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

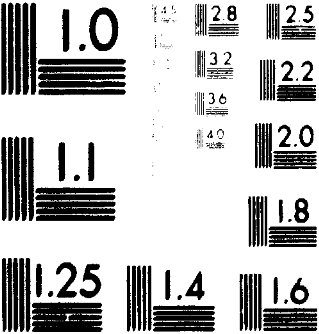
FAIR USE POLICY

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



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

CONFIDENTIAL

FINAL REPORT

UNIDO CONTRACT NO. 77/34

PROJECT NO. SI/YUG/75/827

INVESTIGATION INTO THE MANUFACTURE OF DIFFERENTIAL AXLE HOUSINGS FOR COMMERCIAL VEHICLES

at

MASINSKA INDUSTRIJA NIS
YUGOSLAVIA

for

UNITED NATIONS INDUSTRIAL DEVELOPMENT
ORGANISATION (TEPCO)
P.O. BOX 707
VIENNA
AUSTRIA

NORRIS PARTNERS LTD
EUROPA HOUSE
QUEENS ROAD
BRISTOL BS8 1AU
ENGLAND

30 JUNE 1977

NORRIS PARTNERS LTD

CLIENT:	United Nations Industrial Development Organisation (TEPCO) Vienna Austria
REPORT:	FINAL REPORT
SUBJECT:	Investigation into the Manufacture of Differential Axle Housings for Commercial Vehicles at Masinska Industrija-Nis, Yugoslavia.
DATE:	30 JUNE 1977
PREPARED BY:	FIELD TEAM: - D.H. BARRIE, B.Sc., C.Eng., M.I.Mech.E., M.I.Prod.E. - A.H. WORTHY, B.Sc.(Eng.) HOME OFFICE SUPPORT TEAM: - J.G. NORRIS, C.Eng., F.I.Mech.E., F.I.Prod.E., M.B.I.M., F.Inst.D. - D.F. PARRY, C.Eng., F.I.Mech.E., F.I.M.H., F.I.P.C. - R.T. LOMAX, C.Eng., M.I.E.E.
APPROVED BY:	J.G. NORRIS, Managing Director.
COPIES:	30 Copies - UNIDO, VIENNA. 6 Copies - NORRIS PARTNERS LTD.

1.00 SYNOPSIS

A. PRODUCTION PROBLEMS

Masinska Industrija-Nis (hereinafter to be referred to as M.I.N.) have been manufacturing axle housings since 1973. Problems have been encountered since the inception of manufacture on material cracking, weld quality, and heat treatment (both on preheat prior to pressing and stress relieving).

The production problems noted above are substantially the result of:

1. Incorrect basic design of the case.
2. Lack of control on incoming steel.
3. Lack of furnace control at press stage.
4. Type of plant available for manufacturing processes.
5. Plant layout.
6. Lack of Management responsibility due to spread of production into several different isolated departments.

B. RECOMMENDATIONS

The recommendations are given in three stages:

1. Minor modifications to existing plant and control techniques involving minimum capital expenditure.
2. Introduction of limited new facilities to be incorporated into existing methods of manufacture.

1.00 CONT'D.

B. RECOMMENDATIONS (Cont'd)

3. A modern plant layout incorporating all technical features suitable for a production of 25,000 axle housings per annum, with approximations on capital expenditure involved.

2.00 TABLE OF CONTENTS

2.00 TABLE OF CONTENTS (Cont'd)

BIBLIOGRAPHY

Paper by Dr. Eng. Marin Gabrovsek and Co-authors Grad. Eng. I. Rak and Grad. Eng. F. Slibar on "DEVELOPMENT OF PRODUCTION OF FINE-GRAIN STEELS AT JESENICE IRON AND STEEL WORKS - PROBLEMS OF WELDING AND WELDED STRUCTURE STRESS ANNEALING".

FIG. REFERENCES

2.00 TABLE OF CONTENTS (Cont'd)

FIG. REFERENCES

3.00 INTRODUCTION

A. PROJECT APPRAISAL

Masinska Industrija-Nis was established in 1963 resulting from the amalgamation of two factories founded in 1884 and 1913. The programme of work of Masinska Industrija-Nis comprises the research, development, design and manufacture of locomotive and rolling stock, fabrication of steel structures of all kinds, manufacture of processing machinery and a wide variety of components formed by pressing and forging, grey iron steel and non-ferrous castings.

The medium term development plan of this enterprise comprises the development of heavy road vehicles and manufacture of their components.

The pressing technology utilizes old machinery, following a hot pressing process. It is planned to introduce new cold pressing processes for all thicknesses of steel sheets and plates.

For instance, the manufacture of the rear axle halves for commercial vehicles consists of hot pressing of two halves followed by welding. The halves are prepared by gas cutting, the heating is carried out by fuel-oil furnaces at $950^{o}C \pm 50$, and the pressing and straightening by hydraulic presses. A final testing is carried out to ascertain the micro-structure. The main problem lays in the heating; during the straightening process, cracks appear on radius and middle spots as well as on the welding near the attachment to the spring seats. The

3.00 CONT'D.

A. PROJECT APPRAISAL (Cont'd)

halves are joined by a longitudinal weld with root penetration with MIG CO_2 process using short-arc welding. The weld filling is also achieved by MIG CO_2 process. It is planned that the welding joining the attaching elements be carried out by manual operation with coated electrodes. The longitudinal seams are planned to be automatically welded.

Some problems are found in the stress relieving of the whole rear axle with attachments, which is carried out after the welding is completed.

