Impact of Wire Rod Rolling Mill Mechanisation on Job Requirements

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THE present investigation has the purpose of identifying the effects of mechanisation on the work force requirements in the steel rolling mill plants.

In order that this study will not add to the confusion or be ascribed an importance beyond its validity, the whole framework of the investigation will be considered before proceeding.

The labour aspects of mechanisation will be investigated only as they are encountered in the restricted area of the steel rod rolling mill plants.

We shall consider what happens to labour requirements under increasing mechanisation only in three plants representing different stages of mechanisation which are characterising the technological development of this kind of rolling plants.[1]

In this way the mechanisation effect alone could be isolated with the consideration of the jobs change through the three rolling plants. It is not correct to assume that this study represents an experience on the impact of automatic machinery on labour outside the restricted area in which the data are collected.

The usefulness of the present examination lies therefore in revealing patterns of experience with automation that may be typical of rod rolling mill development, and in identifying their effect on the work force requirements.

Plants descriptions

The three plants on which this investigation has been carried out are a small hand rolling mill, a semi-automatic rolling mill and a continuous modern rolling mill. These plants have a common production pattern of rods ranging from 8 to 26 mm ϕ.

In order to make easier the understanding of the aspects of mechanisation differentiating these plants, a very short description of the rolling mills and production processes will be given.

Owing to the same type of products, the whole of the activities carried out in these rolling mills can be sub-divided into a number of common basic working processes which differ in detail according to the particular mechanisation level of the mill. This is the reason why the following description will be given pointing out the difference between the plants in each of these common basic processes.

Heating facilities: Both in the hand and in the semi-automatic rolling mill, an overhead crane transfers material into a truck, which is hand-pushed to the furnace charging door. In the continuous rolling mill the charging equipment is more complex. The material is transferred by an overhead crane into a swinging grate conveyor. The billets fall into a roller table and then are conveyed to the furnace charging door.

At the heating furnace the working process has the highest mechanisation standard of the whole hand rolling mill plant, owing to the recent installation of a modern heating furnace. The mechanisation level of a heating furnace depends on the extent of the use of control instruments and of charging-discharging mechanical devices.

Roughing: The three rolling mill plants are extremely different from each other as far as the roughing process is concerned.

The roughing stands in the continuous rolling mill are arranged in a straight line and the rolling process is therefore entirely automatised.

In the hand rolling mill a tilting table conveys the material to a three-high stand, the entering of the bar is ensured by a catcher-man. A delivery tilting table performs an identical function in addition to conveying the bar away from the mill after the final pass.

In the semi-automatic rolling mill there are two three-high roughing adjacent stands, the first similar to the corresponding hand rolling mill stand, the second provided with an automatic spiral repeater.

Intermediate rolling: In the hand rolling mill there is a single three-high intermediate stand, and the bar is manually entered in the roll grooves. In the semi-automatic plant there are four intermediate stands; the first two are arranged in a straight line, the others are adjacent to the second and provided with repeaters. In the continuous rolling mill the intermediate stands are arranged in a straight line.

Finishing rolling: In the hand rolling mill there is a finishing train. Mills in train have the rolls of separate stands in the same line, the rolls of one mill being driven from the end of the rolls of an adjacent stand. The tongsmen catch the bar in the back or in the front end as it emerges from the rolls.

When the bars are relatively flexible, they are caught by the tongsmen in the front end as they emerge from the rolls and pulled around in a half circle and entered into the next pass.

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That is to say the catchers start the piece through each of the passes, before the piece itself is through the preceding one, thus forming a loop.

In the semi-automatic rolling mill the stands in the finishing line are provided with repeaters, devised to conduct bars from one stand to another. Only at the finishing stand the entering of the bars is made by the catcher.

In the continuous rolling mill the finishing rolling operation is performed by several stands of rolls arranged in a straight line (in tandem), with each succeeding stand operating with roll surface speed greater than that of its predecessor. Reduction takes place in several passes at the same time until the piece emerges as a finished rod from the last roll stand.

Straight rod cooling and shipping : In the continuous and in the semi-automatic rolling mills the finished rods flow into a roller table and are delivered to the shear. The shear cuts automatically. After leaving the shear the rods are automatically delivered to cooling bed, where they are cooled before shipping.

In the hand rolling mill all these operations are performed manually by workers.

Coils reeling and shipping : Each plant is provided with reeling facilities adjusted to the finishing output of the mill.

In the hand rolling mill the rod is manually inserted into the reel. The coils are removed and transferred by an overhead crane.

The continuous rolling mill is provided with automatic reels. The coils are delivered to a hook conveyor and carried to the automatic balance for weighing. The coils are finally hooked by an overhead crane provided with tongs.

In the semi-automatic rolling mill the reeling facilities are at the same mechanisation level as in the continuous mill.

The handling of the coils is performed in a similar way as in the hand rolling plant.

Levels of mechanisation

In order to give evidence of the different levels of mechanisation involved in each of the described rolling mill plants, the concept of the mechanisation profile has been used[2].

The introduction of this concept has been possible after having carried out a very deep production process analysis. The actions to which the material is subjected have been considered as well as each action that must be contributed to the processing sequence.

The sequence of events of the manufacturing process has been sub-divided into a chain of operations, and for each operation attention has been given to type and nature of mechanical accomplishment[3].

The concept of level of mechanical accomplishment has been adopted and an additional analysis has been carried out on the way the machinery supplement man's muscles, mental process, judgment and degree of control.

The mechanisation levels are arranged as shown in Fig. 1.

A graphical representation of this analysis can be obtained if the levels of each operation are plotted against the chain of operations required by the accomplishment of manufacturing process.

Such a chart is called mechanisation profile, and portrays roughly the character of mechanisation of each rolling process.

In the other common basic working processes the alternative production systems profiles reveal differences not so essential as in the proper rolling processes.

Job analysis

In order to appreciate the impact of automation on labour, let us consider its effects on work force job requirements.

The manufacturing process is carried out in each rolling mill by a workman set variable with the type of product. That is why the maning of each rolling mill is given for the 8 mm rod production (Table I, II, III). The list of the jobs enables to consider their distribution in each common basic working process, in which the manufacturing in the rolling mills can be distinguished.

