; dryer and kiln; off-loading, packaging machine and fork-lift loading. The responsibility extends to maintenance and the men change jobs to ensure that they are familiar with the whole process. Operating at 6000 bricks/hr. the plant can produce its output in 16 hours per day or 5 hrs. 20 mins. out of each shift leaving 2 hrs. 40 mins. for meals, adjustments, maintenance, etc.

This plant is essentially a second generation plant, quite different from

TABLE 14

LABOUR REQUIREMENTS OF NEW WIRECUT BRICK FACTORIES IN U.K.

m.h./1000

Part of Process	N.B.A.C. recommendations 1947	B.C.R.A. recommendations 1958	NEW FACTORIES						
			I 1962	II 1964	III 1964	IV 196[illegible]	V 1966	VI 1966	VII 1966
Winning and Haulage	0.75 - 1.25	1.0	0.16	0.57	0.20	0.2[illegible]	0.33	0.22	0.13
Making and Drying	2.25 - 2.75	1.1	0.72	0.64	0.55	0.9[illegible]	0.33	0.47	0.27
Setting Drawing and Firing	3.12 - 4.87	3.25	2.61	2.05	2.58	2.5[illegible]	2.40	2.31	1.60
TOTALS		5.35	3.49	3.26	3.33	3.74	3.06	3.00	2.00

the standard highly mechanised plants elsewhere in the world. It uses the
Fig. 1 simple concept of one high stacking on headers on kiln cars (Fig. 1) in order to simplify the setting process, but more importantly the unloading process. By this means it is possible to pick up a row of fired bricks and place them directly onto a conveyor, whence they proceed to an automatic packaging device. From the stiff extruder through to transport the bricks are never touched by hand, indeed the first person to touch the bricks is the bricklayer on site. As a secondary consideration the bricks fire more rapidly because they are more equally exposed to the hot gases and the time through the tunnel kiln is only 7 hrs. 20 mins. Since drying time is 11 hrs. bricks are readily supplied within 24 hours from extrusion.

A more conventional plant with low productive labour requirements is the new plant of Gebruder Schultheiss in Germany. This started in October 1966 producing 673,000 bricks per week. There is three shift operation for five days, one shift on Saturday with two shift operation of the preparation plant. The two day shifts have 5 men on each, while the night shift has only 2 men because there is no preparation or drawing. This tunnel kiln is the first and only kiln in Germany which is run without any attendants. With 2 men on shift over the weekend the labour requirement comes out at 0.89 m.h./1000. This does not include winning but the labour cost of this will be small.

The charge hand on each shift is a qualified electrician to ensure the reliability of the entirely automatic plant. Two of the remaining men are similarly only supervisors over preparation and making, but one man operates the setting machine and one man straps the packs of bricks and draws them directly from the tunnel kiln cars by fork-lift truck.

It is thus readily possible to build a brickworks which will produce for around 1 m.h./1000 but the level of operative required is high, and the tendency has been to use trained fitters at least as shift supervisors. In addition the capital cost of the works per unit of output becomes higher as works become more highly mechanised.

2.4 Costs

2.4.1 Capital costs of new works

The capital costs of building new plants are known with some precision for U.K., but costs have also been collected for a number of different works 15 and different processes in other countries. The data are given in Table 15 and include ex-works selling prices. For many years in U.K., the capital cost was £1 per brick per week, that is £100,000 for an output of 100,000 bricks per week. Now, excluding land, but including site preparation, access roads, stockpiling areas, all buildings and machinery with the plant handed over in full production the price may be over £1.75 per brick per week, but depends upon the length of tunnel kiln needed to fire the clay. Soft extrusion with drying lies between £1.5 and £1.75 per brick per week while stiff extrusion is likely to be about £1.4 per brick per week. Lower costs than this have been achieved in many plants, however, and plants in America need not be more expensive than British.

. 2 The capital cost is plotted against time in Fig. 2. The solid line joins the original (1955) cost of works E1 and the calculated 1967 cost based on 5% per annum inflation. The plants in the Northern American states have covered storage areas and more elaborate processing than those in the Southern States (F & G). The design cost of the new works E2 is thus in line with the cost of the earlier E1. Plant B1 is chiefly roofing tiles and hence has more extensive preparation equipment but the selling price per unit weight is twice that of bricks. D is a highly mechanised plant of novel design and low man-power for that time. Plant F on the other hand has the lowest man-power requirement of all and yet compares in cost with the lower group of plants.

The increasing capital cost is due not only to inflation but also to ig. 3 greater mechanisation. In Fig. 3 man-power is plotted against time. The upper set of works have a separate drying operation, while the lower set are either stiff extruded and set direct or the drying is a part of a wholly automatic process. Works K, G and F have setting machines.

TABLE 15

INTER-COMPANY COMPARISONS FOR NEW WORKS, CAPITAL COSTS AND PRODUCTIVE LABOUR ONLY

Works	Country	Date of data	Date of Erection	Products	Output b. e./wk thousands	m.h./th.	Capital £ million	Costs £ per brick per week	Approx. Average ex-works price £/1000	Average annual turn-over £/million	Ratio turn-over capital
A	Holland	1959	1958	Handmade Softmud	300 250	9.6	0.3	0.545	7 6	0.187	0.623
B1	Switzerland	1965	1965	Bricks Roofing tiles	400	10.0	0.833	2.03	—	—	—
B2	Switzerland		1960	Bricks (two shifts)	680	2.8	0.5	0.74	—	—	—
C	Switzerland		1962	Common bricks Facing bricks	480 120	4.4	0.917	1.53	10 25	0.406	0.443
D	Switzerland		1963	Bricks and blocks	500	2.3	1.0	2.0	25	0.650	0.650
E1	U. S. A. (North)	1967	1955	Stiff extrusion	1050	3.6	1.16	1.105	14.6	0.797	0.69
E1	Calculated cost built at current prices						1.856	1.763	14.6	0.797	0.429
E2	U. S. A. (North)*	1967	1968	Stiff extrusion Soft mud	1000 500	2.5	2.857	1.9.5	14.6 18.2	1.242	0.43
F	U. S. A. (South)	1967	1967	Stiff extrusion	630	1.4	0.893	1.417	13.6	0.446	0.499
G	U. S. A. (South)	1967	1966	Stiff extrusion	490	2.2	0.536	1.091	14.3	0.364	0.680
H	Denmark (Design output)	1968	1967	Wirecut facings Commons	240 60	3.1	0.40	1.33	15 8	0.212	0.530
I	U. K.	1968	1966	Wirecut facings	400	3.1	0.50	1.25	18	0.374	0.748
J	U. K.	1968	1966	Wirecut facings	300	3.0	0.410	1.37	21	0.323	0.800
J	* Second kiln with two shift working						0.720	1.20	21	0.655	0.910
K	U. K.	1968	1966	Wirecut facings	325	2.0	0.40	1.23	16.8	0.284	0.710

2.4.2 Running Costs

Actual monetary costs of production are not very informative because not only the efficiency, but the type of product and ex-works price varies from works to works and more from country to country. However a comparison may be made by means of the proportion of the total costs of production attributable to different parts of the process. Table 16 gives data for works in which a complete survey of the process was carried out. The costs have been rounded off and combined into the parts of the process shown.

TABLE 16

Cost of manufacture as a percentage of total cost

tput per year	I Handmade 2 million	II Wirecut 5 million	III Stiff-plastic 5 million	IV Semi-dry press 13 million	V Roofing tiles roller-bat process 10 million (12000
nning & haulage	3.3	8.0	9.5	1.2	5.1
ay preparation	6.9	0.5	5.0	5.8	11.8
king (and drying)	27.5	12.2	7.0	13.7	
el and Power (drive)	10.3	17.3	5.5	4.3	5.4
tal cost of green production	48.0	38.0	27.0	25.0	22.3
tting drawing & firing labour	9.1	21.4	21.0	18.2	23.8
fuel	5.9	16.6	19.0	21.8	31.9
otal cost of firing	15.0	38.0	40.0	40.0	55.7
verheads	37.0	24.0	33.0	35.0	22.0
Totals	100.0	100.0	100.0	100.0	100.0
otal labour costs abstracted	46.8	42.1	42.5	38.9	40.7

The high cost of hand-making is clear in Works I. In Works II a very simple clay preparation sequence of mixer and rolls accounts for the low labour. Fuel and power at Works I and II includes steam for the main drive and drying. Works I uses fork-lift setting and drawing.

It is of course the large differential between wage rates in developed and developing countries which enables labour intensive processes to continue in the latter. In a factory in Pakistan the labour requirement is 22 mh./1000, but this is only 16% of the total costs[5] compared with the 40% approximately which it would be in Europe. The last line in the table shows the percentage labour costs abstracted for these processes.