B. OBJECTIVES

The purpose of the project is to assist in the improvement of the whole manufacturing process, particularly in the cold pressing of steel sheets, welding and heat treatment. The experts to carry out the field work are expected to give in-plant advice on the technological processes and to submit a report recommending a reorganization of the plant.

C. STUDY FORMAT

The difficulties in the manufacture of axle housings at M.I.N. can be placed into four main categories, viz:-

(1) Excessive scrap at the pressing stage due to cracks and tears on tight radii, such cracks being most prevalent in the gear carrying area, i.e. the banjo.

3.00 CONT'D.

C. <u>STUDY FORMAT</u> (Cont'd)

(2) Further rejects occur with the occurence of incipient cracks becoming apparent following straightening after assembly and welding.

Both top and bottom spring saddles caused serious problems due to weld failure in the early days of manufacture.

(3) Axle housings are supplied to customers in rough machine condition. Problems are being experienced in the spindle ends not cleaning up after machining due to out of line distortions introduced during assembly and after welding.

(4) Symptoms of accelerated fatigue believed to be caused by overheating and possible lack of control procedures during final stress relieving operation. Steel in vicinity of fractures showing signs of Widmanstratten structure.

<u>These problems have been investigated on the basis of putting forward recommendations to improve the following</u>:

(5) To establish laid down procedures to be introduced and established for inspection and routine testing of all incoming materials.

(6) Furnace control prior to pressing. Such control is only possible by the introduction of a pyrometer, and the initiation of flow through the furnace on a

3.00 CONT'D.

C. STUDY FORMAT

(6) cont'd......

continuous basis with the object of obtaining minimum times to achieve and maintain without variation throughout the furnace consistent temperatures at 850°C.

The procedures adopted must ensure that blanks do not remain in the furnace for more than 45 minutes, and a target time of 20 minutes must be aimed at.

(7) To improve control on the pressing operation by the introduction of shut height stops, and blank location stops.

(8) Full investigation to improve clamping and jigging methods. Investigation into welding techniques using Inert Gas (CO_2) especially with reference to wire size to maintain maximum deposit rates and speed of operation conducive to minimum penetration of 80%. Methods to eliminate weld splatter, especially in the tube arms where removal by shot blast is problematical. Inspection requirements with emphasis on porosity using either penetrating dies or magna flux.

(9) To investigate and suggest procedures for improving stress relieving with recommendations on temperature, time and cooling procedures.

3.00 CONT'D.

C. STUDY FORMAT (Cont'd)

(10) To check floor to floor times on all operations in order to highlight bottlenecks on certain plant, and to put forward recommendations on flowlines in order to increase current production, i.e. 6000 axle housings a year to 10,000 per year in the immediate future, and within twenty-four months 15,000 per year, and ultimately 25,000 axle casings a year within 10 years.

4.00 PRELIMINARY SECTION

1. STEEL PRESENTLY USED FOR AXLE HOUSINGS

A. Results

(1) The steel being used for axle housing manufacture at M.I.N. is obtained as hot rolled plates from SLOVENSKE ZELEZARNA JESENICE. The Mill is situated in the North-West of Yugoslavia on the Austrian Border, and is very remote from Nis.

(2) The plant is specialising in the production of high grade low alloy steels and stainless steels.

The steel currently being used in the manufacture of axle housings at M.I.N. goes under the steel maker's trade name NIOVAL 47.

The chemical composition is as follows - all figures are maximum:

C%	Si	Mn	Nb	V	Al
0.20	0.35	1.54	0.04	0.06	0.020

The steel being aluminium killed is suitable for axle manufacture. The addition of small quantities of niobium acts as a grain refining agent and is desirable - the inclusion of vanadium seems a rather unnecessary luxury, but we have nothing against it.

4.00 CONT'D.

1. STEEL PRESENTLY USED FOR AXLE HOUSINGS

A. (2) cont'd.....

Even with the addition of vanadium, the yield variation on inspection checks taken from selected stock plates varied between 38 and 64 kp/mm^2. Under no circumstances should the yield be allowed to drop below 43 kp/mm^2.

(3) The surface finish of the steel is poor - skin laminations (see Fig. 1A & 1B) are common, there are irregular surface patterns (Luders Lines). These develop markedly after pressing (see Fig. 2). Orange peel granulations giving a coarse grain surface condition; again these are accentuated after pressing.

(4) Rolled in dirt, i.e. extraneous matter rolled into the plate, also appears to be widespread (see Fig. 3).

The material thickness called for is 15 mm. The allowable rolling tolerance is plus 5% of material thickness, i.e. ZERO + .75 mm.

Rolling tolerance is vital on these types of pressed components.

It would appear from M.I.N's past inspection records that the rolling tolerances are not being maintained. The .75 mm top tolerance is being exceeded by .25 mm regularly, and on occasions