At the higher mechanisation levels the total number of job places is smaller, and the quality of work is also changing. The comparison between the job places in a working process and the corresponding ones in another plant shows clearly

INITIATING CONTROL SOURCE	TYPE OF MACHINE RESPONSE	POWER SOURCE	LEVEL NUMBER	LEVEL OF MECHANIZATION
FROM A VARIABLE IN THE ENVIRONMENT	RESPONDS WITH ACTION	MECHANICAL (NONMANUAL)	10	OTHER LEVELS HIGHER THAN 9 LEVEL
	RESPONDS WITH SIGNAL		9	MEASURES CHARACTERISTIC OF WORK
FROM A CONTROL MECHANISM THAT DIRECTS A PREDETERMINED PATTERN OF ACTION	FIXED WITHIN THE MACHINE		8	ACTUATED BY INTRODUCTION OF WORK PIECE OR MATERIAL
			7	POWER TOOL SYSTEM, REMOTE CONTROLLED
			6	POWER TOOL, PROGRAM CONTROL (SEQUENCE OF FIXED FUNCTIONS)
			5	POWER TOOL, FIXED CYCLE (SINGLE FUNCTION)
FROM MAN	VARIABLE		4	POWER TOOL, HAND CONTROL
			3	POWERED HAND CONTROL
		MANUAL	2	HAND TOOL
			1	HAND

Fig. 1.

TABLE I

Hand rod mill.

WORKING PROCESSES INVOLVED	No.	JOBS	JOB PLACES	F_1	F_2	F_3
Feeding	1.1	Feeder	1	–0.742	–0.522	–0.464
Heating	1.2	Heater	1	1.819	–1.077	–2.918
	1.3	Pusher	1	–0.392	–0.467	1.510
	1.4	Discharger	1	0.762	–0.854	0.767
Roughing Mill	1.5	Rougher	2	1.554	–1.033	0.802
	1.6	Roughing Catcher	5	0.242	1.932	–0.530
Intermediate Mill	1.6	Roughing Catcher	2	0.242	1.932	–0.530
	1.7	Shearman	2	–0.260	–0.566	–0.270
	1.8	Hooker	3	–0.360	0.459	0.033
	1.9	Hooker	3	–0.277	0.623	0.937
Finishing Mill	1.10	1st Finishing Catcher	3	0.458	1.902	0.227
	1.11	2nd Finisging Catcher	4	0.240	1.868	0.775
	1.12	1st Roller Helper	1	0.947	1.681	–0.267
	1.13	2nd Roller Helper	1	0.566	1.669	0.272
	1.14	Looper	4	–0.962	–0.312	–0.608
	—		-	—	—	—
Rod Bundling and Shipping	1.15	Rod Inspector	2	0.998	–1.120	–2.968
	1.16	Shearman	1	–0.048	–0.561	0.320
	1.17	Rod Table Worker	2	–1.175	–0.122	–0.941
	1.18	Shearman Helper	1	–0.814	–0.450	–1 297
	1.19	Rod Hooker	3	–1.184	0.314	–1.028

TABLE II

Semi-automatic rod mill.

WORKING PROCESSES INVOLVED	No.	JOBS	JOB PLACES	F_1	F_2	F_3
Feeding	2.1	Feeder	1	–0.716	–0.102	–0.523
	2.2	Craneman	1	0.160	–1.428	1.556
Heating	2.3	Heater	1	2.745	0.297	–4.118
	2.4	Billett Pusher	1	–0.197	–0.003	–0.776
	2.5	Heater Helper	2	1.468	0.775	–1.114
	2.6	Furnace Worker	2	–0.734	1.136	–0.283
Roughing Mill	2.7	Rougher	1	2.189	–0.714	1.028
	2.8	2nd Rougher	1	1.721	–0.848	2.336
	2.9	Trimmer Shearman	1	–0.095	–0.779	0.331
	2.10	Roughing Catcher	3	–0.576	0.190	0.431
Intermediate Mill	2.11	Shearman	2	0.233	–0.671	0.528
	2.12	Switch Operator	2	0.269	–1.692	0.260
Finishing Mill	2.13	1st Finishing Catcher	4	1.652	2.018	1.382
	2.14	2nd Finishing Catcher	2	0.955	2.112	2.417
	2.15	Roll Shop Craneman	2	0.979	–1.405	1.604
Roughing, Intermediate, Finishing Mill	2.16	Roller	1	2.651	0.102	–0.852
	2.17	Oxicutter	1	–0.045	–0.211	1.097
	2.18	Scrapman	6	–0.914	0.152	0.532
Rod Bundling and Shipping	2.19	Rod Inspector	1	1.050	–1.576	–2.694
	2.20	Shearman	1	0.277	–0.914	1.415
	2.21	Reel operator	1	0.608	–1.609	1.427
	2.22	Rod Table Worker	1	–0.992	–0.047	–0.521
	2.23	Straight Rod Hooker	4	–1.172	0.078	–0.940
	2.24	Coil Hooker	5	–1.172	0.078	–0.940
	2.25	Coil Bander	1	–1.145	–0.263	–1.299

that the total number of job places is decreasing when passing from the hand rolling mill to the continuous rolling mill, as far as the proper rolling processes are concerned.

Each job is characterised by the main task accomplished by the man at work. If one assigns to a job mechanisation level of the operation corresponding to the accomplishment of its main task, it is easy to put the jobs in a cumulative rank list according to mechanisation (Table IV).

The higher the mechanisation ranks of the jobs, the more mechanised the corresponding working processes.

For instance, the only two high ranked jobs of the hand rolling mill are at the heating furnace, where the working process has the highest mechanisation standard of the whole plant.

The remaining part of the jobs in the hand mill are all low ranked. The greatest part of the high ranked jobs is constituted by continuous rolling mill jobs, and the medium ranked ones are semi-automatic rolling mill jobs.

In order to obtain a more realistic idea of the contribution of human work in the different rolling mills, a careful job analysis has been performed. The collected data have been classified, taking into account the twelve characteristics of a job evaluation system used in iron and steel plants.

f_1 = Pre-Employment Training ... Grade A, B, C.
f_2 = Employment Training and Experience ... Grade A, B, C, D, E, F, G, H, I.
f_3 = Mental skill ... Grade A, B, C, D, E.
f_4 = Manual skill ... Grade A, B, C, D.
f_5 = Responsibility for material Grade A, B, C, D, E.
f_6 = Responsibility for tools and equipment ... Grade A, B, C, D, E.
f_7 = Responsibility for operations Grade A, B, C, D, E, F, G, H.
f_8 = Responsibility for safety of others ... Grade A, B, C, D.
f_9 = Mental effort ... Grade A, B, C, D, E.
f_{10} = Physical effort ... Grade A, B, C, D, E.
f_{11} = Surroundings ... Grade A, B, C, D, E, F.
f_{12} = Hazard ... Grade A, B, C, D, E.

A proper definition of these characteristics and of the different grades is provided by the manual of this job evaluation system[4].

Factorial analysis of job characteristics

The mentioned job evaluation manual has been

Table III

Continuous rod mill.

