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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

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UNIDO/DECHEMA Seminar on Operation, Maintenance, Design and Manufacturing of Chemical Plants and Equipment in Developing Countries

Königstein (Taunus) near Frankfurt/Main
Federal Republic of Germany
25 - 26 June 1970

PROCESS EQUIPMENT INCLUDING MATERIALS OF CONSTRUCTION 1/

by

Luis Michael Fluiters
Director
Canzler Iberica
Madrid, Spain

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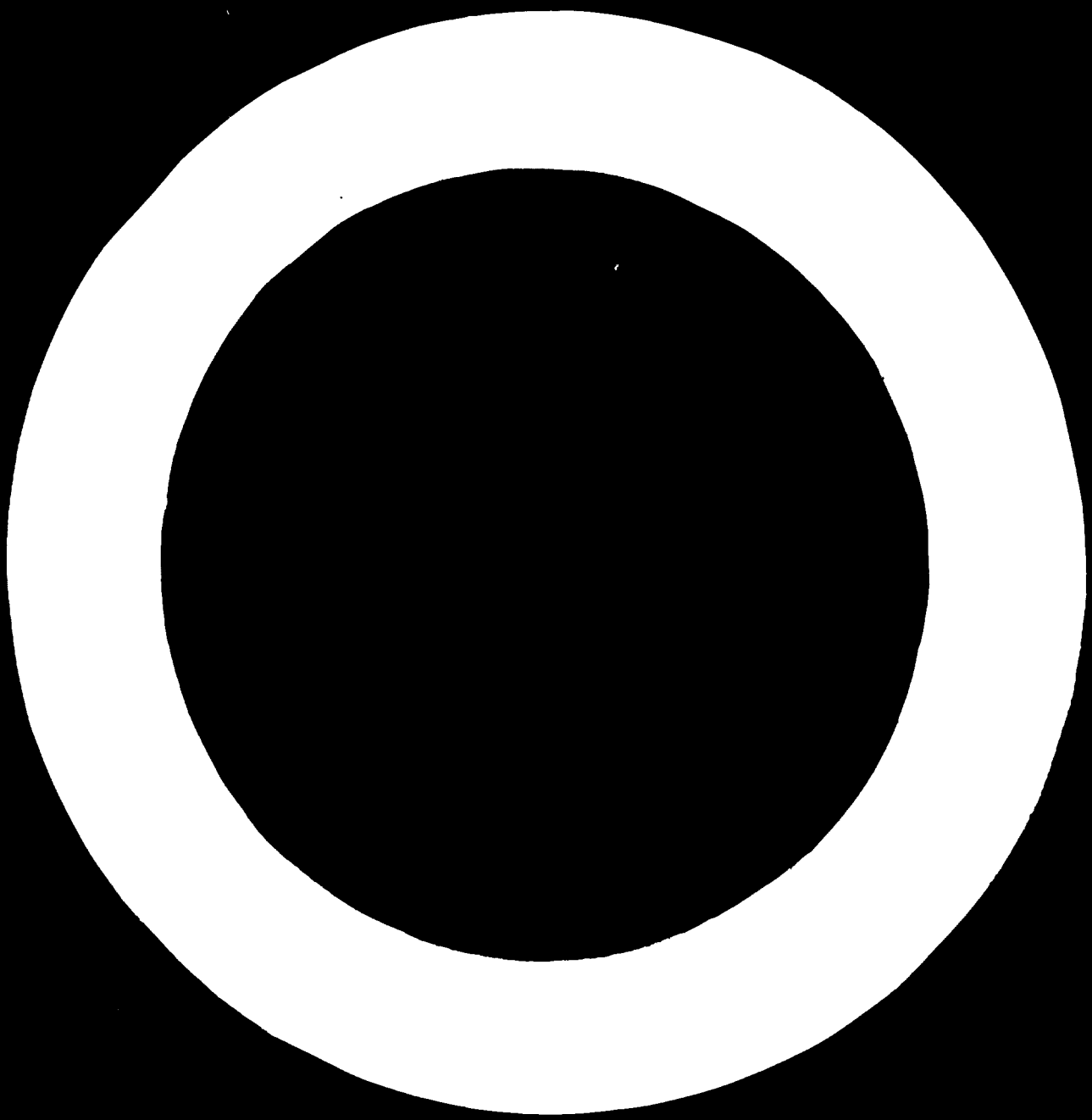
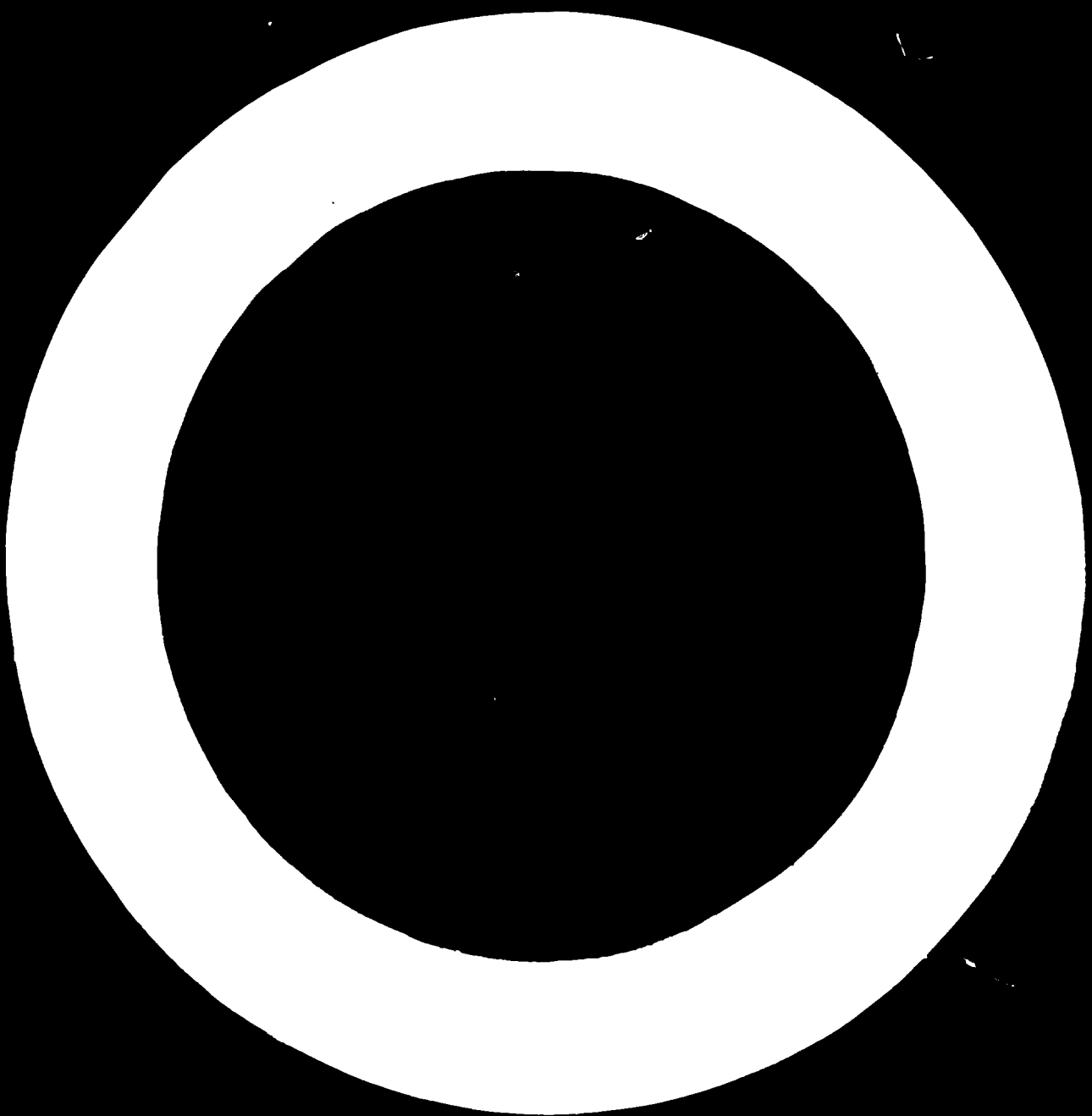