SURFACE FINISH OF STEEL

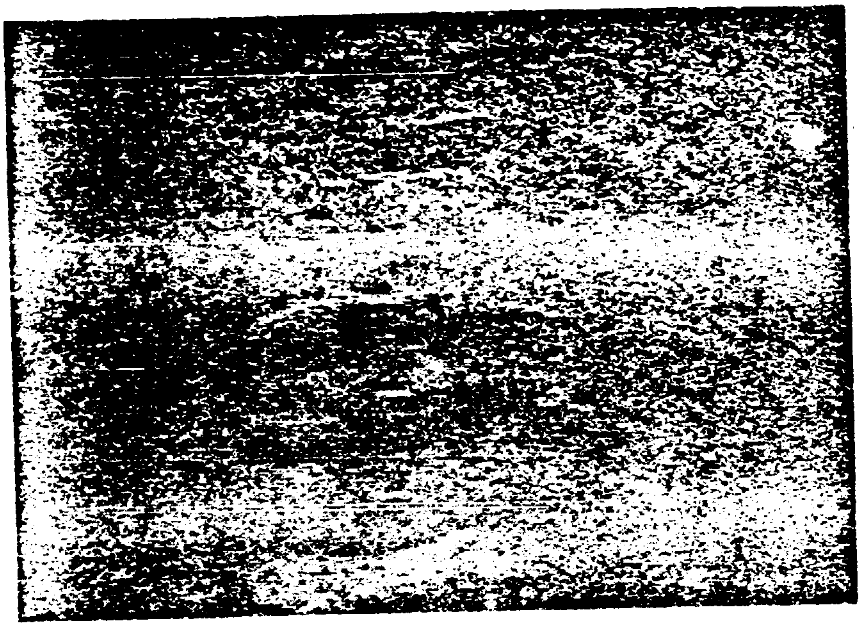


Fig. 1A.

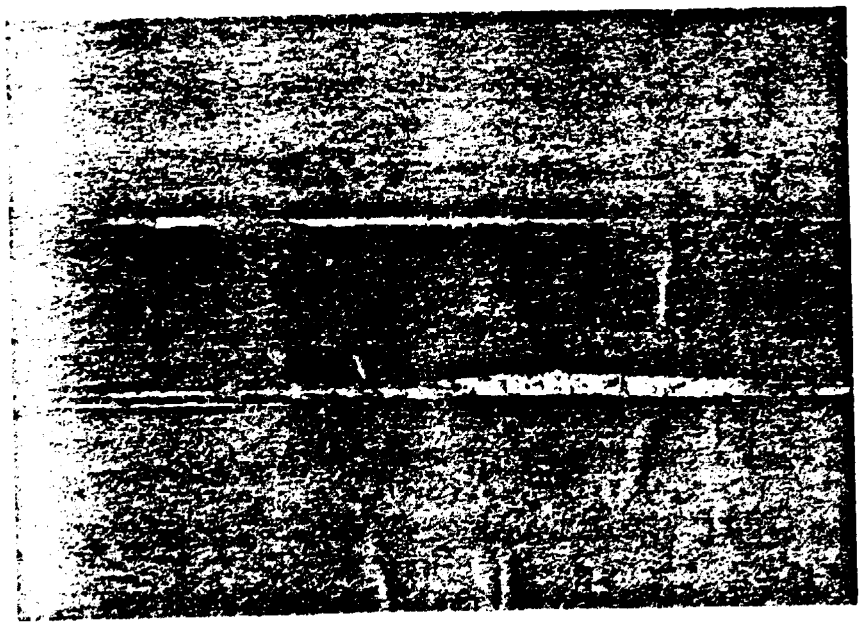


Fig. 1B.

SURFACE FINISH OF STEEL

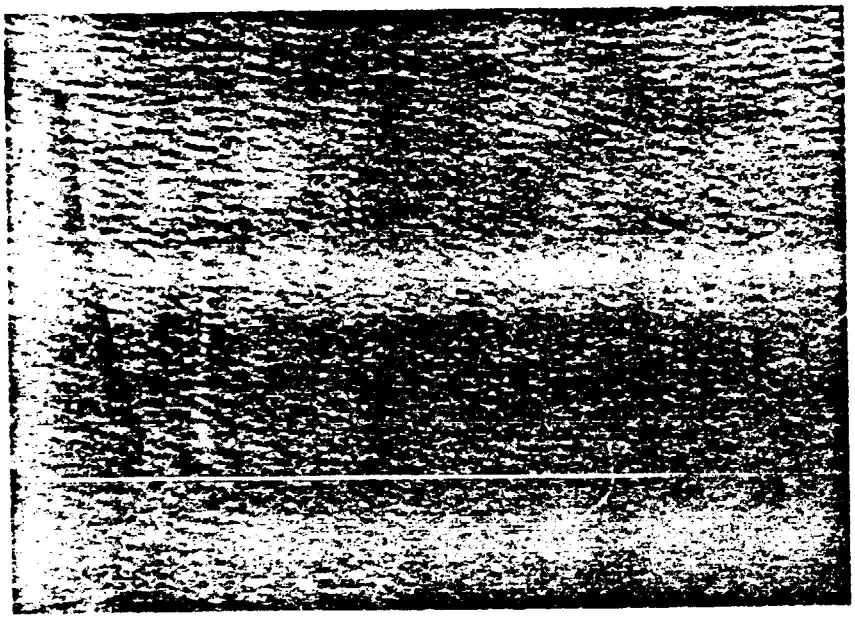


Fig. 2.

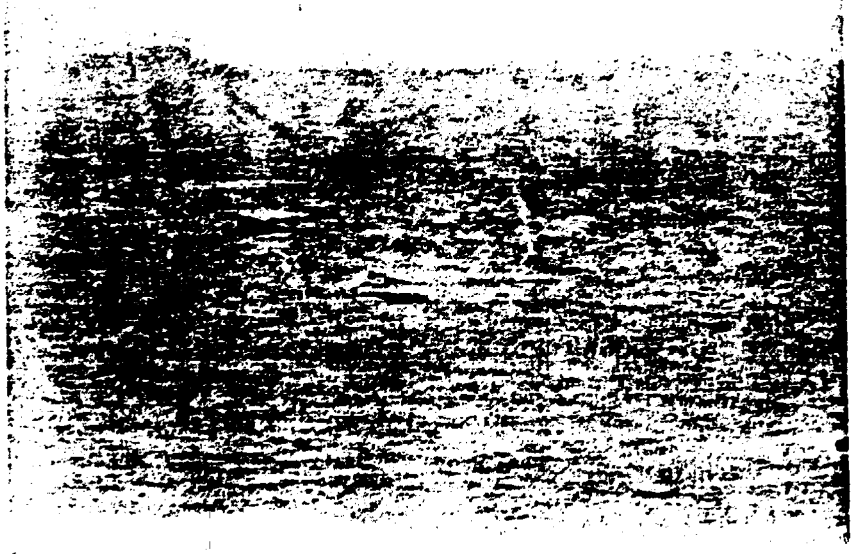


Fig. 3.