The E.C.A.[1] have suggested cost figures for the brickworks proposed for various African countries by 1980. These have been recast and reduced

Table 17 to percentages of total costs in Table 17. The data presumably reflect the different conditions in the various countries but the proportion allocated to labour is surprisingly high in some cases. The summary figures indicate the cheaper labour costs and dearer fuel and electricity in the central region.

3. RESEARCH AND DEVELOPMENT

The development of a viable brick industry producing adequate quality of ware depends upon the proper exploitation of raw materials resources, adequate control of the process, testing of the finished product, knowledge of the properties of the product which affect its performance in work and the development of new products. All these factors require proper research and development facilities on the works or at a central establishment.

3.1 Central Laboratories

In many countries national laboratories, often controlled by the trade association, carry out research and development or sometimes just provide testing services for a particular product. Often bricks and roofing tiles share the same resources, while sewer pipes are a separate organisation.

Percentage breakdown of costs for proposed brick factories for certain African countries in 1980 (After Horvath [1])

	Proposed new capacity 1000 t/yr	Wages, Expenses	Fuel	Electricity	Maintenance	Insurance & Sundries	Depreciation	Interest
Dahomey	32	33.6	12.9	12.7	7.4	1.7	23.0	8.7
Gambia	8	40.3 o	12.2	10.2	7.0	1.5	21.4	7.4
Ghana	160	25.0	14.0	7.6	9.3	2.3	30.1	11.7 o
Ivory Coast	190	24.7	13.5	8.4	9.4	2.3	30.2 o	11.5
Liberia	20	31.0	13.7	8.5	8.3	2.2	25.4	10.9
Mali	14	34.4	18.8	16.2	5.8 x	1.2 x	17.5 x	6.1 x
Mauretania	8	35.7	10.8	20.5	6.2	1.3	19.0	6.5
Niger	17	26.2	22.0	18.5	6.1	1.4	18.7	7.1
Nigeria	440	24.0	16.6	12.8	8.2	2.0	26.3	10.1
Senegal	115	25.0	13.1	11.8	8.2	2.2	28.0	11.0
Sierra Leone	60	31.5	14.1	6.5 x	8.6	2.2	25.9	11.2
Togo	10	39.5	12.3	13.1	6.6	1.4	20.1	7.0
Upper Volta	25	33.0	22.9	9.9	6.3	1.4	19.4	7.1
Algeria	80	29.7	15.3	11.0	9.8	2.0	22.4	9.8
Libya	150	26.1	10.9	15.1	10.7 o	2.1	24.4	10.7
Morocco	140	25.6	13.0	14.3	10.5	2.1	24.0	10.5
Tunisia	150	24.5	17.7	12.8	10.0	2.0	23.0	10.0
Sudan	190	27.2	11.4	16.8	9.9	2.0	22.8	9.9
Camerouns	75	16.2	10.6	26.6	10.2	2.9 o	23.3	10.2
Tchad	75	15.6	20.4	26.3	8.2	2.4	18.9	8.2
Brazzaville Congo	10	27.5	12.2	23.8	8.0	2.3	18.2	8.0
Kinshasa Congo	450	11.6 x	21.1	24.2	9.4	2.7	21.6	9.4
Central African Republic	30	20.7	24.7 o	15.4	8.6	2.4	19.6	8.6
Gabon	20	17.2	9.4 x	29.5 o	9.6	2.8	21.9	9.6
Range	8 - 450	11.6–40.3	9.4–24.7	6.5–29.5	5.8–10.7	1.2–2.9	17.5–30.2	6.1–11.7
<u>Summaries for regions:</u>								
West Africa	1100	25.9	15.3	11.0	8.5	2.1	26.8	10.4
North Africa	710	26.4	13.4	14.4	10.2	2.0	23.4	10.2
Central Africa	660	13.3	19.7	24.6	9.3	2.6	21.2	9.3

x = minimum

In Great Britain the national organisation is the British Ceramic Research Association which has the unique distinction of being the only fully integrated ceramic research organisation in the world, dealing with the whole of the ceramic industry as it is understood in U.K. and having separate divisions for Pottery, Refractories, Special Ceramics and Heavy Clay. The responsibility of the Heavy Clay Division is for bricks and blocks, roofing tiles, floor quarry tiles and sewer pipes.

The Association is one of 49 Research Associations in Great Britian which derive their income partly from a levy on the turnover of their members and partly by a Government grant based on the amount of levy received. Membership is entirely voluntary, but a large proportion of the various industries, in some cases over 90%, is in membership.

The services provided besides the research programme, include advice and assistance with exploration for new clay sources, or exploitation of existing ones; advice and assistance with processing problems and the optimization of processing conditions; and an impartial chemical and physical testing service to provide certificates of the fitness of raw materials and the quality of products. Extensive liaison services are maintained to ensure that the results of research are rapidly disseminated to and applied by industry. The Liaison Officers make regular routine visits to all member firms and special visits on request for "trouble shooting" or to investigate user complaints.

The British Ceramic Research Association has a staff of 220 of whom about one third are graduates, a further third have technological diplomas, and one third are technical, industrial and clerical staff. The total budget is about half a million pounds sterling of which the Heavy Clay Division contributes just over £100,000. The turnover of the heavy clay industry in Great Britain is about £100 million so the investment in central research is approximately 0.1% including the Government contribution. While it is true that there is far more research needed than the budget will sustain, this kind of proportion is adequate to enable useful work to be done and for sufficient resources to be available for it to be accomplished rapidly and effectively.

It should be noted, however, that the Heavy Clay Division is able to draw on central services provided for all divisions so that the effective size of the budget is larger. The services include Library and Information, major workshop facilities, physical and chemical testing laboratories, X-ray, electron probe microanalyser, direct reading spectrometer for rapid chemical analysis, electron microscope, and other specialised facilities including publications and photography.

Not all these are essential to a central laboratory, but there is a certain minimum viable size. Library and information services are crucial, and they must at least provide an effective abstract service. Sufficient analytical facilities must be available to enable various kinds of raw materials to be identified and evaluated as well as sufficient equipment to test the properties of the different products at various stages of manufacture and after firing. Basically the central laboratory should be the ultimate authority on its industry and able to advise that industry on all matters affecting production and able to advise government on proposals affecting the industry.

The total output of the brick industry in developing countries in Africa (25 countries) in 1965 according to E.C.A. was about 217 million bricks per annum worth on average \$18 per thousand, this is a turnover of approximately \$4 million or about £1.6 million sterling. The largest individual output was Algeria 91 million, worth therefore approximately \$1.6 million or £670,000. Taking 0.1% of this yields £670 per annum, and even taking the turnover of the whole output of the 25 developing countries would give only £1600 for a regional central laboratory. A higher levy on producers, perhaps 1%, would not be unreasonable, and levies of this order are paid to some of the smaller Research Associations in Great Britain. However, the more likely solution seems to be that, at first at least, the laboratory should be set up and maintained by the Government.

In this case it will almost certainly be convenient and most effective to locate the laboratory near to other scientific resources which can be used and paid for on an as required basis. Thus the laboratory might be situated on a University campus, or it might be part of a larger government laboratory.

3.2 Works laboratories

Works laboratories vary in size from one man equipped with a ruler who maintains quality control records of the dimensions of products to research and development laboratories as large as many central laboratories. Again, however, the budget of the laboratory is usually some quite small proportion of the turnover of the company, and in Great Britain at least true laboratories, capable of testing raw materials and products, are not usually found in companies whose total turnover is less than £1 million so that 1% would provide £10,000 per year for technical services. It is the inescapable expense of providing in-house laboratory facilities which has led to the considerable success of the Research Associations.

Nevertheless there are some rudimentary facilities which should be provided on any works which wishes to improve and maintain the quality of its product. These include:-

(i) Regular (daily) measurement of samples of green and fired bricks. The former to detect die wear, the latter as a check on conformity with the standard;

(ii) Moisture content determinations on green bricks as a check on the consistency of tempering, and on dried bricks as a check on drying where artificial dryers are in use. Occasional checks should also be done on raw materials to establish the limits of variation;

(iii) Compressive strength and water absorption of fired bricks.

While it may not be possible to increase the maximum strength obtained, quality control procedures of this kind should ensure the maintenance of a standard and tend to reduce the amount of variation.

3.3 Distribution of research and development effort

It will be apparent from the foregoing that the function of the works laboratory is to investigate and maintain the quality of the products from a particular factory. Large works laboratories may also develop new products. The function of the central laboratory is to carry out research and development on projects which will be of use and benefit to the whole industry or to a substantial portion of it, and to provide advice and information services on all matters of interest to its industry. At first such advice and information may well be restricted to raw materials and processing problems but as the industry becomes more sophisticated it will be found that the topics broaden and the whole field of building construction, including competitive products tends to come under review.