WORKING PROCESSES INVOLVED	No.	JOBS	JOB PLACES	F_1	F_2	F_3
Feeding	3.1	Billett Inspector	1	0.886	-1.547	-1.867
	3.2	Billett Yardman	3	-1.080	0.059	-0.438
	3.3	Billett Charger	1	-0.363	-1.415	0.111
	3.4	Billett Yard Craneman	1	0.081	-1.385	2.177
Heating	3.5	Billett Pusher	1	0.523	-1.540	0.504
	3.6	Heater	1	2.450	-1.048	-3.088
	3.7	Feeder	1	1.097	0.464	0.561
	3.8	Discharger	2	0.514	-1.104	0.417
Roughing Mill	3.9	Rougher	1	1.461	0.237	-1.098
	3.10	Motor Operator	1	2.057	-1.746	0.706
Interm. Mill	3.11	Flying Shearman	1	-0.054	0.792	-0.478
Finishing Mill	3.10	Motor Operator	1	2.057	-1.746	0.706
	3.12	Rod Finisher	2	2.241	0.072	-2.067
Roughing, Intermediate, Finishing Mill	3.13	Scrap Baller	2	0.220	0.021	0.897
	3.14	Cricutter	1	0.047	-0.230	1.599
	3.15	Mill Craneman	2	0.159	-1.421	2.392
Rod Bundling and Shipping	3.16	Rod Inspector	1	0.998	-1.120	-2.968
	3.17	Reel Operator	2	0.524	-1.425	0.777
	3.18	Coil Bander	5	-0.886	0.053	0.059
	3.19	Coil Unloader	3	-0.607	-0.195	0.639
	3.20	Coil Conveyor Worker	2	-0.908	-1.003	-0.484
	3.21	Rod Table Operator	1	0.044	-1.954	0.999
	3.22	Shearman	2	0.133	-0.439	0.639
	3.23	Shearman Helper	3	-0.659	-0.333	1.436
	3.24	Straight Rod Hooker	7	-1.180	-0.087	-0.792
	3.25	Storage Craneman	1	0.154	-1.280	1.121

used as starting point for a quantitative evaluation of the twelve characteristics in the jobs.

Linear correlations of these characteristics f_i ($i=1...12$) have been calculated for the cumulative population of job places in the three rolling mills. The correlation coefficients are presented in Table V.

This correlation matrix has been factored by Centroid Method[5].

Factoring has been stopped after the extraction of the third factor, the residuals being so small to be negligible.

The Centroid analysis has given the loadings shown in columns I, II and III of Table VI. Communality of each characteristic f_i is also reported in column h^2, Table VI.

The communality of a characteristic can be defined as its common factor variance[6]; in other words, that part of the total variance of a characteristic which is attributable to the common factors. As can be seen, the three common factors take out a variance of 8·57 of the total 12, that is the 71%.

The third factor residuals being very small, factor loadings on Table VI and correlation matrix on Table V can be considered as equivalent; very little information is lost passing from the correlation matrix to the factor loadings.

In order to visualise the intercorrelation of the twelve characteristics f_i, a vector model is adopted[7]. The correlation matrix on Table V can be represented by a set of vectors, whose scalar products are the correlation coefficients. In Fig. 2 we have such a model, in which the characteristic vectors are represented by long pins, stuck into a central sphere. Each pin represents a characteristic vector. The correlation

Fig. 2.

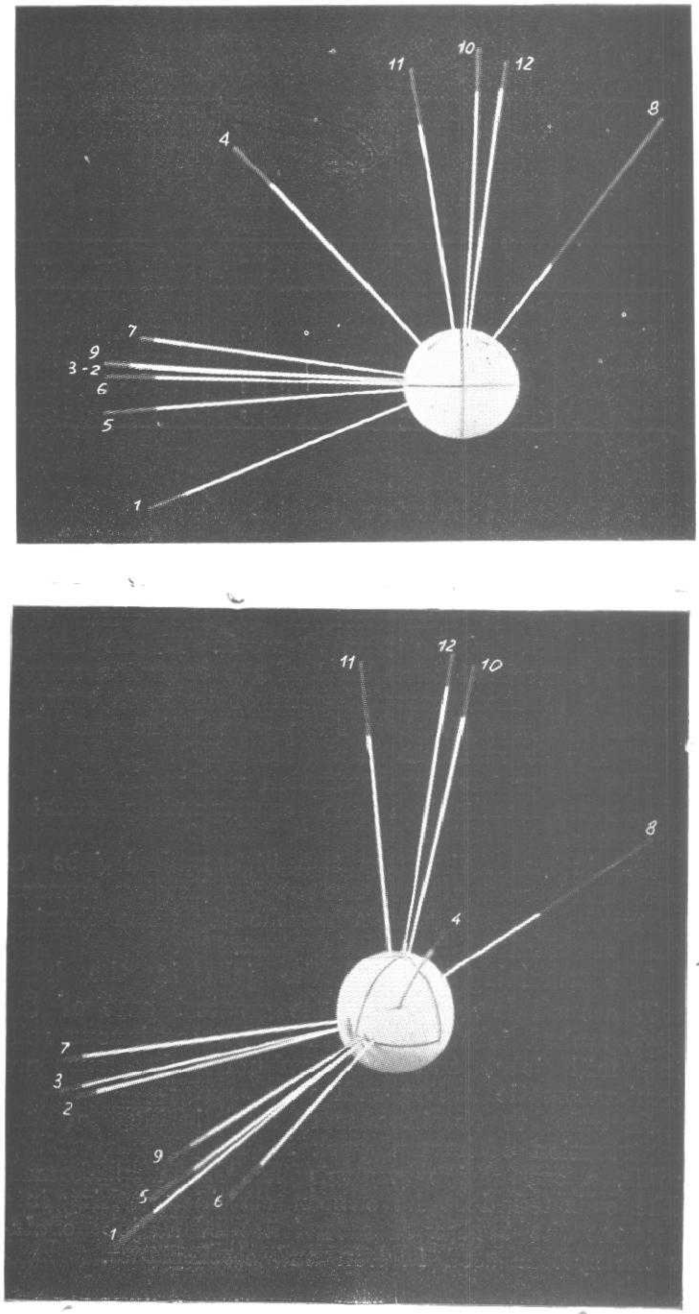


TABLE IV

Mechanisation scale of job places.