4.00 CONT'D.

1. STEEL PRESENTLY USED FOR AXLE HOUSINGS

A. (4) cont'd.....

by .5 mm - such tolerances are unacceptable for axle housing manufacture.

(5) The chemical analysis of the steel is found to be fairly constant from (M.I.N.) past records, but the mechanical properties deviate by up to 10.6% on yield from the manufacturer's published figures. The results are being extracted from past records.

B. Conclusions

(1) The type of steel is acceptable. The analysis is acceptable and appears to be fairly uniform, although variations have been found in samples taken from the same plate. This is a most undesirable factor, but from more recent records it would appear that the position is improving.

Mechanical properties must be brought into line with manufacturer's printed figures.

(2) The surface imperfections appear to be caused by not cleaning (SCARFING) the ingots prior to rolling, also trying to get too much yield from the ingot.

(3) After investigation, it is apparent that Yugoslav Standards cater for only one quality on hot

4.00 CONT'D.

1. <u>STEEL PRESENTLY USED FOR AXLE HOUSINGS</u>

B. (3) cont'd.....

rolled plates, i.e. in similar plate size the same tolerance for welded fabrications is obtained as for pressed components.

(4) In the case of the plates delivered to M.I.N. the listed tolerance is 10% of plate thickness if the plate is reduced to the minimum roll width - even so, this is $2\frac{1}{2}$% above the acceptable tolerance, and the price is considerably increased.

(5) Just what surface finish and rolling tolerances can be achieved will only be determined after full discussions with the steel manufacturers. M.I.N. Management are currently endeavouring to get a technical team from the Steel Company (Zelezarna Jesenice) to visit Nis by an early date. It was obviously desirable for the field team to visit the Steel Company - this was the original intention, but as it involves a fourteen hour journey by car each way, time available in the project area would not allow the three days that would have been necessary.

4.00 CONT'D.

1. STEEL PRESENTLY USED FOR AXLE HOUSINGS

C. Recommendations

(1) It must be stressed to the steel manufacturers that axles for trucks and buses are "life and limb" components, i.e. if a bus axle breaks, a lot of people can be killed. The surface imperfections must be greatly improved, more care must be taken in the preparation of the ingots, and dirt inclusions must be eliminated. ROLLING TOLERANCES MUST BE MAINTAINED.

2. QUALITY OF PRESSINGS

A. Results

(1) The quality and dimensional discrepancies of the half pressings produced are very poor, and 90% of the following difficulties in the welding techniques and the rough machining being experienced at M.I.N. stem from this first operation.

(2) The basic problem is the tooling. The punch and die are too shallow by an estimated 75 mm respectively. The tools are only working over the drawing radius from arms into banjo: they should be ironing over the end of the arms and into the bottom of the banjo if a true rounded up half pressing is to be produced.

4.00 CONT'D.

2. QUALITY OF PRESSINGS

A. (3) These half pressings were taken at random from the first run off the press and marked. The pressings were removed to the Inspection Department and measured. Existing press and die tools with half pressings are shown in Fig. 4.