It is likely that the only works large enough to sustain a works laboratory under the conditions prevailing in developing countries will be the larger factories set up in cities. Certainly any modern factory should have a quality control system and such products would set a standard of quality for the whole industry to aim for. These works laboratories will assist production staff in the development of new products for that factory, but in general all true research and development may be expected to be carried out by the central laboratory.

The topics suggested for the initial programme for the central laboratory are as follows:-

(i) Survey of raw materials resources. This would be carried out in conjunction with the national geological survey. It is not envisaged that a geological field survey of the whole country would be carried out, but rather that existing brickmaking sites would be visited, the clays and products sampled and subsequently tested. In this way a body of information about the existing industry would be built up which, coupled with information obtained by the geological survey department about clay sources found in their normal surveys, would provide the basis for the establishment of a more widespread industry;

(ii) Survey of existing brick making practices, and development of improved methods either from existing knowledge or by experiment. The improved methods must then be disseminated to the brickmakers and this implies a fairly extensive liaison and advisory service;

(iii) Determination of the best processing methods to use the available raw materials, and demonstration of the properties of the ware likely to be produced in new factories. This includes development of new products. This kind of work really requires pilot plant facilities and although these are expensive the knowledge obtained takes some of the guess work out of investing in new plant;

(iv) The survey of the properties of all the products presently produced, mentioned under (i), provides the basic data from which it is possible to start producing national standards. Such standards must codify what the user needs and what it is possible for the industry to make, not some arbitrary standard fixed only by the wishes of the user. A knowledge of the level and variations of the various properties of current products is therefore vital, not so that all of them, no matter how bad, may meet the standard, but rather to find an acceptable average quality to which all must aim.

These four broad topics will, of course, be fairly long term, depending on the resources it is possible to allocate to them, but this background information should be obtained before initiating research and development programmes in new fields.

3.4 The development of new products

While each factory may be expected to develop new products to meet new markets which it anticipates, development in completely new fields is the job of the central laboratory and so listed under (iii) above. The basic products will be bricks, solid and perforated, hollow blocks, and floor and roofing tiles. New designs of block, for example, for use in reinforced or prestressed floor beams, may well arise from an individual works, but the technical skills necessary and the ability to test the material are more likely to reside in the central facility. Similarly the existence of clays useful for light weight aggregate production may emerge from the surveys.

Truly new products, of course, imply a fundamental programme of ceramic research to establish the optimum conditions of manufacture. As an example, in Cuba hollow clay blocks about one meter long, 300 mm. wide and 100 mm. thick are laid horizontally between concrete posts to form the walls of low cost housing. These blocks are a development from the conventional size of hollow block. In Great Britain at the same time research had produced storey height planks of hollow clay, that is a long hollow block used vertically. These planks, the M-G plank,(6) are 2.6 m. long, 300 mm. wide, 100 mm. thick, with 50% hollows, made, dried and fired as a single piece of ceramic and placed together with a neoprene strip between each to make a vertical dry joint. The problems in making a plank of this length are considerable and it was necessary to carry out a fundamental ceramic programme on the properties of heavy clay bodies and how they might be modified by various additives, to invent and patent a completely new design of dryer, and to investigate different profiles and systems of making a dry joint between the planks. The first planks were made in the Pilot Plant at Mellor-Green Laboratories, and problems of die design and balance also had to be solved before straight planks were achieved. It will be clear from this example that the development of truly new products requires extensive facilities which should be provided by the central establishment.

In general, however, it is to be anticipated that there will be many years of development of the brick and tile industry to a level of sophistication equal to that in already developed countries, before it becomes necessary to consider the production of truly novel products.

4. TESTING

Standard testing procedures must be used. Either tests already in use in developed countries should be utilised or special methods should be established by the central laboratory. These methods should be tested to ensure their reproducibility and to determine the errors inherent in them. Any standard requirements can then be fixed in relation to the accuracy of the method.

4.1 Quality control testing

Quality control is a method whereby the results of tests on samples of the production as part of a continuous inspection system are plotted sequentially on a control chart. The control chart is so drawn that it quickly becomes apparent when the process is going out of statistical control.

The basic tests of quality of bricks are dimensions, strength and water absorption. Suitable methods for determining these are described in B.S.3921:Part 2:1969, "Bricks and Blocks of Fired Brickearth, Clay or Shale."(7)

Variations in the individual values of these properties are inevitable, and all testing makes use of the average of a number of tests on individual units. The variation may be due to chance causes which are inherent in the process, and are permissible because it is not possible or worthwhile to eliminate them, for example, small changes in the quality of the raw material, or to assignable causes which should be eliminated and which arise from abnormal variation causing a loss of efficiency. The purpose of control charts is to define the limits of the variation which is to be expected by chance and hence to indicate those variations which should be investigated further.

In order to set up a control chart, data are collected over a relatively short period of time, recorded in the order in which they are obtained, and then divided into rational sub-groups. Such sub-groups are groups within which it is expected that any variation is due to chance causes, and between which assignable causes may be expected. Thus data for different raw materials or from different works cannot be combined into rational sub-groups. Typical rational sub-groups might be samples taken on different days, or a series of results divided into convenient groups, for example 100 readings divided into 20 groups of 5.

The mean ($\bar{X}$) and range ( ) for each group is calculated and the grand mean ($\bar{X}$) and average range ( ) for the whole. From this the standard deviation may be calculated and for small groups (up to 12 individuals) this is conveniently done by dividing the range by a value obtained from statistical tables which varies according to the number in the group (n) and for n = 5 for example is 2.326. Charts are then drawn for the mean and range separately one under the other on the same sheet and control

g. 4a limits inserted. (Fig. 4a). For the chart of means the control value is the grand mean and the inner control limit is drawn at $\bar{X} \pm 1.96$ and the outer control limit at $\bar{X} \pm 3.09$. If the process is in control there is a 1 in 40 chance that succeeding group means will fall outside the inner limits and a 1 in 1000 chance that they will fall outside the outer limits. In other words 1 in 20 are to be expected to lie outside either the upper or the lower inner control limit and 1 in 500 will fall outside either the upper or lower outer control limit without this being due to the operation of any variation other than chance. If group means fall outside these limits more frequently then there is some assignable variation to be investigated.

On the range chart the control limits are not symmetrically distributed about the mean range and the position of the 1:40 and 1:1000 limits is found by multiplying the standard deviation by factors found in statistical tables which very according to the number in the group.

If the points on the average chart go out of control while the range chart remains in control, this shows that the system is inherently capable of operating satisfactorily, but some special factor is causing the mean to shift.

g. 4b (Fig. 4b) An example is die wear causing larger bricks to be made. If the range chart goes out of control on the other hand while the averages remain at the same general level then there is something different wrong with the process

g. 4c (Fig. 4c). This might, for example, be wear in the timing mechanism of an automatic cutter so that bricks of different thicknesses result.

The construction of control charts thus displays the inherent variation of the process about the average value determined. In this case the magnitude of the variation permitted is that represented by the standard deviation found, but there is another use for control charts in which a specification is laid down which the product must meet. In this case the average is defined and so are the limits. Such a quality control scheme for dimensions is described in B.S.3921.

The benefits obtained from regular testing and the use of control charts are considerable. The charts provide an easily read visual record and show immediately short term and long term trends of change. Departures from the norm are readily identified and action may be taken to correct the fault before too much reject material has been produced. Even though a test on a small sample complies with a specification, this is no guarantee that the rest do. With statistically controlled production, however, the level of quality is known accurately and the specification limits with which it complies may be stated. The importance of quality control on the strength of bricks has been confirmed in the draft revision of the British Standard Code of Practice C.P.111:1964 "Structural Recommendations for Load-Bearing Walls" [31] by the acceptance of higher permissible stresses in load-bearing brickwork when the bricks supplied are subject to a quality control testing scheme. The control chart is of course all important when an attempt is being made to bring a process under control or to assess the affect of changes in the raw materials or process. When the process is brought under control testing is reduced to a minimum.

4.2 Central testing services

Central testing services have two important functions. They enable personnel and equipment to be provided to carry out a wider range of tests than can be accomplished in individual works laboratories, and they provide a service independent of a particular manufacturer so that the tests are seen to be impartial.