With regard to organisation and technical installations for the mechanical machining, the apparatus manufacturing industry should be on the level of a medium-sized European industry for the construction of apparatus.
A survey concerning organisation and technical installations is given by 2 diagrams.
It is recommendable to fabricate only construction parts of well weldable steel in the opening stage of the manufacture. Material recommendations are given by 4 diagrams. Steel quality and dimensions of the construction parts should be in such a way that an unobjectable welding process is guaranteed as supposition for the seam quality concerning the requirement of security, and that heat treatment can be avoided.
Easily applicable welding processes are to prefer. Recommendations as to procedures and welding material are shown in the diagram.
The welding engineering-equipments should cover first of all current sources (rectifier), oxygen-, acetylene- and argon supply.

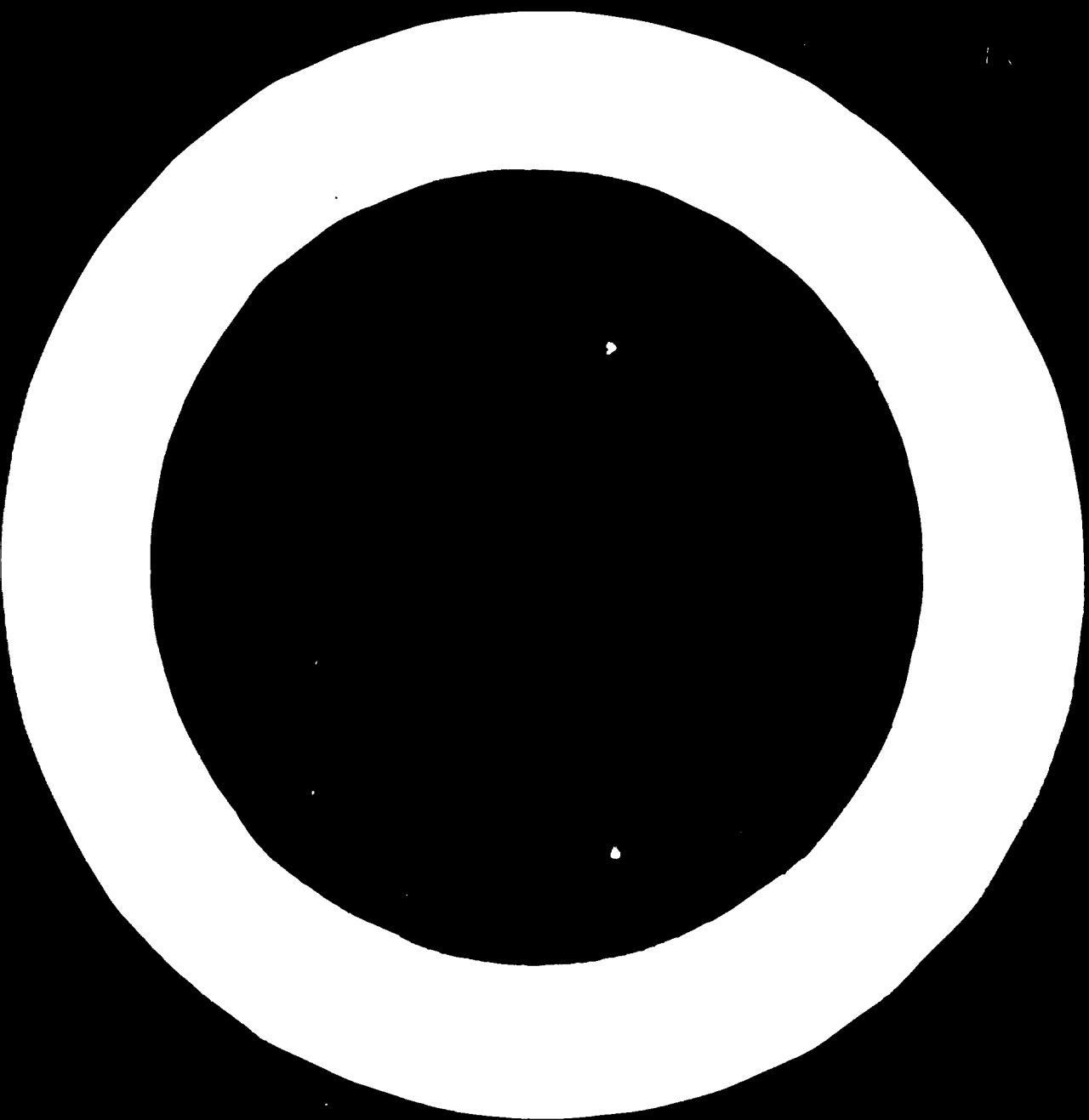
Suitable welding equipments in a sufficient number must be available as well as trained welding staff and experienced welding supervising staff in order to guarantee a good workmanship.
The training level has to be equal to the European standard.
The quality control and acceptance require suitable controlling equipments and well-trained controlling personnel.
Devices for non-destructive testing (x-ray testing, surface control, spectroscopic analysis, hardness test) are necessary for the control of the quality and acceptance.