B. Conclusions

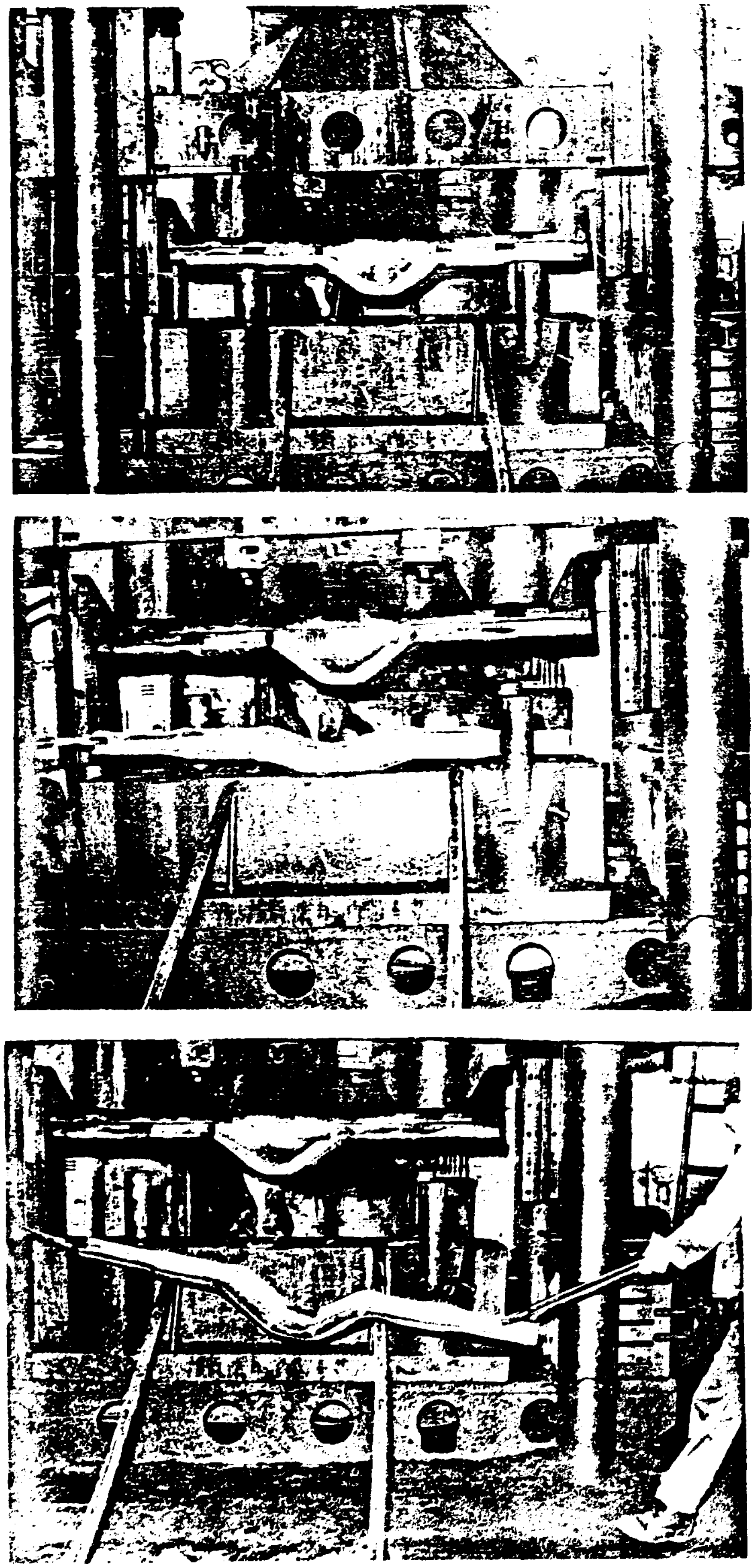
(1) The results are given in the following tables Fig. 5A and 5B.

It will be noted that on all pressings the same discrepancies are apparent. The pressings are on the average approx. 7 mm too wide and the arm ends are shallow.

(2) This condition means that when assembled the arms are not round, and on later processes they have to put in a 4 mm filler weld between pressings to make it possible to clean up the spindle ends on the machining operations.

C. Recommendations

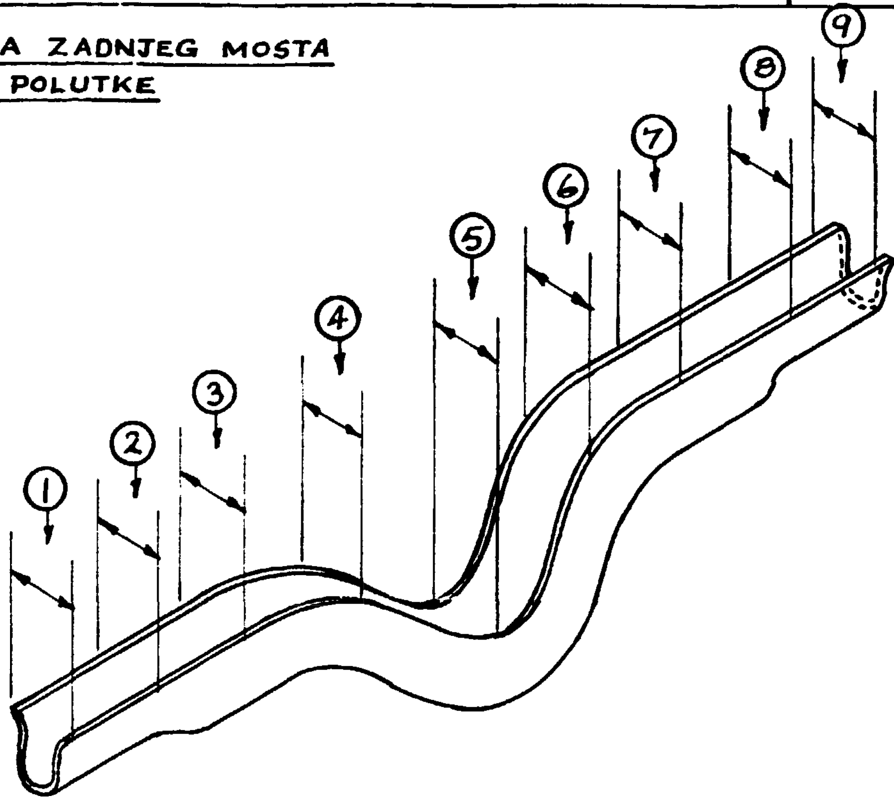
(1) To overcome these problems, the most satisfactory procedure would be to manufacture a new set of tools. This however would be extremely expensive, and in view of the fact that the axle is a very old design with limited life expectancy,



Photographs showing existing Press & Die Tools
with Half Pressings

NORRIS PARTNERS LTD.	Figure: 5A
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title REAR AXLE HALF PRESSING HALF PRESS WIDTH	Scale: N.T.S.