Mechanization level	Hand Rod Mill	Job places	Semi-Automatic Rod Mill	Job places	Continuous Rod Mill	Job places
10	Heater	1			Heater	1
9						
8					Rod Table Operator	1
7	Discharger	1				
6					Motor Operator	2
					Rod Finisher	2
					Rougher	1
			Roller	1		
6-5					Reel Operator	2
			Reel Operator	1		
5					Billett Pusher	1
					Flying Shearman	1
4	Rougher	2	Rougher	1	Discharger	2
			2nd Rougher	1	Billett Charger	1
			Craneman	1	Storage Craneman	1
			Roll Shop Craneman	2	Mill Craneman	2
			Heater	1	Billett Yard Craneman	1
			Heater Helper	2	Feeder	1
			Shearman	2		
	Shearman	2	Trimmer Shearman	1		
			Shearman	1	Shearman	2
			Switch Operator	2		
	Shearman	1				
3			Oxicutter	1	Oxicutter	1
					Scrap Baller	2
3-2					Coil Unloader	5
					Shearman Helper	3
2			Feeder	1	Coil Conveyor Worker	2
			Billett Pusher	1		
	Pusher	1	Rod Table Worker	1		
	Hooker	3				
	Hooker	3				
	Roughing Catcher	7	Roughing Catcher	3		
	1st Roller Helper	1	1st Finishing Catcher	4		
	2nd Roller Helper	1	2nd Finishing Catcher	2		
	1st Finishing Catcher	3				
	2nd Finishing Catcher	4	Furnace Worker	2		
	Looper	4	Scrapman	6		
	Shearman Helper	1				
1	Feeder	1	Straight Rod Hooker	4	Straight Rod Hooker	7
	Rod Hooker	3	Coil Hooker	5	Billett Yardman	3
	Rod Table Worker	2	Coil Bander	1	Coil Bander	5

TABLE V

Correlation matrix.

f_i	1	2	3	4	5	6	7	8	9	10	11	12
1		.799	.748	.147	.675	.624	.650	−.127	.685	−.305	−.232	−.355
2	.799		.858	.405	.738	.659	.833	−.122	.796	−.017	.075	−.037
3	.748	.858		.393	.731	.678	.866	−.154	.793	−.035	.140	−.101
4	.147	.405	.393		.413	.557	.475	.104	.565	.463	.446	.332
5	.675	.738	.731	.413		.601	.674	−.162	.746	−.136	−.015	−.085
6	.624	.659	.678	.557	.601		.711	−.011	.675	.047	.051	−.154
7	.650	.833	.866	.475	.674	.711		−.255	.784	.050	.221	−.056
8	−.127	−.122	−.154	.104	−.162	−.011	−.255		−.141	.346	.032	.258
9	.685	.796	.793	.565	.746	.675	.784	−.141		−.077	.169	−.055
10	−.305	−.017	−.035	.463	−.136	.047	.050	.346	−.077		.570	.764
11	−.232	.075	.140	.446	−.015	.051	.221	.032	.169	.570		.697
12	−.355	−.037	−.101	.332	−.085	−.154	−.056	.258	−.055	.764	.697	

TABLE VI

Factor matrices.

f_i	Unrotated Loadings			Rotated Loadings			Communality h^2	Specific Variance s^2	Total σ^2
	I	II	III	F_1	F_2	F_3			
1	.854	−.040	−.072	.795	−.310	−.070	.733	.267	1
2	.841	.337	−.204	.915	.065	−.147	.863	.137	1
3	.846	.335	−.210	.920	.063	−.152	.873	.127	1
4	.302	.708	.329	.490	.516	.439	.699	.301	1
5	.796	.231	.067	.820	−.058	.112	.688	.312	1
6	.734	.335	.224	.790	.035	.278	.703	.297	1
7	.820	.401	−.251	.920	.138	−.182	.899	.101	1
8	−.257	.219	.185	−.180	.270	.214	.151	.849	1
9	.826	.376	.111	.895	.060	.174	.835	.165	1
10	−.341	.779	−.046	−.060	.849	.070	.729	.271	1
11	−.159	.719	−.224	.100	.759	−.113	.599	.401	1
12	−.416	.767	−.191	−.130	.884	−.070	.803	.197	1
					Totals		8.575	3.425	12

between any two characteristics is equal to $h_i h_j \cos\phi_{ij}$, where h are the lengths of the white zone of the pins, and ϕ_{ij} is the angle between them.

If two vectors in the model make a right angle, the corresponding correlation coefficient is zero. The scalar product of a vector with itself is h_i^2, the angle ϕ_{ii} being zero, and $\cos\phi_{ii}$ being one. Hence the square of the length of a vector f_i is equal to its communality h_i^2.

From such a model, we should be able to reconstruct the correlation matrix, from which the model was built. In other words, they give the same information. Fig. 2 gives two different views of the same model.

It is to be noted that the axes we could get by centroid process have been rotated, retaining ortogonality[8]. This new reference frame has been chosen so that:

one of the axes F_1 passes through the centroid of cluster of vectors f_1, f_2, f_3, f_5, f_6, f_7, f_9 (forming the more compact and numerous group in the structure, as may be seen).

plane F_1 F_2 contains the centroid of characteristics f_{12} and f_{10}.

Rotated factor loadings are shown in Table VI, column F_1, F_2, F_3.

Some interesting remarks can be made on the inter-correlations of the twelve characteristics f_i, that can be obtained from the values shown in Table VI, or even directly from the correlation matrix (Table V).

The evidence of such remarks can be visualised by the model shown in Fig. 2.

These remarks can be summarised as follows:

(*a*) The vector configuration of Fig. 2 shows two clusters.

The first one is formed by vectors:

f_1 (Pre-employment training)
f_2 (Employment training and experience)
f_3 (Mental skill)
f_5 (Responsibility for material)
f_6 (Responsibility for tools and equipment)
f_7 (Responsibility for operations)
f_9 (Mental effort)

The second one is formed by vectors:

f_{10} (Physical effort)
f_{11} (Surroundings)
f_{12} (Hazard)

(*b*) The two clusters make nearly a right angle.

These two facts are also made evident by inspecting correlation matrix: the characteristics within a cluster have high correlations between themselves, while the correlations between pairs of characteristics from different clusters are very low (near zero).

The reference frame has been chosen so that vectors of the first group are clustered round axis F_1, and vectors of the second group are clustered round axis F_2.

(*c*) The vector f_4 (Manual skill) is the only one showing an appreciable component of its variance due to the axis F_3, but more than 50% of its total variance is due to factors F_1 and F_2.

(*d*) Vector f_8 (Responsibility for safety of others) has a very low communality; its position in the configuration is not of great interest.

From the above considerations, one can try to find out an interpretation of the reference factors.

Factor F_1 is strictly involved in characteristics f_5 (Responsibility for material), f_6 (Responsibility for tools and equipment), f_7 (Responsibility for operations), i.e. characteristics concerning job responsibilities. But, on the other hand, communality of characteristics f_1 (Pre-employment training), f_3 (Mental skill) and f_9 (Mental effort), namely characteristics concerning mental requirements for job performance, are almost entirely due to the same factor.

Hence it occurs reasonable to consider F_1 as a "Responsibility factor", or also as a "Mental requirement factor": each of these definitions implies the other, the two groups of characteristics being strictly intercorrelated.

The seventh factor associated with F_1 is f_2 (Employment training and experience).

Characteristic vectors f_{10} (Physical effort), f_{12} (Hazard) and f_{11} (Sourroundings) show the highest saturation on factor F_2; it stands to reason to consider such factor as a "Physical requirement factor."

The interpretation of factor F_3 is more doubtful.