The range of tests to be carried out is considerable and hence the facilities required. Mineralogical equipment will be required, including X-ray facilities, for the examination of raw materials and fired products, but a great deal of information is yielded by the somewhat less sophisticated tests which make up the "Clay Report" carried out by the Testing Department of the British Ceramic Research Association. The tests include: mineralogical examination; chemical analysis; particle-size determination; making characteristics: drying characteristics, volumetric drying shrinkage, empirical drying test; shrinkage under load to determine the optimum firing temperature, fired strength, water absorption and volumetric firing shrinkage; and fired colour. The results are evaluated in respect of the manufacture of different products and suitable processes recommended. The various test methods have been described.[8,9]

An analytical chemistry laboratory is required not only for the examination of raw materials and additives, but also for the determination of soluble salts in products and associated materials. It should also be capable of carrying out other tests which provide information useful in the investigation of brickwork failures, for example the composition of mortar and the determination of calcium sulpho-aluminate in cases of sulphate attack on mortar. Rapid methods of silicate analysis are available.[10]

The physical testing laboratory should be equipped to carry out all standard tests including those, for example, strength, also carried out on the works. Thus it can provide a referee service in cases of dispute between manufacturer and user. It need hardly be emphasised that the equipment must be of the highest standard, easily capable of carrying out the test required and regularly serviced and tested by its makers. The central facility for
. 5 compressive testing of bricks in Great Britain (Fig. 5) is a 500 ton capacity machine thus able to test bricks to destruction up to a strength of 28000 lbf/in^2 (c. 2000 kg/cm^2) and is itself tested and certified as a Grade A machine every 6 months.

In summary the central testing service must be equipped to carry out all the standard tests relating to its industry, desirably it should also be able to test other products used in association or competition and if possible there should be sufficient flexibility in the service to be able to carry out ad hoc tests to solve particular problems and to develop new testing methods appropriate to local conditions.

5. STANDARDISATION

5.1 National Standards

National standards for building materials provide on the one hand a common form of specification to which all purchases can be made thus safeguarding the customer in terms of the properties which he has specified and safeguarding the manufacturer against subsequent claims for properties which are not specified, and on the other they form part of an interlocking framework of regulations which ensure the safety and general adequacy of buildings. This place in the control of building has been well summarised[11] and the

Fig. 6 figure is reproduced here. (Fig. 6)

The guiding principle of standardisation is "the elimination of unnecessary variety", and the classical sequence of steps in their production is Catalogue Classify: Simplify: Standardise. That is, collect the necessary data: arrange it in a logical sequence: eliminate unnecessary variety and any inconsistency and correct any inadequacies found: publish the standard and publicise and promote its use.

In order that it shall be effective a standard must deal with a real need provide a solution acceptable to all concerned and finally it must be used. It is the last which is the most difficult to ensure in countries where a standards organisation is only just starting, and trade associations play a key role in pressing for standards to be published, providing data and members of the standard committee, and in publicising and promoting the use of the standard among their members. There is of course a certain level of commercial activity which has to be reached before individual companies will join together in a trade association and it seems likely to be necessary for the same level to be reached before standardisation can become effective.

The first standards should undoubtedly be simple, it may be sufficient to do no more than standardise dimensions. There are still a number of British Standards which are "dimensions and workmanship only". The workmanship clause may be no more than ". . . shall be reasonably free from cracks, large stones and expansile particles of lime . . ." but this is sufficient to set some minimum requirement. It should be emphasised that standards should be realistic. They should reflect the current level of technology so that far from setting limits difficult for the manufacturers to attain they should standardise the average quality that is available. Subsequent revisions may be expected to raise that standard.

Standard products should command a higher price than non-standard and this provides an incentive for all makers to conform. The universal availability of bricks and blocks of standard sizes leads to more uniform and efficient building and tends to reduce building costs since accurately dimensional structures are more readily built without cutting and botching. Bricklayers speedily learn to demand the more regular product that enables them to lay more bricks with less fatigue and thus a market is created for the standardised product.

Once the concept of standardisation is accepted, as the industry develops so it becomes possible to introduce more complicated standards in which the properties of the products which affect their behaviour in use are also specified and standard test methods laid down. Rarely will it be necessary for developing countries to initiate their own standards since they can use the extensive range of British, European or American standards as models and adapt them to local conditions.

5.2. Requirements for a standards organisation

In developed countries the standards organisations are well established and interlinked through the International Standards Organisation. It should be noted that while in some countries standards and codes of practice are written by professional bodies (for example by the Danish Association of Engineers), the British Standards organisation merely provides an administrative machine which sets up and services committees and publishes the standards they produce.

The content of a British standard is determined by the members of the committee writing it, that is by industry and by the users and not by B.S.I. staff except that they perform an editing function for the sake of consistency. Thus the standards are as good as those able and willing to serve on the appropriate committee.

The composition of the committee is intended to represent all the interested parties, usually by members from trade associations rather than individual firms, but research organisations, government laboratories, government departments and universities are also represented. Thus the British Ceramic Research Association has membership of all ceramic standards committees, providing the Chairman in some cases, and it is to be expected that the central laboratory would be represented on any standards organisation in a developing country in order to advise on the technical content of the standard and to experiment with, and where necessary devise, methods of test.

Before a standards organisation can be set up the need must be apparent. It is desirable that it should be separate from government in order to maintain a wholly impartial appearance, but it may well be supported by a government grant. The governing body will be eminent men and the committees at first chosen carefully to represent fully all the various interests involved.

The various government and industrial laboratories have a key role in assessing the effectiveness under local conditions of test methods used in other countries, and of providing the technical data on products which enable the standards to be formulated. Technical backing of this kind reinforced by advice from professional engineers and architects is essential to the proper functioning of a standards organisation.

Some form of trade association is required to provide a consensus of view of all the producers. If no trade association exists it may be possible to achieve some progress by having representation from the largest makers on the grounds that they are the leaders of industry and where they lead the others will follow. Similarly organisations which represent bodies of users, for example, builders federations, professional associations, should be invited and where these do not exist the second best of the most important individuals must again be chosen.

The basic requirement for setting up a standards organisation is a panel of qualified impartial experts who can assess the relevance of existing standards in other countries to the situation in their own. This apart the two chief obstacles in a developing country may be money to set up and maintain the organisation, and the practical problem of disseminating standards widely in conditions where literacy is not universal.

6. MODULAR CO ORDINATION

Dimensional co-ordination is defined [12] as

> "The application of a range of related dimensions to the sizing of building components and assemblies and the buildings incorporating them."

It implies a reduction in the variety of sizes of components and the ability to fit them together on site without modification. Such modification was reported by the British Ministry of Works in 1954 to result in waste of time and material amounting to 5-15% for brickwork, 19-21% for partition blocks, 31-37% for plaster board, and 11-45% for timber [13].

Modular co-ordination is [12]

> "Dimensional co-ordination using the international basic module, multimodules, sub-modules and a modular reference system."

It is not new, Fred Heath an American engineer suggested a standard building module of 4 in. in 1925, although A. F. Bemis in "Rational Design" 1936, is usually thought the originator of true dimensional co-ordination. However, Professor Tine Kurent, measuring excavations at Emona (Ljubljana) in Roman feet (29.57 cm.) found simple multiples and sub-multiples of the foot in the relations between the building components and the building spaces. It has been suggested, therefore, that Vitruvius in "On Architecture" used "commodulatio" to mean "modular co-ordination" (14) !

The original 4 in. module was chosen because it was related to the 4 in. timber studs used in American houses, but in the early 1940s Bergvall and Dahlberg in Sweden suggested 10 cm. as the metric equivalent. At the same time Germany suggested a 12.5 cm. module. The Building Research Station in England between 1954 and 1961 worked on a system of preferred dimensions which involved 3 in. and 4 in. and the brick industry wished to have a flexible system based on 4½ in or 3 in. The change over to the metric system in the construction industry in Great Britain will be complete by the end of 1972 so that apart from Germany the 10 cm. module now has complete acceptance in Europe. This basic module of 10 cm. is represented by the letter M.

Since dimensional co-ordination involves the dimensions of both the components and the relevant building space, full modular co-ordination would mean that both all the components and the sizes of walls, floors etc. and the dimensions of rooms, windows, doors etc. are modular. To be modular means that the co-ordinating dimensions are multiples of the basic module M. Cor-ordinating dimensions are those which affect co-ordination with other components. For example in a door set the exterior dimensions of the frame are co-ordinating dimensions but the interior dimensions, i.e. the door, need not necessarily be modular. Thus modular co-ordination is a dimensional guide to both the manufacturer and the designer.