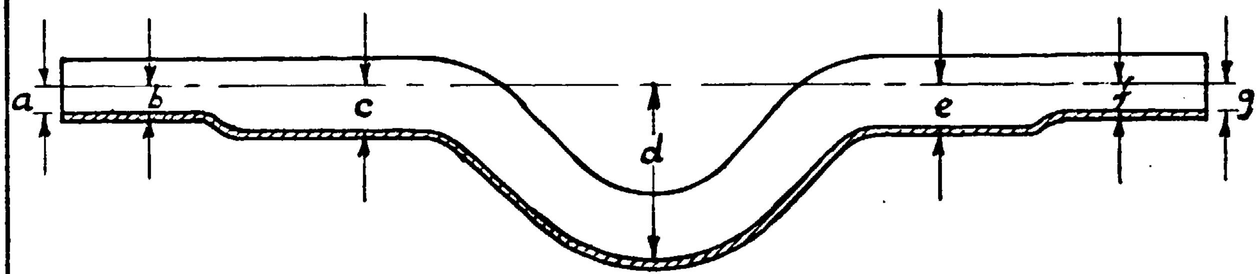
POLUTKA ZADNJEG MOSTA
ŠIRINA POLUTKE



MEASURING POINT MERNA MESTA	SIZE PER DRAWING MERA PO CRTEŽ	TOLERANCE TOLERAN	ACTUAL SIZE – IZMERANO		
			AXLE NUMBER – BR. MOSTA		
			1	2	3
1	93	+1 -0	101	101	101.5
2	93	+1 -0	100	100	101
3	130	+1 -0	137	137	137
4	154	+2 -0	161	160	160
5	154	+2 -0	158	159	159
6	154	+2 -0	159	159	160
7	130	+1 -0	137	137	136
8	93	+1 -0	101	101	100
9	93	+1 -0	101	102	101

NORRIS PARTNERS LTD.	Figure: 5B
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
Title STRAIGHTNESS OF REAR AXLE PRESSING IN VERTICAL PLANE	Drn. by: R.T.L.
	Scale: N.T.S

ODSTUPANJA OD OSE MOSTA U VERTIKALNOJ RAVI



MEASURING POINT MERNA MESTA	SIZE PER DRAWING MERA PO CRTEŽ	TOLERANCE TOLERAN	ACTUAL SIZE – IZMERANO		
			AXLE NUMBER – BR. MOSTA		
			1	2	3
a	31·5	+0.5 −0	36·5	36·5	36·5
b	31·5	+0·5 −0	31·5	31·5	31·5
c	50	+0·5 −0	50·5	50·5	51
d	194	+1 −0	194·5	195	193.5
e	50	+0·5 −0	50·5	50·5	51
f	31·5	+0·5 −0	31·5	31·5	31·5
g	·31·5	+0·5 −0	36·5	36·5	36·5

4.00 CONT'D.

2. QUALITY OF PRESSINGS

C. (i) cont'd.....

i.e. it is expected to be phased out of production within two to three years, it is recommended that the tools should be reconditioned.

(2) Punch to be packed, in order to increase by minimum 75 mm and to be reground.

(3) The female should be plated on top with a steel plate, again minimum thickness of plate 75 mm, surface and radii ground and new tool steel inserts fitted, new steelings to be blended into original tool. The punch packings, steelings, and top plate to be fully completed prior to breaking down the tool for fitment to avoid production delays; even so, it is estimated that final grind after assembly coupled with tool try-out will take 14 to 21 days and with a further 7 days allowed for contingencies, stockpiling of half pressings to cover customers requirements will have to be catered for.

(4) The resultant half pressing will then fully form round the punch giving the true semi-circular half round arm required. The pressing will tend to stick to the punch, but it will need only a simple stripper to be fitted to the tool to maintain automatic ejection.

4.00 CONT'D.

2. QUALITY OF PRESSINGS

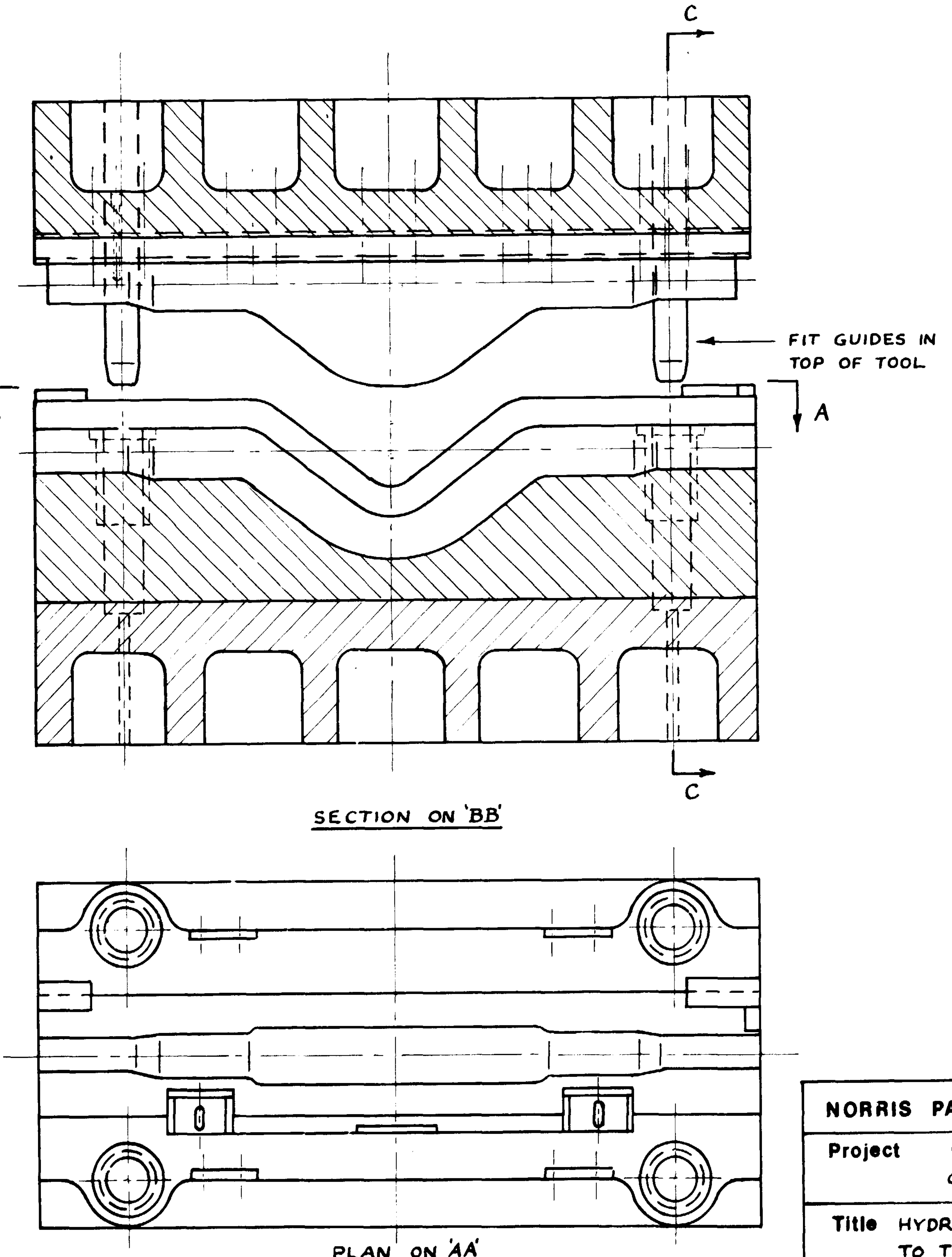
C. (5) The guide pillars on the press should be removed from the die and mounted in the punch; this simple modification would mean that with the ram up, the press bed is completely clear for loading and unloading, thus improving the handling.