It contributes to explain the part of f_4 (Manual skill) communality, which is not explained by factors F_1 and F_2.

From the point of view of information concerning the total structure, this factor makes a contribution far less important than the others.

The regression equations for estimating the three common factors have been found using Bartlett's method.[9]

Values of $\angle F_{1p}$, and $\angle F_{2p}$ and $\angle F_{3p}$ have been calculated for each job p and are reported in Table I, column F_1, F_2, F_3.

Conclusions

In Table VII the 140 job places of the three rolling mills are arranged in a decreasing order, from the highest to the lowest, in accordance with factor F_1. Values of F_2 and F_3 are also reported.

From the ranking of the jobs according to F_1 it is possible to evaluate the content of responsibility requirements of each job, and accordingly to compare them.

The data are arranged into the eight histograms of Fig. 3, representing frequency distribution of F_1 and F_2.

Fig. 3.

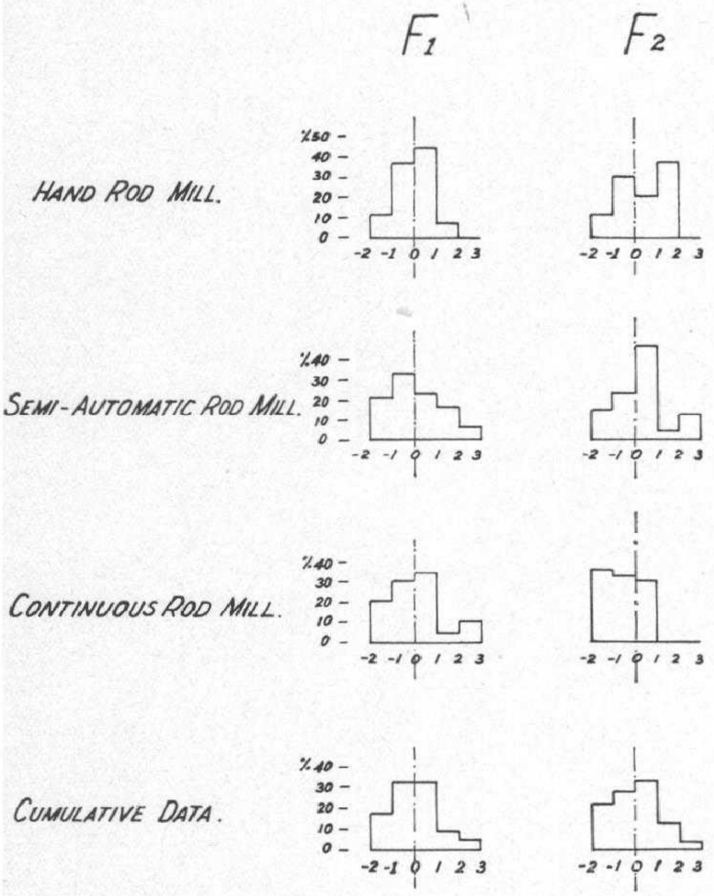


TABLE VII

Classification according to F_1 value.

Reference Number			JOBS	JOB PLACES	F_1	F_2	F_3
Hand R.M.	S.A. R.M.	Cont. R.M.					
	2.3		Heater	1	2.745	0.297	-4.118
	2.16		Roller	1	2.651	0.102	-0.852
		3.6	Heater	1	2.450	-1.048	-3.088
		3.12	Rod Finisher	2	2.241	0.072	-2.067
	2.7		Rougher	1	2.189	-0.714	1.028
		3.10	Motor Operator	2	2.057	-1.746	0.706
1.2			Heater	1	1.819	-1.077	-2.918
	2.8		2^{nd} Rougher	1	1.721	-0.848	2.336
	2.13		1^{st} Finishing Catcher	4	1.652	2.018	1.382
1.5			Rougher	2	1.554	-1.033	0.802
	2.5		Heater Helper	2	1.468	0.775	-1.114
		3.9	Rougher	1	1.461	0.237	-1.098
		3.7	Feeder	1	1.097	0.464	0.561
	2.19		Rod Inspector	1	1.050	-1.576	-2.694
1.15			Rod Inspector	2	0.998	-1.120	-2.968
		3.16	Rod Inspector	1	0.998	-1.120	-2.968
	2.15		Roll Shop Craneman	2	0.979	-1.405	1.604
	2.14		2nd Finishing Catcher	2	0.955	2.112	2.417
1.12			1st Roller Helper	1	0.947	1.681	-.267
		3.1	Billet Inspector	1	0.886	-1.547	-1.867
1.4			Discharger	1	0.762	-0.854	0.767
	2.21		Reel Operator	1	0.608	-1.609	1.427
1.13			2nd Roller Helper	1	0.566	1.669	0.272
		3.17	Reel Operator	2	0.524	-1.425	0.777
		3.5	Billet Pusher	1	0.523	-1.540	0.504
		3.8	Discharger	2	0.514	-1.104	0.417
1.10			1st Finishing Catcher	3	0.458	1.902	0.227
	2.20		Shearman	1	0.277	-0.914	1.415
	2.12		Switch operator	2	0.269	-1.692	0.260
1.6			Roughing Catcher	7	0.242	1.932	-0.530
1.11			2^{nd} Finishing Catcher	4	0.240	1.868	0.775
	2.11		Shearman	2	0.233	-0.671	0.528
		3.13	Scrap Baller	2	0.220	0.021	0.897
	2.2		Craneman	1	0.160	-1.428	1.556
		3.15	Mill Craneman	2	0.159	-1.421	2.392
		3.25	Storage Craneman	1	0.154	-1.280	1.121
		3.22	Shearman	2	0.133	-0.439	0.639
		3.4	Craneman	1	0.081	-1.385	2.177
		3.14	Oxicutter	1	0.047	-0.230	1.599
		3.21	Rod Table Operator	1	0.044	-1.954	0.999
	2.17		Oxicutter	1	-0.045	-0.211	1.097
1.16			Shearman	1	-0.048	-0.561	0.320
		3.11	Flying Shearman	1	-0.054	0.792	-0.478
	2.9		Trimmer Shearman	1	-0.095	-0.779	0.331
	2.4		Billett Pusher	1	-0.197	-0.003	-0.776
1.7			Shearman	2	-0.260	-0.566	-0.270
1.9			Hooker	3	-0.277	0.623	0.937
1.8			Hooker	3	-0.360	0.459	0.033
		3.3	Billett Charger	1	-0.363	-1.415	0.111
1.3			Pusher	1	-0.392	-0.467	1.510
	2.10		Roughing Catcher	3	-0.576	0.190	0.431
		3.19	Coil Unloader	3	-0.607	-0.195	0.639
		3.23	Shearman Helper	3	-0.659	-0.333	1.436
	2.1		Feeder	1	-0.716	-0.102	-0.523
	2.6		Furnace Worker	2	-0.734	1.136	-0.283
1.1			Feeder	1	-0.742	-0.522	-0.464
1.18			Shearman Helper	1	-0.814	-0.450	-1.297
		3.18	Coil Bander	5	-0.886	0.053	0.059
		3.20	Coil Conveyor Worker	2	-0.908	-1.003	-0.484
	2.18		Scrapman	6	-0.914	0.152	0.532
1.14			Looper	4	-0.962	-0.312	-0.608
	2.22		Rod Table Worker	1	-0.922	-0.047	-0.521
		3.2	Billett Yardman	3	-1.080	0.059	-0.438
	2.25		Coil Bander	1	-1.145	-0.263	-1.299
	2.23		Straight Rod Hooker	4	-1.172	0.078	-0.940
	2.24		Coil Hooker	5	-1.172	0.078	-0.940
1.17			Rod Table Worker	2	-1.175	-0.122	-0.941
		3.24	Straight Rod Hooker	7	-1.180	-0.087	-0.792
1.19			Rod Hooker	3	-1.184	-0.314	-1.028