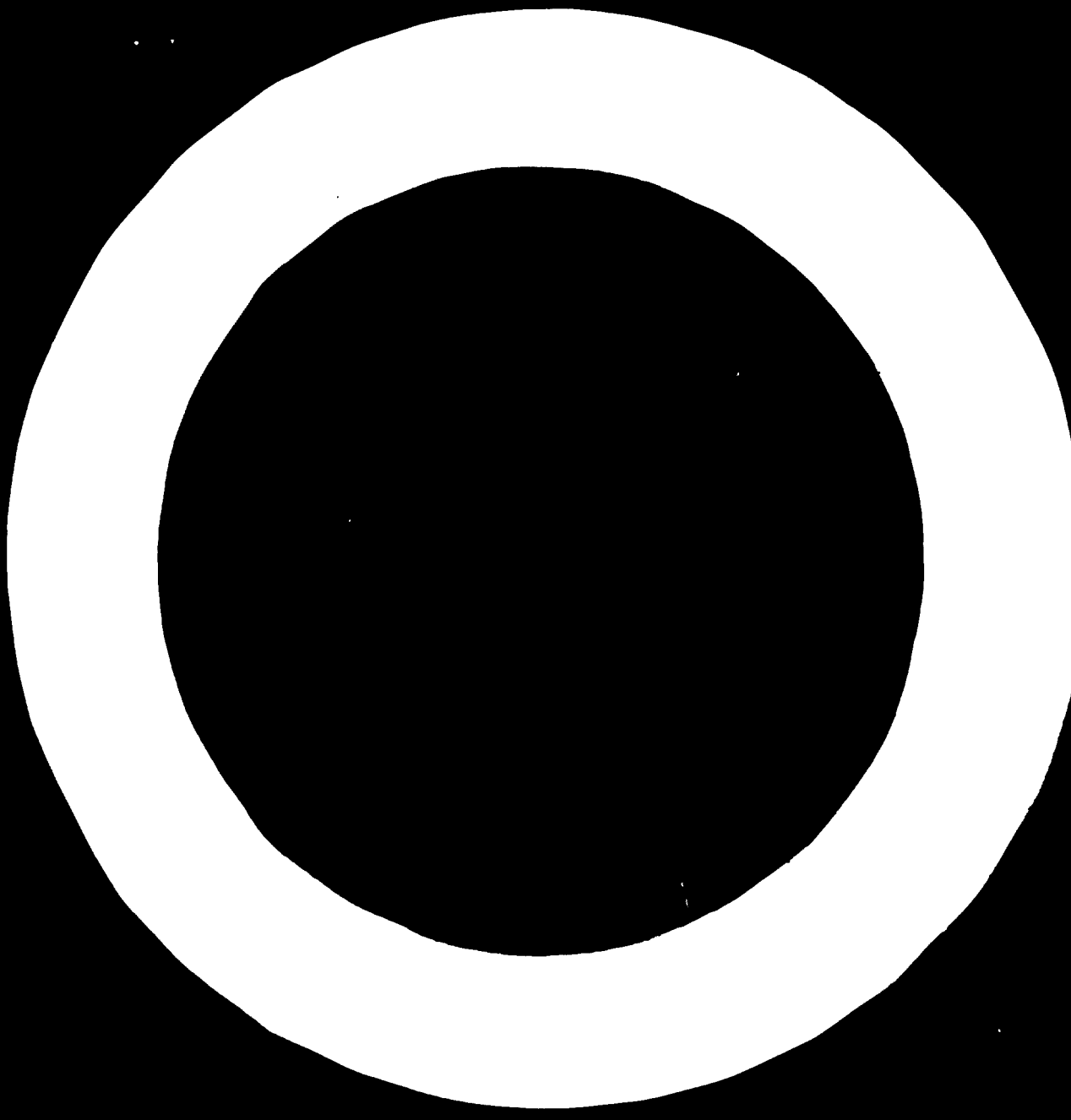
It is recommendable for the purpose of steady supervision of the welding staff to make also non-destructive testing with non-acceptable, pressureless operated construction parts.

A technical office is required for planning and technical execution (procurement of material, making of shop-drawings etc). The staff and the technical installations have to meet the requirements resulting from the manufacturing program. The technical equipments have at least to cover drawing- and working utensils, accessories and one copying machine, besides documentation (codes, standards, tables, material data sheets etc.)

The leader of the technical office has to meet the special high requirements. He should at least be technical engineer (mechanical engineer or even better chemical engineer) with thorough practical and theoretical knowledge. Required is employment of several years in a chemical industry as plant engineer and as shop engineer for construction of chemical apparatus. Employment in an engineering office is desirable. Thorough knowledge of strength calculation, mechanical science, material substance and calculation of welding technique is required, as well as experience with machines, mainly used in chemical plants, i.e. pumps, drives, controllers and measuring instruments.

The level of qualification and training of designers and technical drawers should comply with the European standard.





When building fabrication plants for the manufacture of apparatus for the chemical industry in developing countries, some essential aspects and conditions have to be considered. Within the scope of this lecture there will be tried to herefore give hints and recommendations.
In the following some comtemplations conc. the "Lay out" of an apparatus manufacturer of a minimum size of around 50 professional workmen in the starting phase.

1. Location determination

In this respect, the following points will have to be checked:

Procurement of the rawmaterials under particular consideration of the transportation conditions
choice of workmen
supply of electric power and
climatic conditions

2. General organization

It is the aim of the plant planning to get the optimum arrangement of workshops and equipments enabling the most economical manufacturing and, simultaneously, a safe and satisfactory working for the workmen. That means an arrangement making possible to produce at a price being low enough to make it competitive and to sell it with profit on the market by means of a suitable, productive co-operation of workmen, materials, machines, and appertaining working material.
This is the summary for what the plant has to take care:

a) to co-ordinate all facts which can have influence on them
b) shortest distance at material transporation
c) a smooth working process in the plant
d) the optimal utilization of every room
e) satisfaction and safety for the workmen
f) an adaptable arrangement which can easily be changed

In the following the characteristics of a plant for chemical apparatus plants will be shown. Basing on a minimum size of around 50 workmen (specialist and additional helpers) and the administration required for this, the layout will be worked out in a rough analysis under special consideration of an expansion at a later date.

2.1. Classification of the products

The building of chemical plants will, first of all, be demonstrated by means of the working-up processes and sequence of working-up. It includes in the essential points the following processes, as demonstrated in the enclosure:

Order administration (table 1)

It consists of sale, purchase, finance and works bookkeeping, and stock administration

Design

For the planning and technical processes (material procurement;

making of workshop drawings etc.) a construction office will be required. The staff and technical equipments have to comply with the demands resulting from the fabrication program. The technical equipments should include at least drawing instruments and working instruments as well as accessories and a copying apparatus. In addition to this, documentation (codes, standards, tables, and material sheets etc.) must be available. The leader of the technical office has to comply with specially high demands. He should, at least, be professional school engineer with profound practical and theoretical knowledges. An activity of several years in the chemical industry as work's engineer and in the construction of chemical apparatus will be required. Occupation in an engineer office would be desirable. Good knowledge in calculation of stability, mechanics, material knowledge, welding technique calculation must be required. Knowledge and practical experiences with machines, being mainly in use in chemical plants, such as pumps, drives, controller and measuring instruments, is necessary. Qualification and training of constructors and technical draftsmen have to be of European standard.