(6) To increase ease of location under the above improved conditions, "L" shaped location pads should be fitted for end and side location, and shut height stops to be 0.6 mm above nominal material thickness to be fitted in order to maintain full control of the pressings.

(7) It must be stressed that if these modifications are carried out successfully, a large proportion of the difficulties arising currently on subsequent welding and machining operations will be elimin ated. Press tool modifications are shown in Fig. 6.

(8) M.I.N. are currently using disused engine lubricant on the dies as a drawing compound. We would stress that the use of oil on hot dies as a pressing lubricant is useless, as it burns off immediately it comes into contact with the hot workpiece.

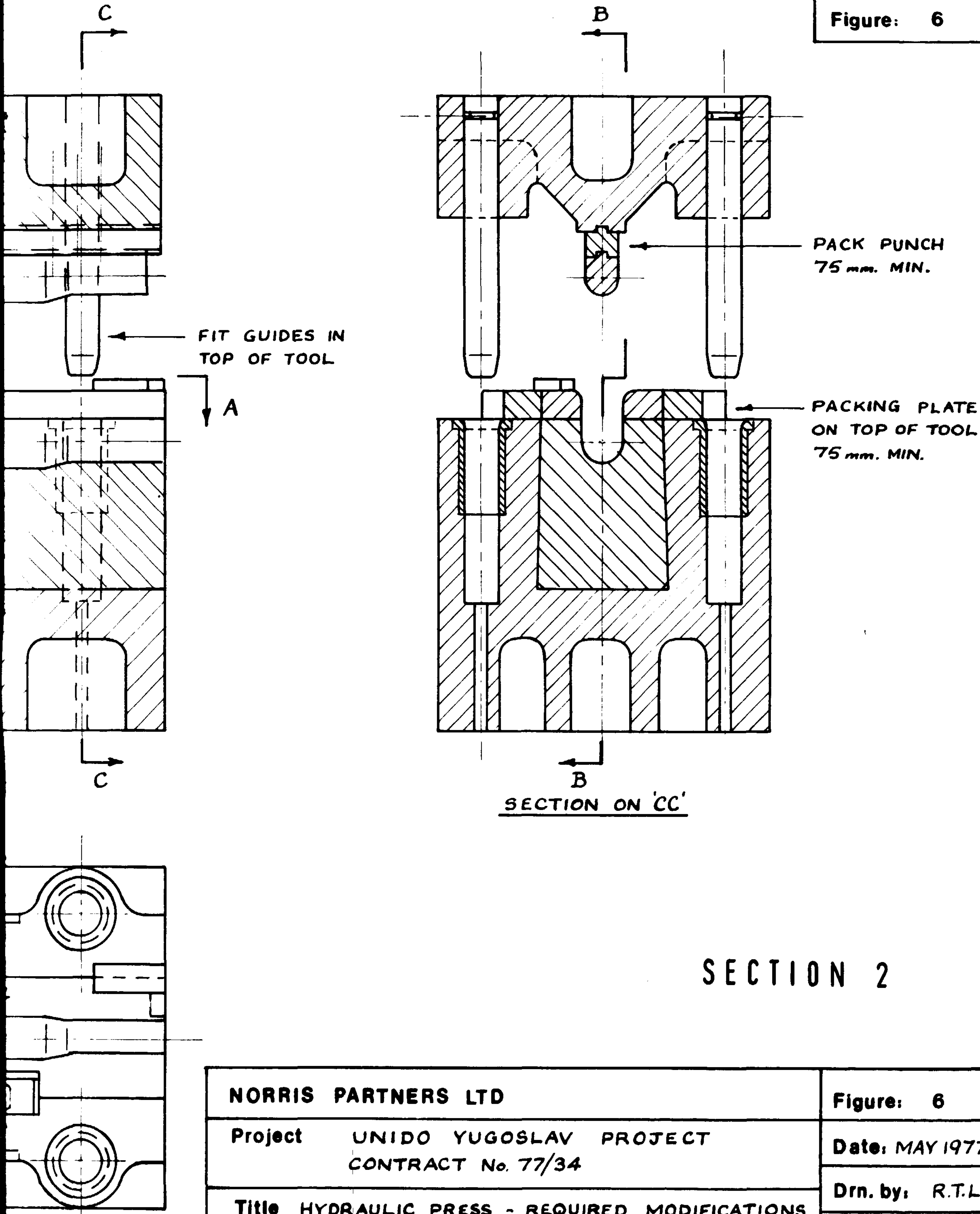
We would recommend the use of spheroidal graphite suspended in water and used in con-