The use of modular components enables the design to be carried out on a grid in which the basic module or some multiple of it is used as the distance between grid lines. This simplifies the work of design and is claimed to reduce the number of drawings needed. International agreement has been reached on the choice of multimodules, and for horizontal dimensions they are 3M, 6M, 12M, 15M, 30M, 60M. The first two, 3M and 6M are intended for housing and the last two 30M and 60M mainly for industrial buildings. In vertical dimensions only 1M is agreed generally as the incremental step for housing with 6M for industrial and agricultural buildings. Since floor thicknesses cannot generally be modular, storey heights and room heights cannot both be modular, and the vertical co-ordinating dimension is the storey height chosen from 26M, 27M, 28M, 30M.

In U.K. the basic sizes for the co-ordinating dimensions of components and assemblies in descending order of preference are:(15)

First: n x 300 mm.

Second: n x 100 mm.

Third: n x 50 mm. up to 300 mm.

Fourth: n x 25 mm. up to 300 mm.

where n is any natural number including one.

Bricks are made in modular form in which the co-ordinating sizes are 300 x 100 x 100 mm. and 200 x 100 x 100 mm. giving, with a 10 mm. mortar joint, work sizes of 290 x 90 x 90 mm. and 190 x 90 x 90 mm. but the British Standard co-ordinating size of metric brick is 225 x 112.5 x 75 mm. This is only 1.6% smaller than the Imperial brick 9 x 4½ x 3 in. and the joint of 10 mm. is 5% larger than the ⅜ in. one. This brick meets the first preference horizontally at 900 mm. = 4 x 225 mm. and vertically at 300 mm. = 4 x 75 mm. Since the standard storey-height in housing is 2.6m, 34 courses can readily be made to fit by minor increases in some of the joint sizes. The brick has the great merit of maintaining the ratios of 2 and 3 in that length is twice the width and three times the thickness, etc.

Modular co-ordination must take into account a system of tolerances to accommodate the dimensional variations found in practice. These are:
Manufacturing tolerances, which limit the deviations allowed to occur in manufacture.
Positional tolerances, which limit the amount a component may deviate from its designated position in work.
Joint tolerances which limit variations in joint thickness.

The advent of metrication has enabled British Standards to be revised to take account of modular co-ordination. In countries where no standards exist therefore an opportunity is offered to develop standards which are all related on a modularly co-ordinated basis. Its protagonists believe that such a scheme would lead to significant economies in building without detracting from adequate freedom in design which the architect demands.

7. USER RESEARCH AND ADVICE FACILITIES

In the early years of the development of a brick and tile industry, the emphasis may rightly be placed on the dissemination and improvement of process technology. To ensure the maximum and most efficient utilisation of the products, however, some form of user research and advice facility should be provided. As the products rise in quality and the buildings become more sophisticated so the need for research into the performance of the products in use becomes more important.

This task may well be assigned to the central research establishment and the distribution of information about good practice in both production and use carried out by the liaison department. Good practice needs to be codified to be heeded, and the issue of Codes of Practice will be a task for the standards organisation. As both the manufacturing and construction industries develop so trade associations may be expected to be formed and those of the manufacturers may provide advice to their customers and support research programmes at universities and elsewhere which seek to provide data for the more efficient use of the products of their members. The research and development departments of individual companies or groups of companies will provide similar data on their own products.

Such activities are economically oriented, they are essentially publicity exercises seeking to increase the share of the market for the particular product. There is nothing improper in this, and in developed countries such activities form a valuable part of the total research scene. There is, however, a need for some quite impartial authority concerned with the safety, health and well-being of the inhabitants of the dwellings. This must inevitably be government sponsored.

Thus there has grown up a network of Building Research Stations concerned with the whole of the building construction field, carrying out research of their own, and disseminating good practice from information obtained from many sources. They provide the data upon which government bases regulations affecting building and provide advice to government on national building programmes whether offices, housing or industrial.

In a fully developed situation then, the user will have a variety of products to choose from at prices which reflect their quality. The properties of the product will have been established by the manufacturer and he can advise on its use, reinforced by the additional resources of the trade associations, using data obtained by research in the central research organisation of the brick industry or in universities. The consumer will have purchased the product to a national standard specification and he will use it in accordance with a code of practice and comply with the national building regulations and local building by-laws. In cases of difficulty or novel situations not covered by normal practice he can expect to get advice and assistance from the government sponsored building research station.

The result at the end of this development road is thus a widely available, inexpensive, durable building product, with known properties, erected to form weather-proof, comfortable, sanitary and safe dwellings which have been constructed to ensure permanence in the particular local conditions of rain, heat, cold, wind, earthquakes etc. Thus may a tolerable standard of housing be provided for the people and their health and welfare better safeguarded.

ACKNOWLEDGEMENTS

The author thanks Dr. N. F. Asthury, C.B.E., Director of Research, British Ceramic Research Association for permission to prepare this paper and to use data from certain B.Ceram.R.A. publications, the Brick Development Association for permission to use material from their series of handbooks and the National Federation of Clay Industries for permission to use data from a survey carried out for the Select Committee on the Clay Tile Industry.

REFERENCES

1. Horvath, I. (1968) "The Clay and Ceramic Industry in Africa" United Nations Economic Commission for Africa, Ethiopia, Private Communication.

2. Hayek, A.G. and Parry, J.P.M. (1968) Claycraft 41:238.

3. West, H.W.H "Productivity in Brickmaking in Europe and U.S.A." XIth International Ceramic Congress, Madrid, 1968.

4. West, H.W.H. (1968) "The American Brick Industry" British Ceramic Society, Stoke-on-Trent.

5. Siddiqui, M.A. (1958) "Brickmaking in Pakistan" British Clayworker, 66, 382-387.

6. West, H.W.H. (1970) "The H-G Plank - A Storey Height Unit". Proceedings, Second International Brick Masonry Conference 1970 under publication.

7. British Standard 3921:Part 2:1969 "Bricks and Blocks of Fired Brickearth Clay or Shale, Part 2, Metric Units." British Standards Institution, London.

8. Keeling, P.S. (1963) "The Geology and Mineralogy of Brick Clays" Brick Development Association, London.

9. Clews, F.H. (1969) Heavy Clay Technology, 2nd Ed. British Ceramic Research Association, Academic Press, London.

10. Bennett, H, and Hawley, W.G. (1965) "Methods of Silicate Analysis" 2nd. Ed. Academic Press, London for British Ceramic Research Association

11. Anon (1970) "Standards, Codes and Approvals: their Role in Building Regulation in Europe" B.R.S. News, 13, Summer, 1970. Building Research Station, Watford.

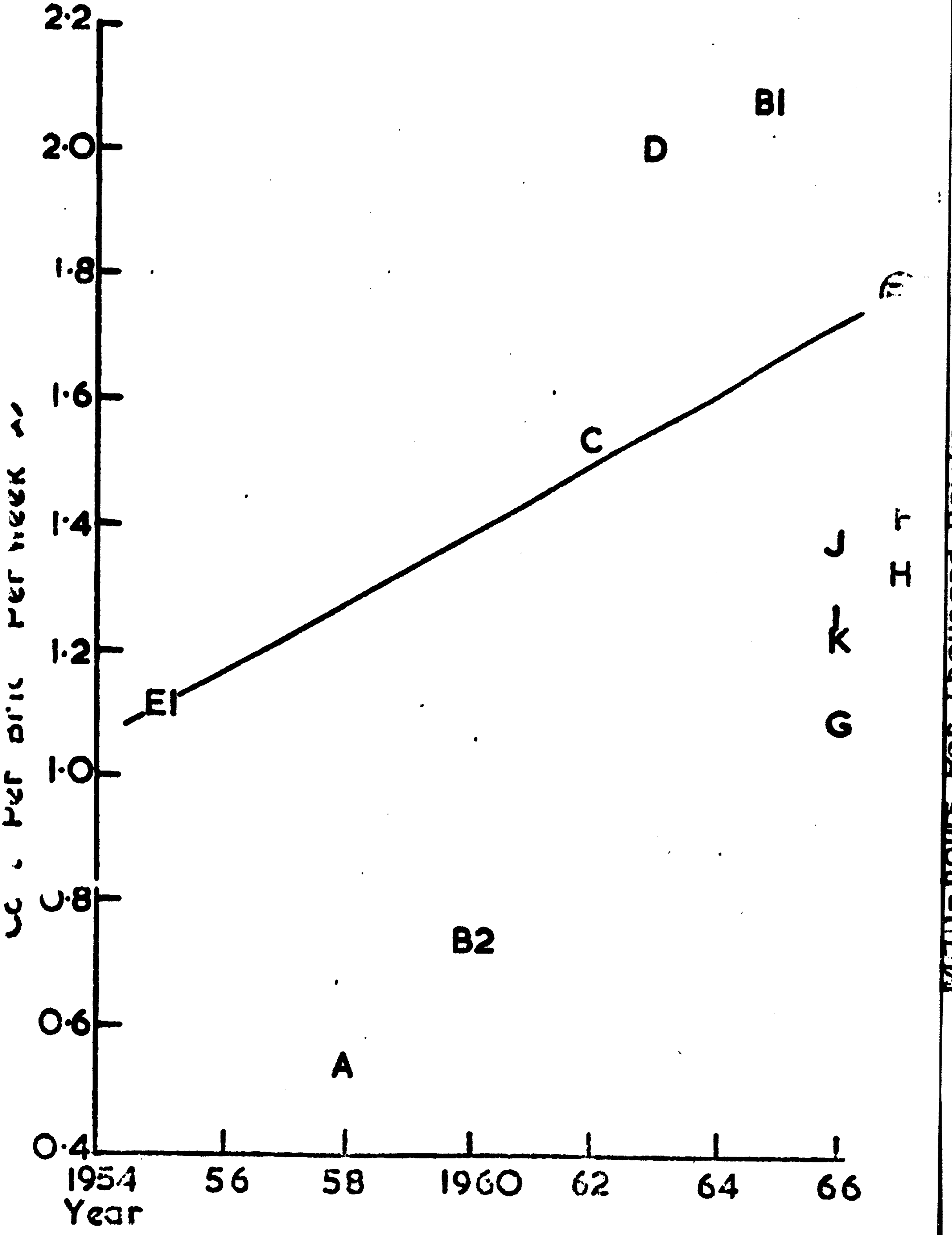
12. British Standard 2900:1970 Metric Units "Recommendations for the Co-ordination of Dimensions in Building Glossary of Terms." British Standards Institution, London.