In the following table average values of F_1, F_2 for the three rolling mills are shown :

	Hand mill	S.A. mill	Cont. mill
F_1, av.	−0·022	0·071	−0·052
F_2, av.	0·544	0·055	−0·528

The information one can obtain from these histograms is :

—as the automaticity increases, the total number of jobs requiring an average reponsibility level is decreasing. In the meantime the number of jobs at very high and very low responsibility levels is increasing.

—the progressive effect of automation is to relieve the operator of manual effort, therefore the number of jobs with high value of F_2 (Physical effort, Hazards, Surroundings) abruptly declines passing from manual to continuous rolling mill.

The ranking of the jobs according to the value of F_1 and F_2 can be simultaneously taken into consideration, plotting the jobs into the F_1, F_2 plane, as Fig. 4 shows.

In order to understand the distribution of the jobs in this diagram, advantage has been taken from the jobs mechanisation ranking, listed and discussed above.

The highly mechanised jobs correspond generally to points falling into a limited area defined by the *a* zone in the diagram. The line limiting this area has been drawn in order to separate it roughly from the surrounding parts of the plane.

The points representing manual jobs are covering two zones, *c* and *e*, in the diagram.

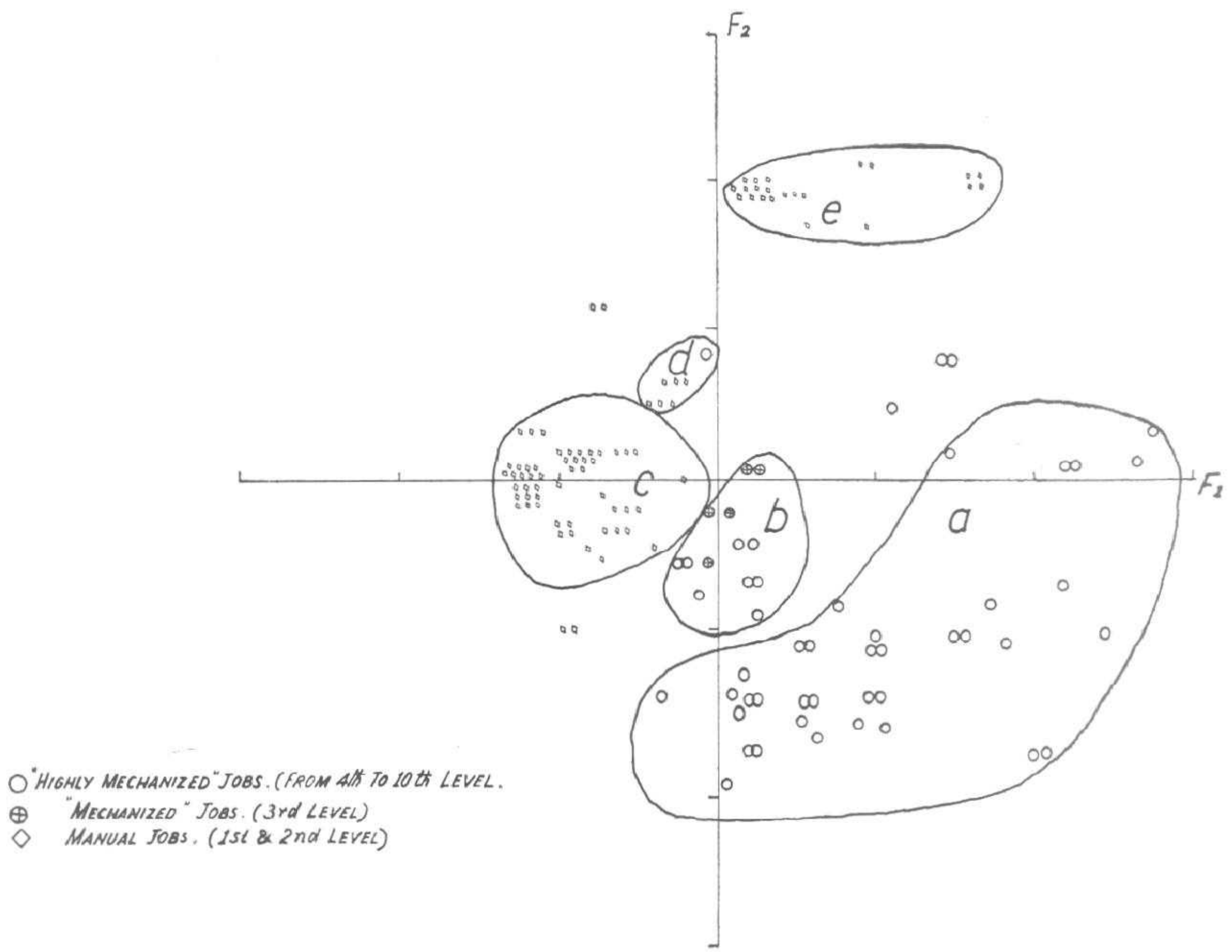
All the jobs at the first mechanisation level are represented by points falling exclusively in the *c* area. The jobs at the second mechanisation level are distributed between the *c* and *e* zones.

The last zone is typical of second mechanisation level jobs requiring special skill (catchers).

Two other zones, *b* and *d*, have also been taken into consideration in order to give explanation to the jobs intermediate among the preceding zones.

The conclusion one can draw from the consideration

Fig. 4.



of the jobs distribution in the F_1 F_2 plane, are summarised by the following conditions :

Unskilled manual jobs	...	*c* zone :	$F_1 < 0$ $F_2 \sim 0$
Skilled manual jobs	...	*e* zone :	$F_1 > 0$ $F_2 \geqslant 0$
Mechanised jobs	...	*a* zone :	$F_1 > 0$ $F_2 \leqslant 0$

The diagrams in Figs. 5, 6, 7, represent the jobs distribution in the F_1 F_2 plane for each rolling mill.