2.2. Operational working-up of orders

for finding-out and providing of suitable dates
for production in proved manner
production divisions.
For the first step, equipment as per table 2 is supposed.

Quality control and inspection:

An expert engineer must be head of the quality control.
There have to be available appropriate test equipments, in order to be able to make a qualitive distinction as to alloy groups (with Mo-content and without Mollybdenum). Appropriate testing processes are the spectroscopic analysis and chemical testing processes (spot test). Control of the semi-finished products must be done when receiving the material. It is recommended to have trained the control personnel by experts of the supplying company for test equipments.

Control of the finished parts

In case of pressure vessels the testing extent is fixed in the inspection instructions. As far as vessels and apparatus, presureless operated, are concerned being not subject to inspection, it is recommendable to test at least for leaks and to X-ray at random in the company. There is also recommended the surface crack test by the dye penetrant test for welding joints. The control is to be unindependent from the production workshop. Recommendable control equipments for non-destructive examinations of welding seams:
One tank X-raying apparatus 300 KV, 3 mA. This apparatus can be used both stationarily and in workshops, as well as on jobsite.

Administration and management

In addition to the divisions being necessary for production and execution of an order, there must be taken into consideration administration and management.

Administration: for supply and administration of the company
Management: for maintenance of the company

2.3. Manufacturing principle

Out of the 3 kinds of working-up (local-bound working-up),

working-up as per performance principle, and flow-principle, the two first processes in combined form will come in question, that means local-bound manufacturing when mounting, but the mechanical working-up as per performance principle. For the choice of the appropriate anterial flow-schemes, and the association with each other, an exact analysis of the products to be made is required before. It can be said that the mounting and the welding shop can be located in one hall, and due to a later production expansion the following dimensions should be kept.

Mounting and welding: width 12 m, height of crane 6 m
Mechanical working-up
and preparation : width 10 m, height of crane 5 m

The association depends upon the product and the planned expansion. Hall lengths of 80 m resp. 60 m as guiding value are sufficient for the mounting. Depending upon the climate, the building also can be made in light patterns with corresponding foundation plates for placing the machines.

There separately must be checked the transportation and the means of transport to be place at disposal. At the beginning, a mobile crane with around 4 tons of lifting power and corresponding transportation facilitites by hand are sufficient. For the hall's craning should be planned not less than 20 tons in the mounting, and in the suppliers' works chiplers shaping 10 tons and cutting shaping 15 tons, particularly because an expansion at a later date would be difficult.

2.4. Organization plan

Same shows the individual spheres and the staff in the summary (table 2).
As a minimum size can be taken for the building of apparatus (in case of an industrial production):

Beginning phase: 50 - 60 workers (directly employed with the production)

30 employees (indirectly employed with the production)

this corresponds to an approxiate proportion:

Employees : workmen = 1 : 2

The possible turn-over volume would have to reach around 5 Mio. DM/year, in the peak up to 7 Mio. DM/year.

Developing phase: These can be made continuously and discontinuously Particular consideration deserves the question as to a training workshop for trainees of the jobs such as welder, mechanic, turner resp. machine operator in order to cover that way the personell demand by themselves.

3. Planning of the fabrication plant

Due to the shortness of the explanations, just a summary can be given. Before starting up, an exact analysis and planning has to be made. The individual tasks are:

a) Planning of the total project (rough analysis), basing on the ideal solution
b) determination of the place
c) operation planning in details (fine analysis) under consideration of the particulars of the products to be made
d) erection of the building and placing of the machines

For the planning, leading questions can help. They can be divided into the following groups:

3.1. Materials

There has to be taken into consideration the rawmaterial, the incoming material, material in the fabrication, finished products, auxiliaries, and working materials, damaged goods, repairs and refinishing work, re-use of waste, scrap iron, shavings, packing material and the material for the maintenance and other auxiliary sections. From this, considerations do result having influence on the material choice, dimensions, construction, variety. Taking into consideration the high and versatile requirements the company has to be faced with as to the welding technical working up of high-quality materials (non-ferrous metals, clad steels, high-corrosion resistant materials) it seams to be recommendable to take up in the product program, at least in the starting phase, concerning developing countries, such construction being manufactured of materials which can good be welded, and are only subject to slight resp. medium stress.

There are given recommendations of materials for construction steels, boiler plates and fine grain steels in table 3 up to 5. Suggestions for acid-proof austenitic steels are included in table 6. An essential point of view for the material choice is the heat treatment. Annealing equipments are expensive investments, there must be also be secured an economical supply of power. Since these conditions will not be sufficiently fulfilled in developing countries, those steels should be taken into consideration with priority when choosing the material which, normally, do not require a heat-treatment after the welding process. As per German prescriptions, this is valid for all steels of table 3 - 5 with exception of boiler plate type I and type II with ASTM-analysis as well as fine grain construction steel type II with ASTM analysis. But for the heat treatment after welding the instructions of the individual producers and/or the local boiler inspection association will be decisive. Due to safety and smooth production process such steels are to be recommended which, based on their alloy composition, do guarantee before all as to the carbon steel content a sufficient viscosity in the welding joint even at unfavourable manufacturing and working-up conditions.

Hints and recommendations for the welding process and filler material as to the materials given under table 3 to 6 shows table 7.

3.2. Working materials

There has to be taken into consideration the necessary equipment as to:

Production machines, special accessories, tools, devices, measuring and testing materials, handtools, and tools operated by hand or by power, control points or testing stations, machines for

maintenance of operation, tools and other auxiliary sections.

Kind, size, number of machines, co-ordination of capacity, main points and special requirements of the production (connection, piping, and canalization etc.) can be of influence on the planning of a factory.

3.3. Workmen

There has to be considered the number of workmen, foremen, chiefs, auxiliary helpers, transportation and storage workers, inspectors, works craftsmen, employees etc. There has to be enclosed in the planning: safety arrangments, working conditions, number of staff, capacity and wages.
For a qualitative work, skilled welders are indispensable. Sufficient specialized knowledges and manual skill can be acquired generally at eductional institutes for welding techniques. As far as these eductional instutes are not available, training of the welding staff could be done in the own factory by the supervising welding engineer of by welding experts. The supervising personnel should have a careful practical and theoretical skill at an eductional institute for welding techniques. There, furthermore practical experiences are desirable, which can for example, be acquired in welding shops of industrial countries. Unindependently from the welding and process tests being fixed in the inspection prescriptions, the manual skill of the welders should be currently supervised. This can be carried out without great expenditure by means of welding samples, the workshop bending samples are taken from and can be checked on simple devices. It is recommended to currently supervise welders following DIN 8560.