13. British Standard 1708:1951 "Modular Co-ordination" British Standards Institution, London.

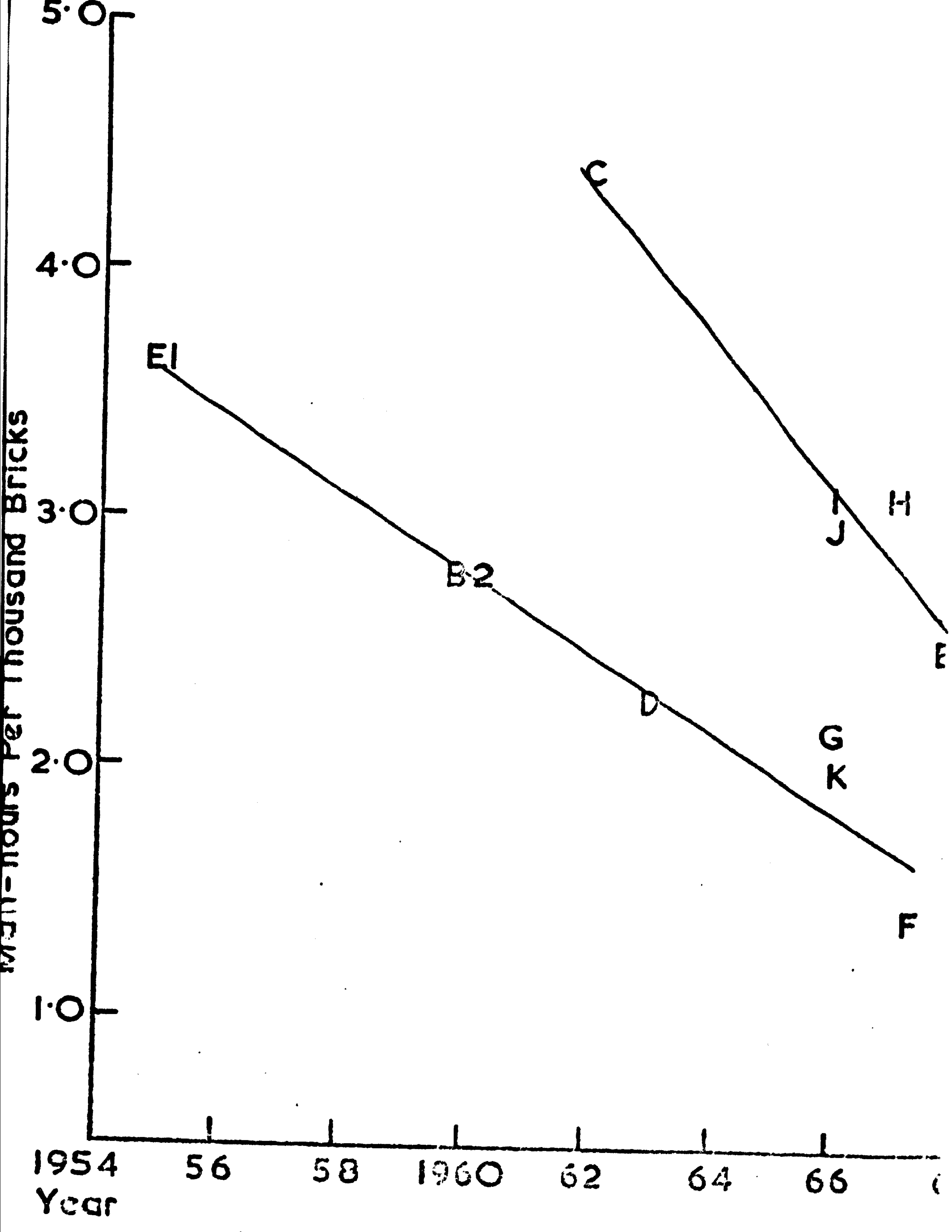
14. ... Thomas, M. (1967) "Modular Co-ordination: Hindsight and Foresight" The Modular Quarterly, 1967, No. 3.

15. British Standard 4011:1966 "Recommendations for the Co-ordination of Dimensions in Building Basic Sizes for Building Components and Assemblies". British Standards Institution, London.