A useful comparison can be made in order to draw a conclusion on the pattern of requirements induced from the mechanisation of the plant into the human contribution to the production process.

Hand rolling mill : the pattern is characterised by the highest percentage of jobs in the *e* zone.

The *d* zone is completely filled up.

A low percentage of jobs is represented by points falling into the *a* and *b* zones.

Semi-automatic rolling mill : the pattern is characterised by the equal distribution of the jobs into the different zones. Only the *d* zone is completely empty.

Continuous rolling mill : the pattern is defined by the *e* zone totally empty, and the highest percentage of jobs falling into the *a* and *c* zones.

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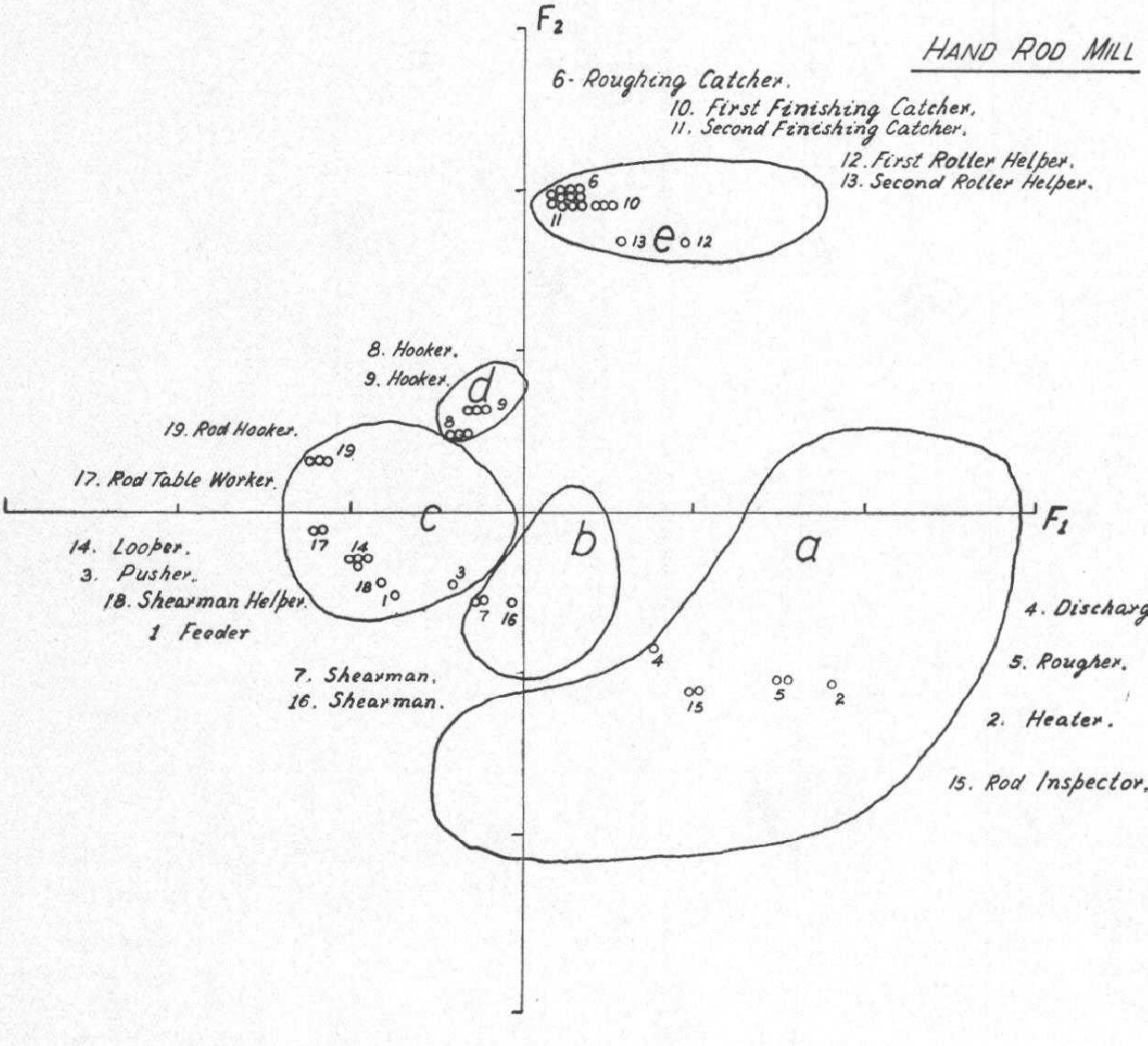
The contribution of Ing. Carlo Riccardi, who

Fig. 5.