3.4. Transportations

There have tobe considered the kinds of conveyance (cranes, transportation means within the workshops, road vehicles), containers for conveying or temporary storage. There has to be taken into account process flow, material movement, the transprotation processes and the available room.

3.5. Waiting and storage times

There has to be taken into consideration for the storage or temporary storage: Where will be received and stored incoming? Where are located the production and intermediate storages? Where can material be stored between the working process? Where are stored products, auxiliaries, waste, etc.? That means: Determination of the storage places, size of storage and storage methods.

3.6. Social equipments, auxiliary and additional equipments such as planning of ways, toilets and wash-rooms, dining and sitting room, equipment for First Aid, telephone connections, doorman, personnel office, wages office, illumination, procurement of power, etc. In addition to this, there will have to be planned place for quality control, manufacturing supervision, repair and waste equipment for power procurement.

3.7. Buildings

Consideration of walls, ceilings, floors, existence of siding, streets, channels etc. Consideration of building with view to capacity expansion at a later date.

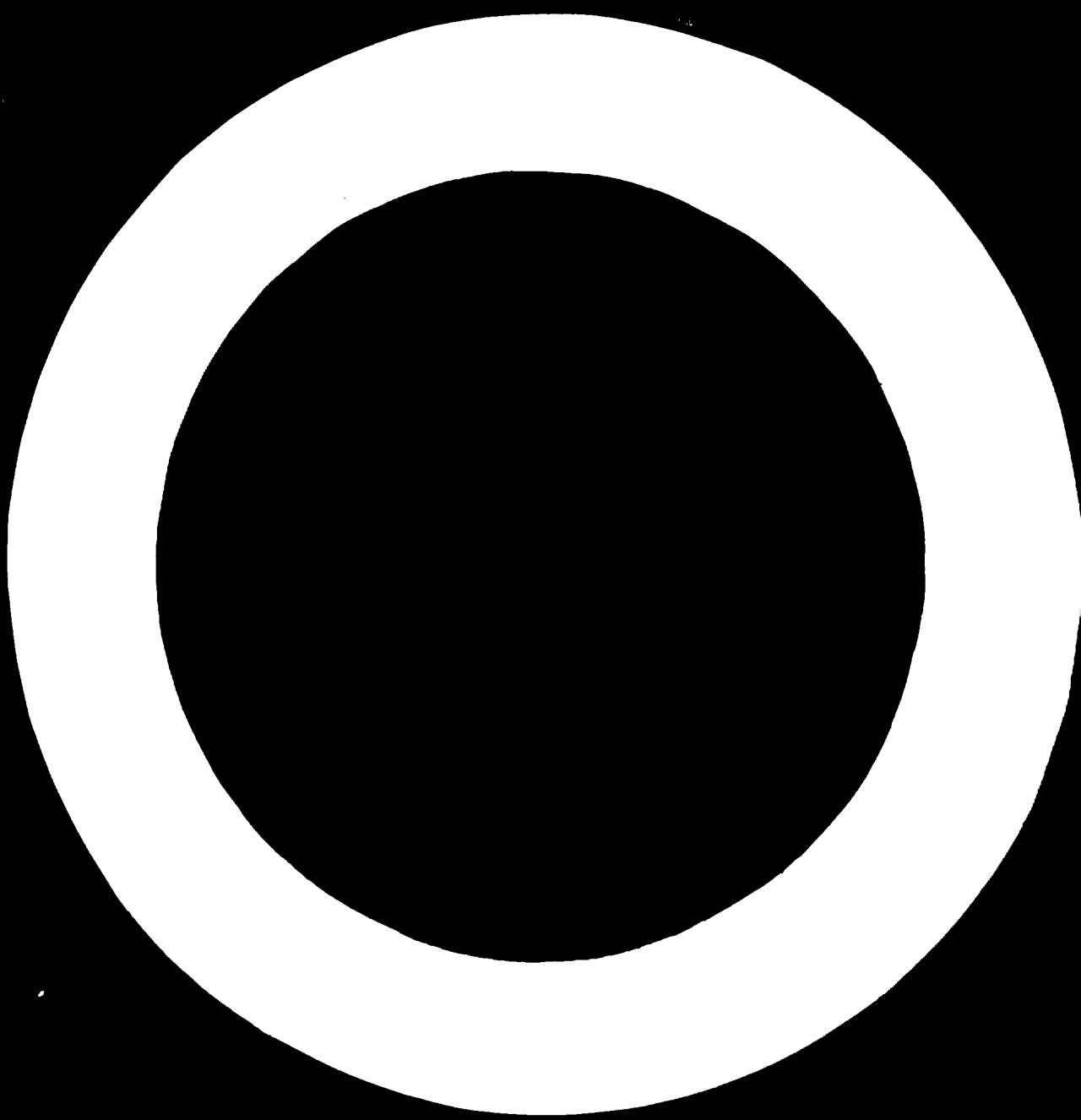
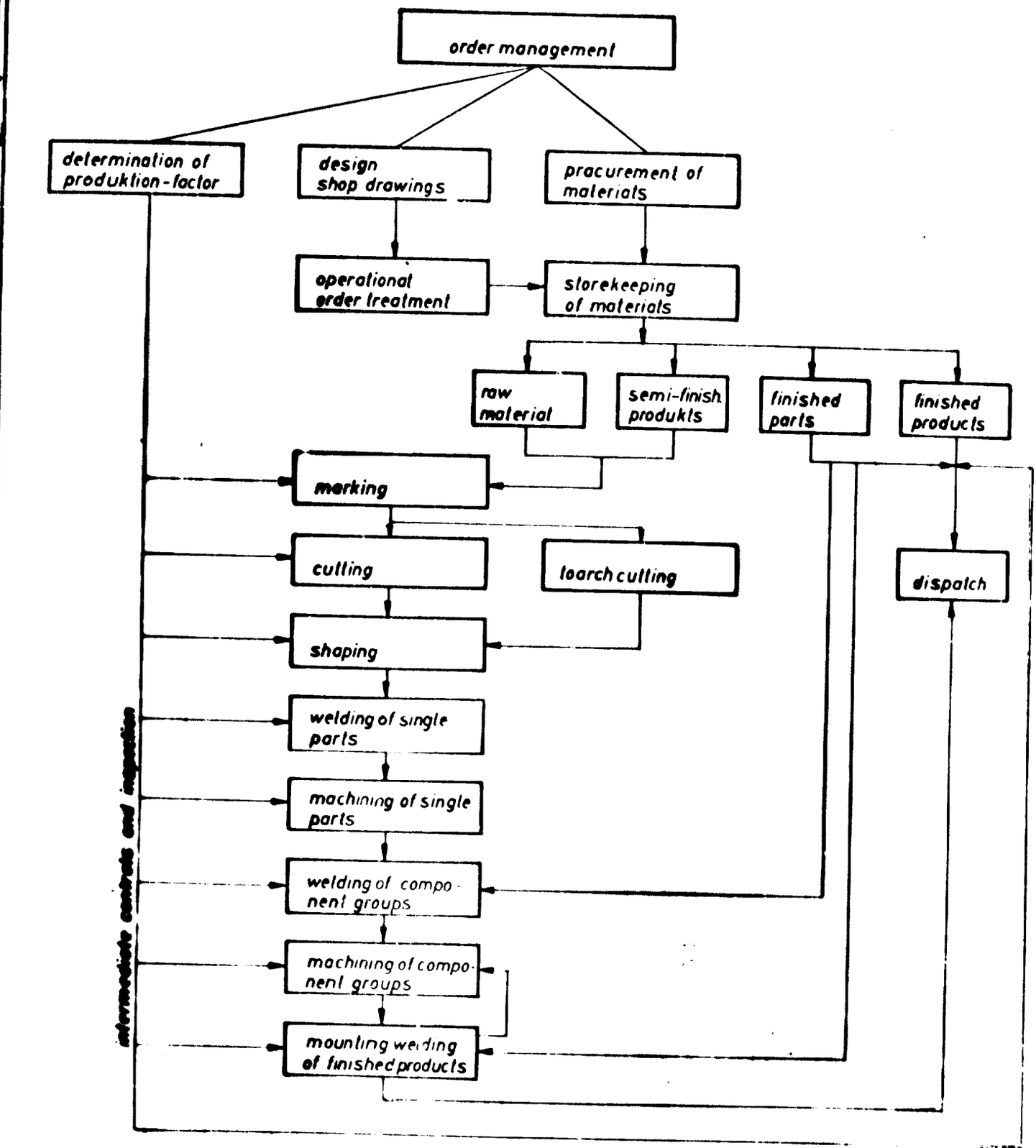
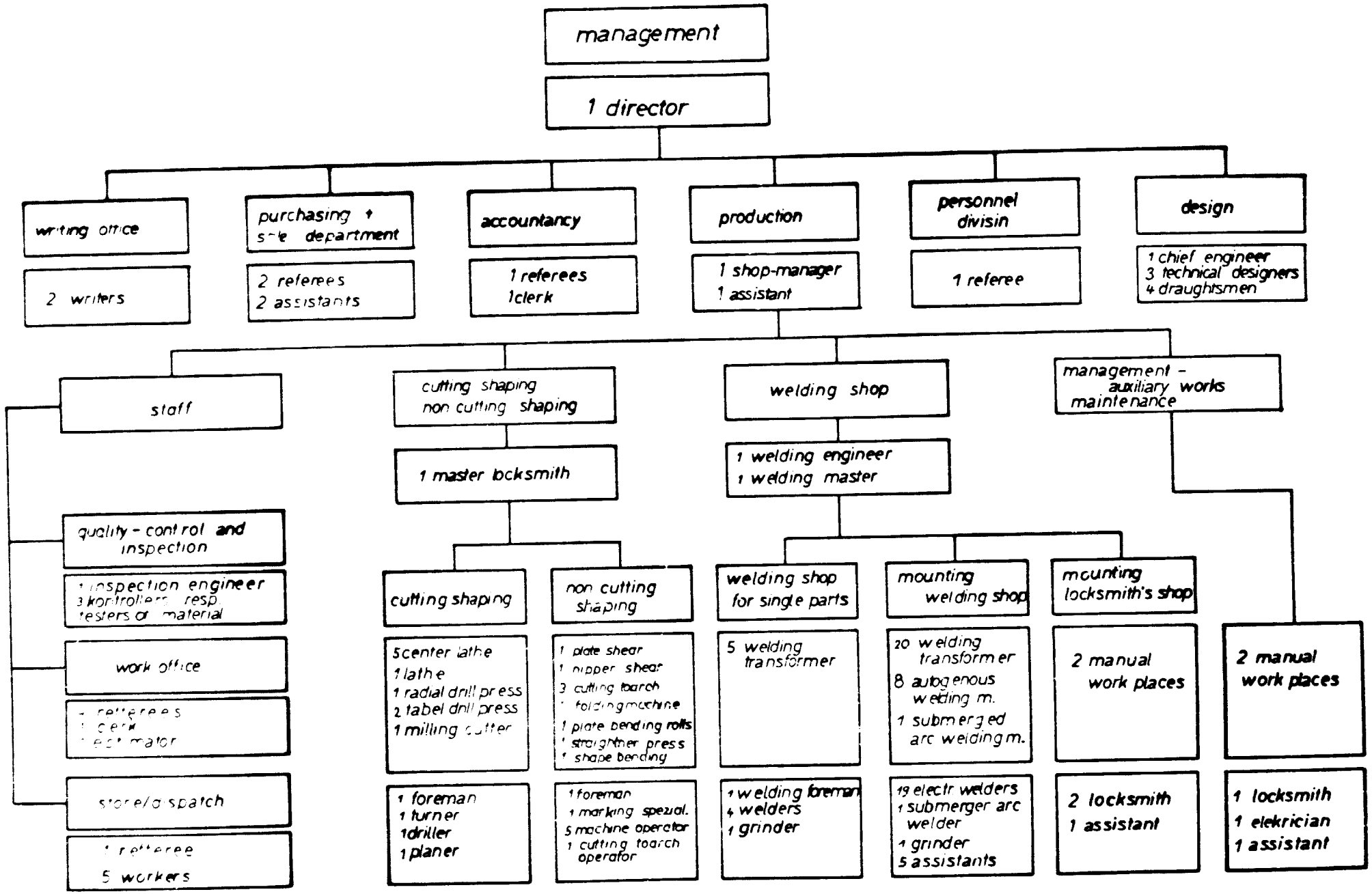