G 2 Capital Cost of New Brick Factories 1955 to 1968



G. 3 . Change in Productive Man-power Requirements
1955 to 1968



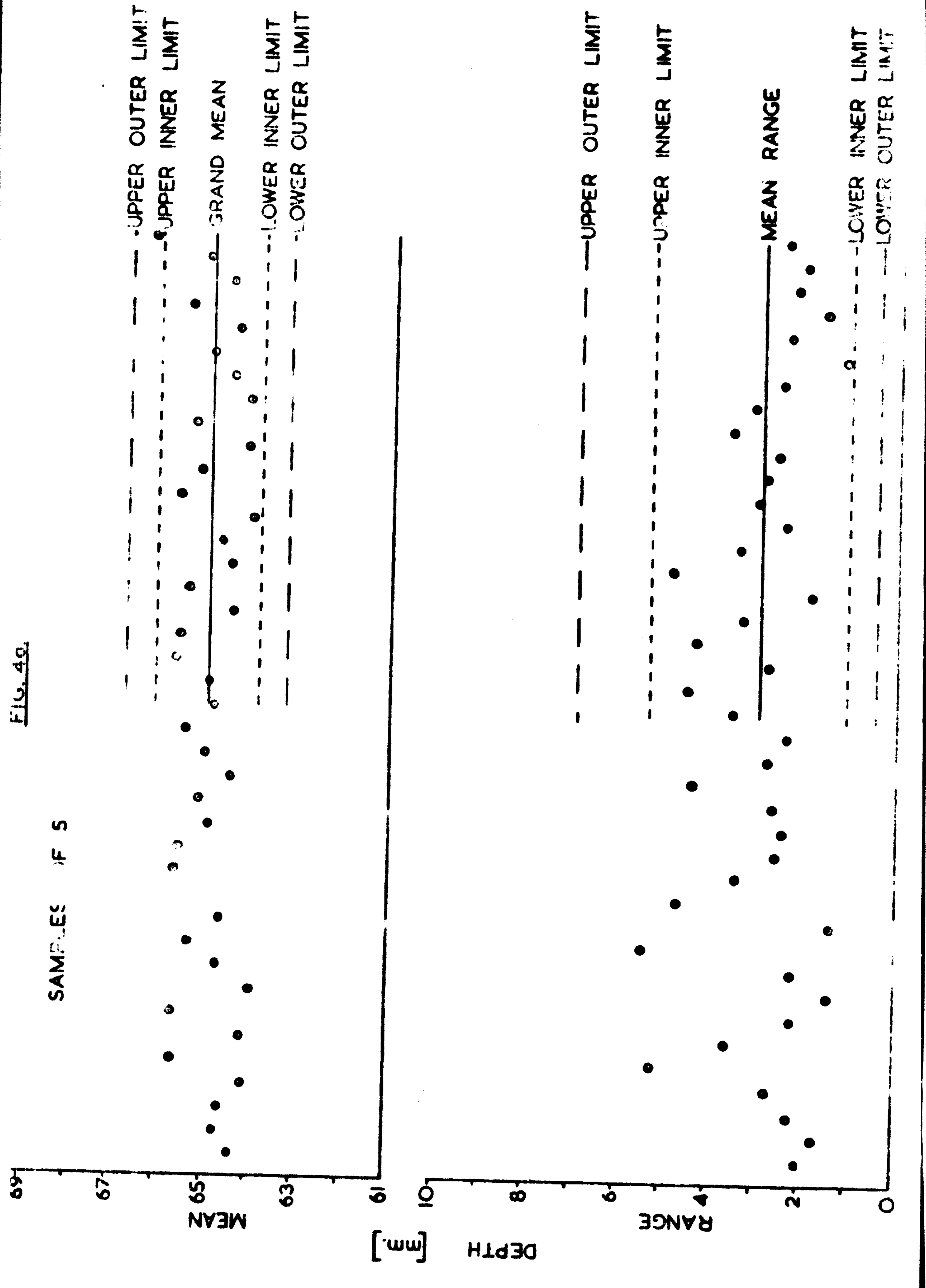


FIG. 4a
SAMP.ES OF 5
UPPER OUTER LIMIT
UPPER INNER LIMIT
GRAND MEAN
LOWER INNER LIMIT
LOWER OUTER LIMIT
MEAN
69
67
65
63
61
DEPTH [mm.]
RANGE
10
8
6
4
2
0
UPPER OUTER LIMIT
UPPER INNER LIMIT
MEAN RANGE
LOWER INNER LIMIT
LOWER OUTER LIMIT

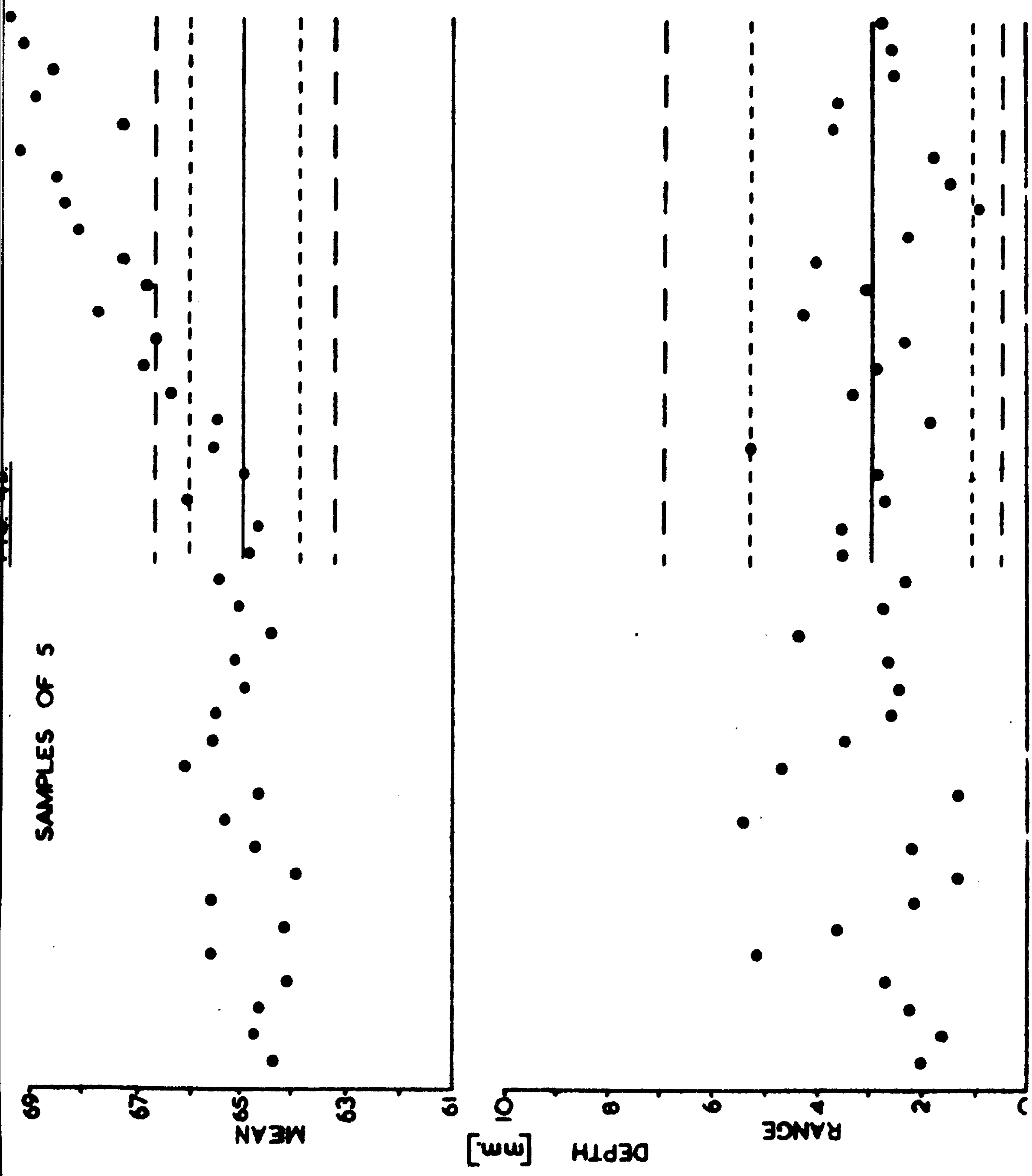
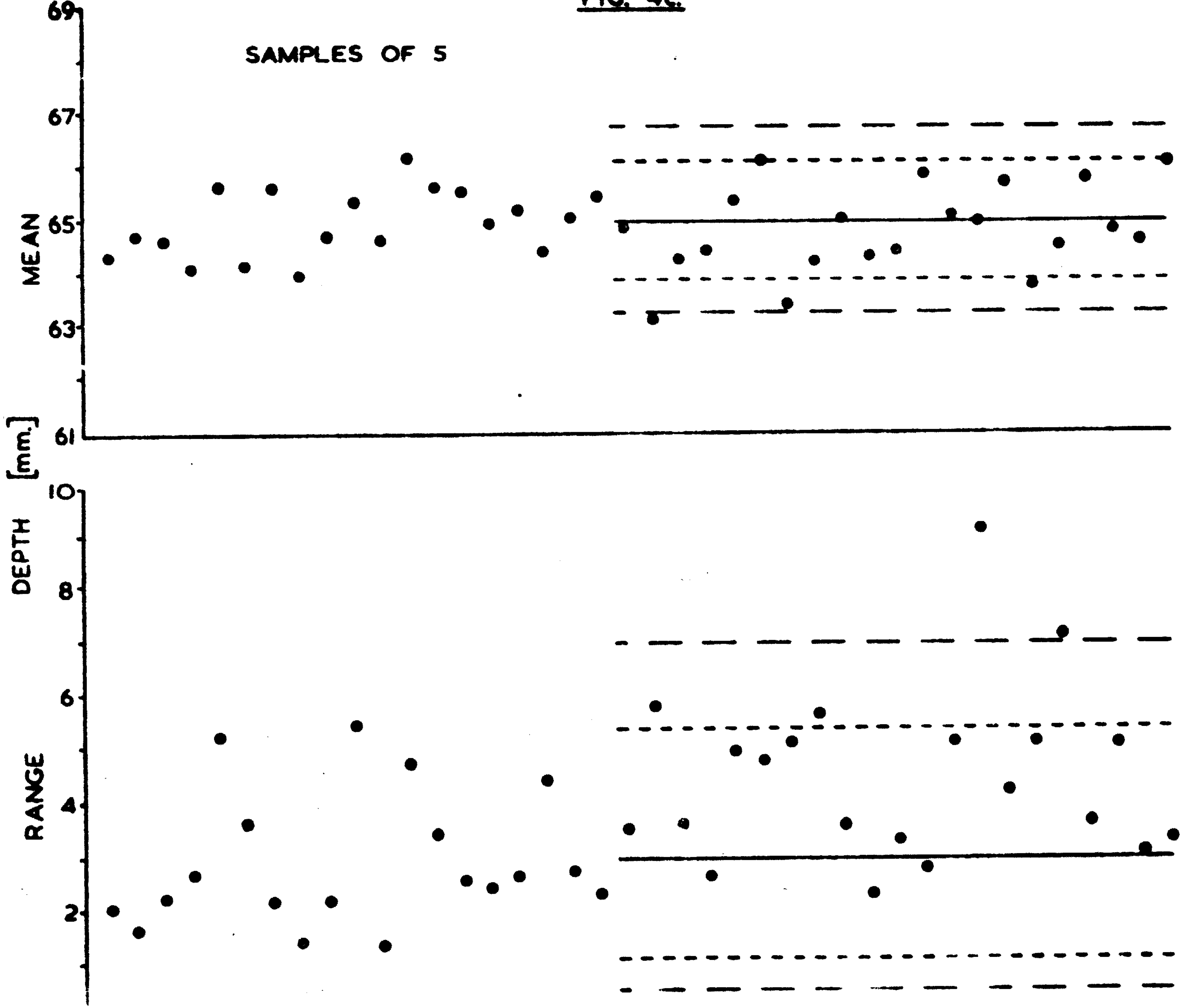

SAMPLES OF 5
MEAN
69
67
65
63
61
DEPTH [mm.]
RANGE
10
8
6
4
2
0

FIG. 4c.