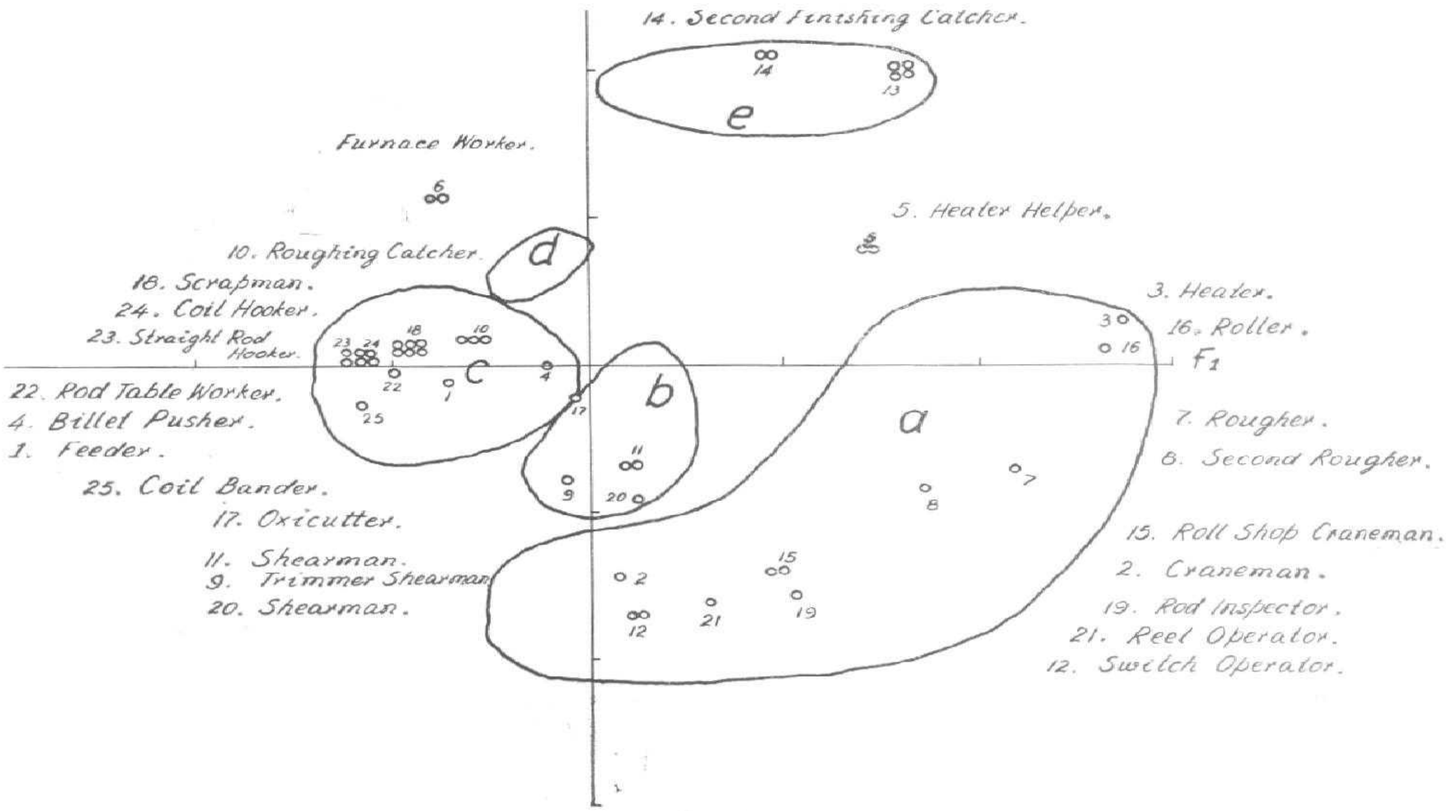
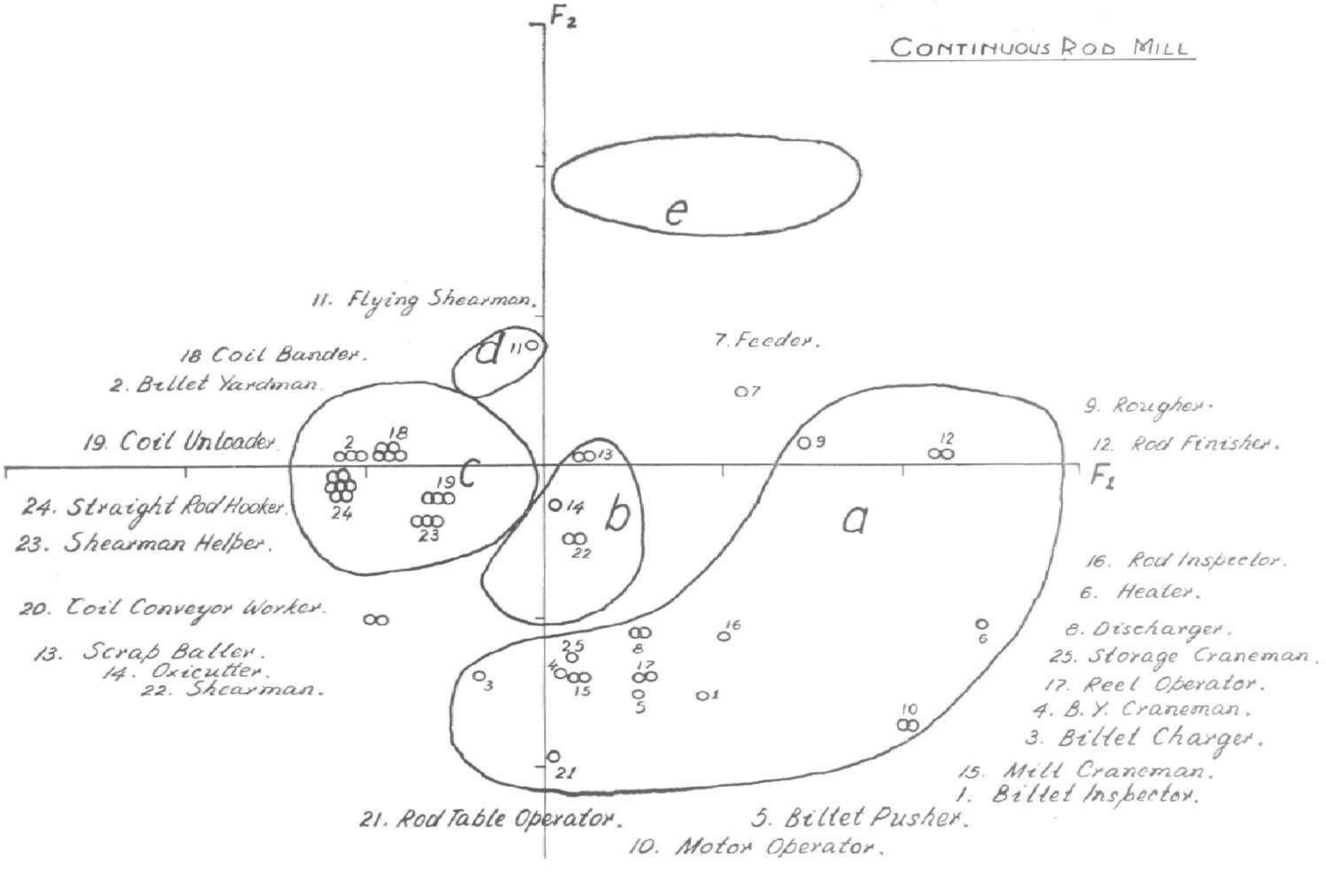

14. Second Finishing Catcher.
e
Furnace Worker.
5. Heater Helper.
10. Roughing Catcher.
d
18. Scrapman.
24. Coil Hooker.
23. Straight Rod Hooker.
3. Heater.
16. Roller.
F_1
c
b
a
22. Rod Table Worker.
4. Billet Pusher.
1. Feeder.
25. Coil Bander.
17. Oxicutter.
7. Rougher.
8. Second Rougher.
11. Shearman.
9. Trimmer Shearman
20. Shearman.
15. Roll Shop Craneman.
2. Craneman.
19. Rod Inspector.
21. Reel Operator.
12. Switch Operator.

Fig. 6.

Fgi· 7.


F_2
CONTINUOUS ROD MILL
e
11. Flying Shearman.
d
18 Coil Bander.
7. Feeder.
2. Billet Yardman.
9. Rougher.
19. Coil Unloader
12. Rod Finisher.
F_1
c
b
a
24. Straight Rod Hooker.
23. Shearman Helper.
16. Rod Inspector.
6. Heater.
20. Coil Conveyor Worker.
8. Discharger.
13. Scrap Baller.
14. Oxicutter.
22. Shearman.
25. Storage Craneman.
17. Reel Operator.
4. B. Y. Craneman.
3. Billet Charger.
15. Mill Craneman.
1. Billet Inspector.
21. Rod Table Operator.
5. Billet Pusher.
10. Motor Operator.

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