Table 1



Carl Canzler Düren	Proceedings of order	70010



Carl Canzler

Diren-

organisation plan

70011

Table 2

Duren-

Table 3

grade of steel	Designation acc to ASTM and DIN 17100	mechanical properties acc to ASTM σ_B kg/mm²	σ_S kg/mm² mind.	$\delta_{2''}$ % mind.	mechanical properties acc to DIN 17100 σ_B kg/mm²	$\sigma_{0,2}$ kg/mm² mind.	δ_5 % mind.	recommended limit of wall thickness mm	chemical composition in % C	Si	Mn	P max.	S max.	N	others	note
Type I	A 44 ASTM A 20¹-65	38,7 bis 45,7	2¹¹	28	-	-	-	25	0,20	0,15 bis 0,30	≤ 0,80	0,040	0,050	-	≤ 0,25 Cu	
	P St 37-2	-	–	-	37 bis 45	24,0	25 1)	25	0,19	–	–	0,055	0,055	0,008	–	piece-analysis
Type II	High strength Low alloy structural steel	≤ 47¹ 2)	32,3	—	–	–	–	20	≤ 0,22	–	≤ 1,25	–	0,050	–	–	
	St 52-3	–	–	-	52 bis 62	36,0	22 1)	20	0,22	-	–	0,050	0,050	0,010	–	piece-analysis

note 1) S 100mm samples in longitudinal sense 2) for S > ¾" ≤ 1½"

CARL CANZLER DUREN	General Structural Steels	70017

grade of sorte	marking in accordance to ASTM and DIN	mechanical properties acc.to ASTM σ_B kg/mm² min	mechanical properties acc.to ASTM σ_S kg/mm² min	mechanical properties acc.to ASTM $\delta_{2"}$ % min.	mechanical properties acc.to DIN 17155 σ_B kg/mm² min	mechanical properties acc.to DIN 17155 $\sigma_{0,2}$ kg/mm² min	mechanical properties acc.to DIN 17155 δ_5 % min.	recommended limit of wall thickness mm	chemical composition % C	Si	Mn	P max.	S max.	Cr	Ni	Mo	others
Type I	Afbq ASTM A201-65	38,7 bis 45,7	21,1	29	–	–	–	25	≤ 0,20	0,15 bis 0,30	≤ 0,80	0,035	0,040	–	–	–	–
	HI DIN 17155	–	–	–	35 bis 45	22,0 1)	$\frac{1000}{\sigma_B}$	25	≤ 0,16	≤ 0,35	≤ 0,40	0,050	0,050	–	–	–	max 0,30 Cr
Type II	Bfbq ASTM A201-65	42,2 bis 50,6	22,5	26	–	–	–	25	≤ 0,24	0,15 bis 0,30	≤ 0,80	0,035	0,040	–	–	–	–
	H II DIN 17155	–	–	–	41 bis 50	25,0 1)	$\frac{1000}{\sigma_B}$	25	≤ 0,20	≤ 0,35	≥ 0,50	0,050	0,050	–	–	–	max 0,30Cr
Type III	Bfbq ASTM A212-65	49,2 bis 59,8	26,7	22	–	–	–	20	≤ 0,31	0,15 bis 0,30	≤ 0,90	0,035	0,040	–	–	–	–
	17 Mn 4 DIN 17155	–	–	–	47 bis 56	28,0 1)	$\frac{1000}{\sigma_B}$	20	0,14 bis 0,20	0,20 bis 0,40	0,90 bis 1,20	0,050	0,050	–	–	–	max 0,30 Cr
Type IV	15 Mo 3 DIN 17155	–	–	–	44 bis 53	27,0 1)	$\frac{1000}{\sigma_B}$	20	0,12 bis 0,20	0,15 bis 0,35	0,50 bis 0,70	0,040	0,040	–	–	0,25 bis 0,35	—

note: 1) for S>16 ≤ 40mm

CARL CANZLER DÜREN	NON-Alloyed and Low Alloyed boiler Plates	70018

Table 4

Table 5

grade of steel	Designation acc. to ASTM and Thyssen-Röhrenwerke	mechanical properties acc. to ASTM σ_B kg/mm²	σ_S kg/mm² min	$\delta_{2"}$ % min.	mechanical properties acc. to Thyssen Rheinrohr σ_B kg/mm²	$\sigma_{0,2}$ kg/mm² min.	δ_5 % min	recommended limit of wall tickness mm	chemical composition in % C	Si	Mn	P max.	S max.	Cr	Ni	Mo	other
Type I	Gr 55 acc to ASTM A 516-65	38,7 bis 45,7	21,1	29	–	–	–	25	≤ 0,20	0,15 bis 0,30	0,85 bis 1,20	0,035	0,040	–	–	–	–
	HSB 40	–	–	–	40 bis 52	29 2)	$\frac{1200}{\sigma_B}$	25	≤ 0,18	≤ 0,50	0,60 bis 1,20	0,04	0,04	–	–	–	Al
Type II	Gr 65 acc to ASTM A 516-65	45,7 bis 54,1	24,6	25	–	–	–	20	≤ 0,26	0,15 bis 0,30	0,85 bis 1,20	0,035	0,040	–	–	–	–
	HSB 45	–	–	–	45 bis 57	32 2)	$\frac{1200}{\sigma_B}$	20	≤ 0,18	≤ 0,50	0,70 bis 1,30	0,04	0,04	–	–	–	Al

note: 1) properties in normally annealed condition 2) for S ≤ 35 mm

CARL CANZLER DÜREN	C-Pates of Medium strength and Fine Grained Structural Steel	70019

Table 1

grade of steel	Designation ACC. to ASTM-A204-63 / DIN 17440	mechanical properties ACC. to σ_B kg/mm²	σ_S kg/mm² min.	δ_2 % min.	mechanical properties ACC. to σ_B kg/mm²	1,0-Dehngrenze kg/mm² min.	δ_5 % min.	recommended limit of wall thickness mm	chemical composition % C	Si	Mn	P max.	S max.	Cr	Ni	Mo	other
Type I	TP 304	≧52,7	21,1	40	—	—	—	6	≦0,08	≦1,0	≦2,0	0,045	0,030	18,0 bis 20,0	8,0 bis 12,0	—	—
	X5CrNi 18 9 W-Nr 1 4301	—	—	—	50 bis 70	23,0	50 1)	6	≦0,07	1,0 max	2,0 max	—	—	17,0 bis 20,0	9,0 bis 11,5	—	—
Type II	TP 304 L	≧49,2	17,6	40	—	—	—	15	≦0,03	≦1,0	≦2,0	0,045	0,030	18,0 bis 20,0	8,0 bis 12,0	—	—
	X2CrNi 18 9 W-Nr 1 4306	—	—	—	45 bis 70	22,0	45 2)	15	≦0,03	1,0 max	2,0 max	—	—	17,0 bis 20,0	10,0 bis 12,5	—	—
Type III	TP 316	≧52,7	21,1	40	—	—	—	6	≦0,08	≦1,0	≦2,0	0,045	0,030	15,0 bis 18,0	10,0 bis 14,0	2,0 bis 3,0	—
	X2CrNi Mo 18 10 W Nr 1 4401	—	—	—	50 bis 70	25,0	45 1)	6	≦0,07	1,0 max	2,0 max	—	—	16,5 bis 18,5	10,5 bis 13,5	2,0 bis 2,5	—
Type IV	TP 316 L	≧49,2	17,6	40	—	—	—	15	≦0,03	≦1,0	≦2,0	0,045	0,030	16,0 bis 18,0	10,0 bis 14,0	2,0 bis 3,0	—
	X2CrNiMo 18 10 W-Nr 1 4404	—	—	—	45 bis 70	24,0	40 2)	15	≦0,03	1,0 max	2,0 max	—	—	16,5 bis 18,5	11,0 bis 14,0	2,0 bis 2,5	—
Type V	TP 321	≧52,7	21,1	40	—	—	—	15	≦0,08	≦1,0	≦2,0	0,045	0,030	17,0 bis 19,0	9,0 bis 12,0	—	Ti
	X10CrNiTi 18 9 W-Nr 1.4541	—	—	—	50 bis 75	25,0	35 1)	15	≦0,10	1,0 max	2,0 max	—	—	17,0 bis 19,0	9,5 bis 11,5	—	Ti ≧ 5X%C
Type VI	X10CrNiMoTi 1810 W-Nr 1.4571	—	—	—	50 bis 75	27,0	35 1)	15	≦0,10	1,0 max	2,0 max	—	—	16,5 bis 18,5	10,5 bis 13,5	2,0 bis 2,5	Ti ≧ 5X%C