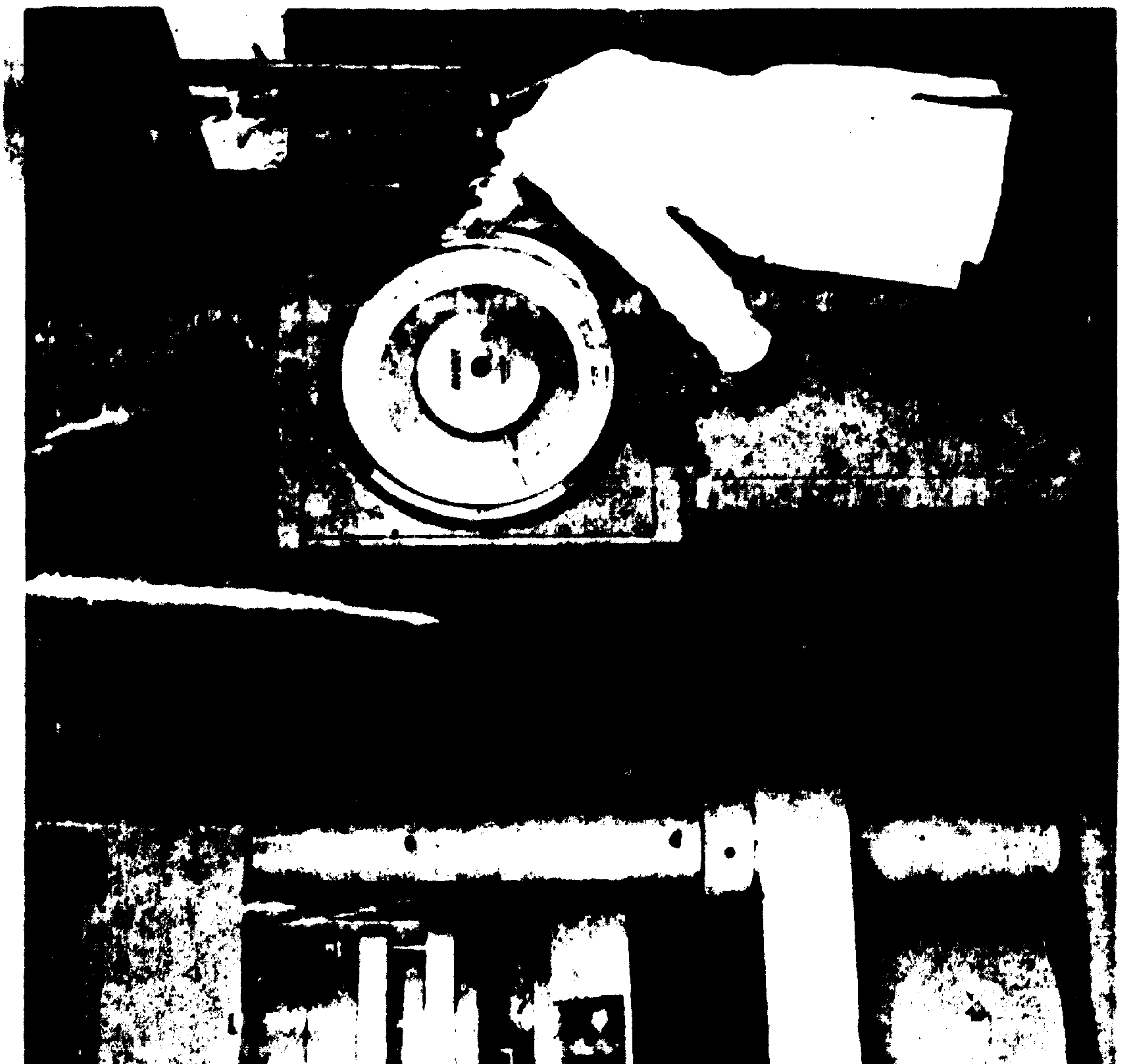
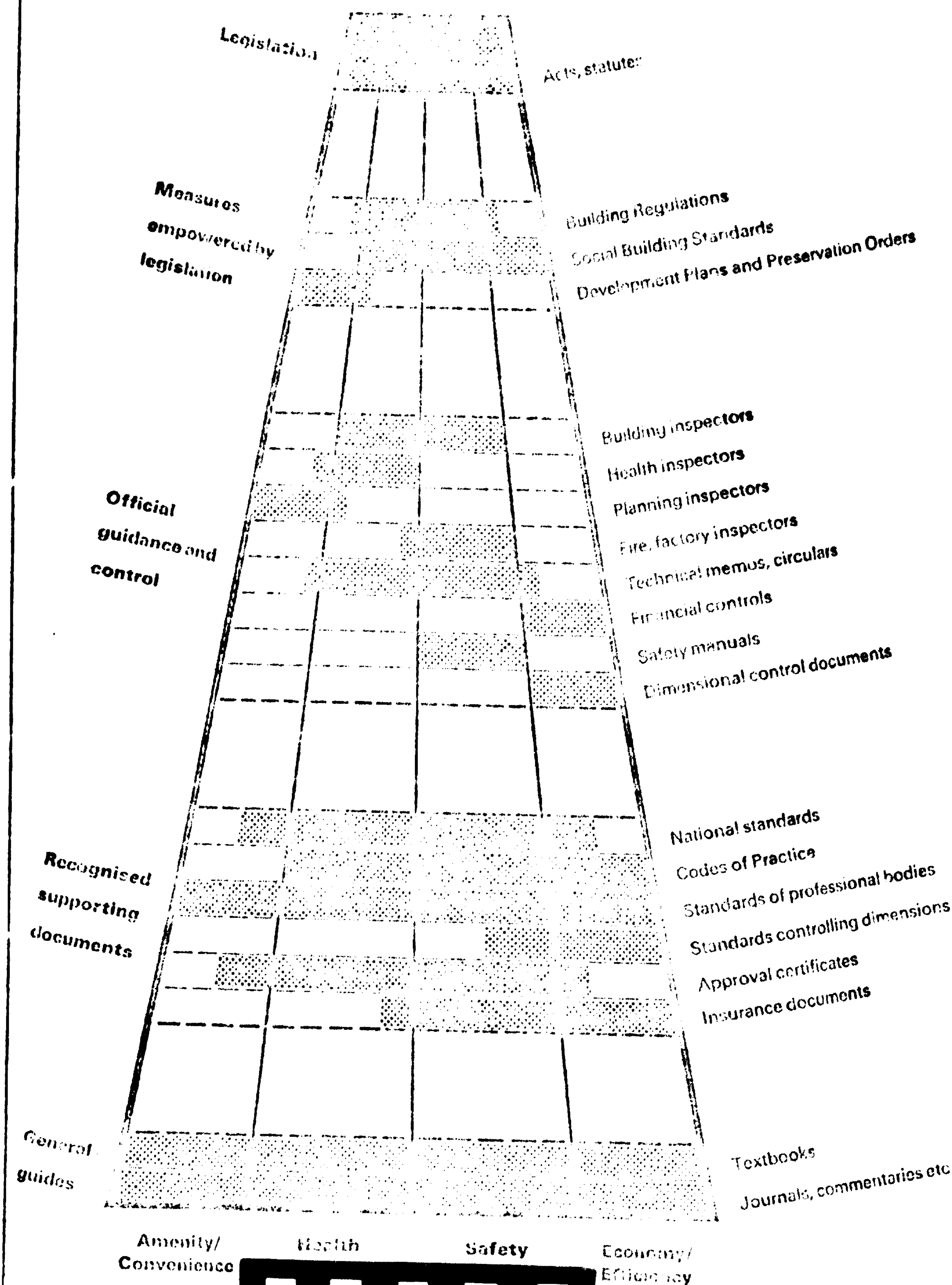


Fig. 5

Some types of control of building and some associated documents.



8. 10. 71