note 1) δ_5-values for plates > 5 up to 10mm, samples in longitudinal sense 2) δ_5-values for plates > 10 up to 20mm, samples in longitudinal sense

Carl Canzler Düren

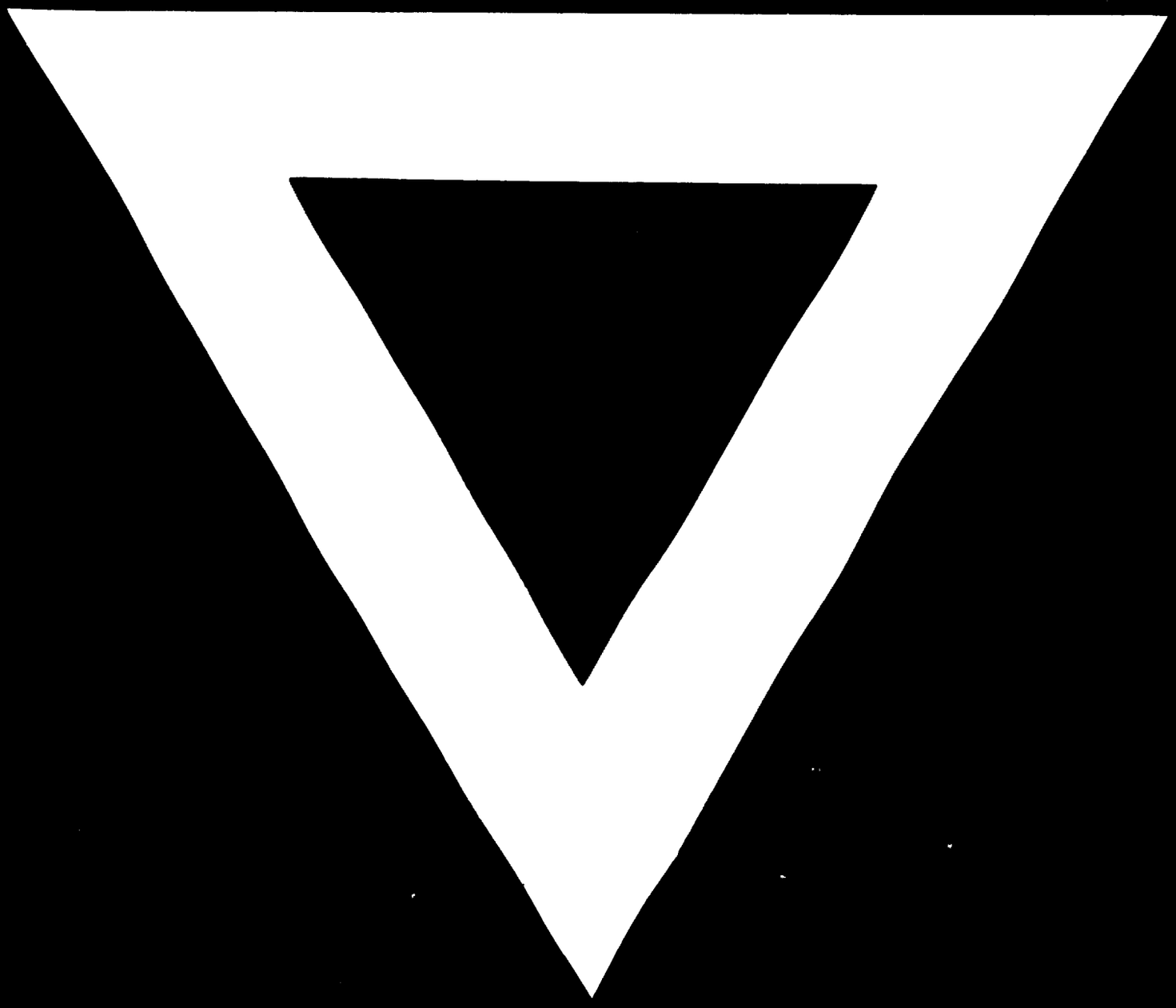
Acid-proof austenitic steel

70020

Table 7

Materials (Compare with table 1-4)	recommended limit of wall tickness mm	welding procedure	filler material
General Structural Steels Type I	25	Open argon arc welding by hand and by UP welding	for open argon arc welding lime based electrodes of Type Kb IX s / 345 / 26 acc. to DIN 1913 corresponding to E 345 B 26 in accordene to ISO and E 7018 acc. to AWS-ASTM for UP-welding wire S2 acc. to DIN 8557 welding powder 487 acc. to DIN 8557
Type II	20		
non alloyed and low alloyed boiler plates Type I Type II	25		
Type III	20		
C-Thick Plates of Medium strength and Fine Grained structural steels Type I	25		
Type II	20		
Low alloyed boiler steel Type IV	20	Open argon arc welding by hand	lime based electrodes of Type Kb XI S 535 26 acc to DIN 1913 corresponding to E 535 B 26 acc. to ISO and E 7015-A1 E 7016-A1 and AWS-ASTM
Acid. proof. austenitic steels TypeI TypeIII	6	Open argon arc welding by hand and by iniertgas-WIG-welding (for S≤ 6mm)	with supp. material acc. to Vornorm DIN 8556 and acc. to ASTM-A298 ASTM-A371
Type II Type IV Type V Type VI	15		

CARL CANZLER DÜREN	Welding procedure and filler material	70021



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