NORRIS PART	
Project	UN CO
Title	HYDRAU TO TOO

SECTION 1

Figure: 6



SECTION 2

NORRIS PARTNERS LTD	**Figure:** 6
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	**Date:** MAY 1977
	Drn. by: R.T.L.
Title HYDRAULIC PRESS - REQUIRED MODIFICATIONS TO TOOLING FOR REAR AXLE HOUSING	**Scale:** 1:12·5

4.00 CONT'D.

2. QUALITY OF PRESSINGS

C. (8) cont'd.....

junction with a small pneumatic hand gun unit (Figs. 7 and 8). The dies should be blown out by air to clear the scale and graphite applied for every press operation.

3. HEAT TREATMENT FOR AXLE HOUSING BLANKS

A. Results

The heating of the axle housing blanks prior to press requires a furnace of the Walking Beam type (as indicated in the appended outline Drawing No. Q1/3875 of Wellman Incandescent Ltd, England, Appendix 1), to obtain a production rate of one blank every two minutes, i.e. 30 per hour. Operating characteristics of the Walking Beam Furnace will be:-

(a) Oil Fired.

(b) Temperature required 850°C.

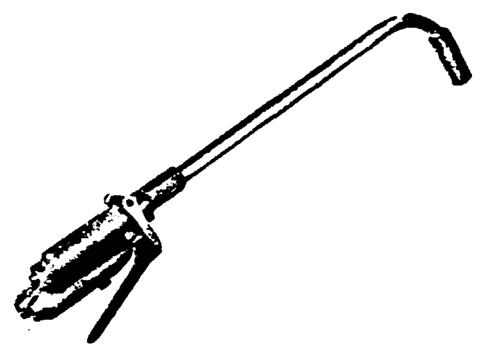
(c) Time required for blanks to pass through furnace - load to offload 24/30 minutes (24 minutes preferable).

Existing furnace and operating conditions for loading and unloading axle housing blanks are shown in Fig. 9.

B. Conclusions

(1) The installation of a new furnace of the Walking Beam type will present considerable difficulty

PNEUMATIC HAND SPRAY GUN UNIT



The Dog Model 085 Hand Blow Gun acts by siphoning. However when the liquid is heavy viscous or when a very long extension tube is required it should be connected to a Dag pressurized liquid tank system.

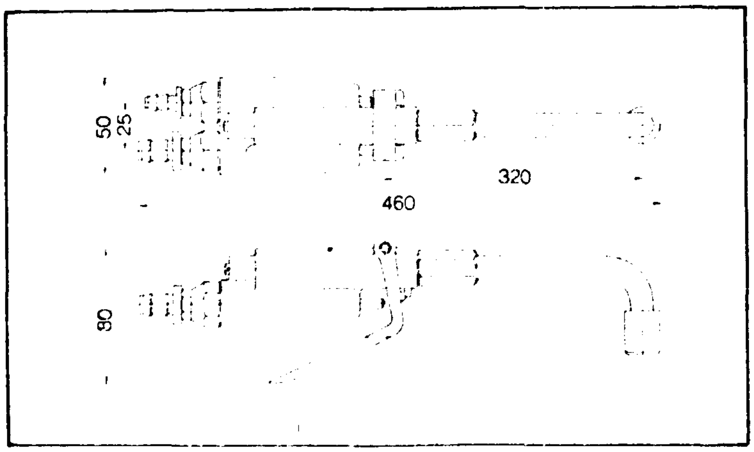
This handgun delivers a large volume of air for cleaning and cooling of the dies. When pushing the dual action trigger lever further an adjustable quantity of the liquid is added to the air and a large jet of the release agent is applied to the die surfaces.

This type of handgun is especially suitable for large pressure die-casting machines or forging presses, by which beside an ample spray also good cooling properties are required.

This model is supplied with a standard aluminium body and the total weight of it is only 360 gr. It is self - cleaning and due to its simplified construction it is practically maintenance free.

The standard aluminium 1/4 inch pipe extension tube is furnished with a 90° bend and is 30 cm. long. Other lengthes and angles may be selected for specific application.

The adjustable liquid metering screw provides positive flow control. The air volume depends on the inlet pressure which may range from 3 - 7 bars.



DESCRIPTION	PART NUMBER
Complete System with handgun and 7,5 l. liquid pressure tank	125 - 1030
Complete System with handgun and 25 l. liquid pressure tank	125 - 2030
Complete System with handgun and 60 l. liquid pressure tank	125 - 4030
Handgun only, without hoses	085 - 0030
Handgun with T head, without hoses	085 - 0530
Handgun only, with hoses	085 - 1030
Handgun with T-head with hoses	085 - 1530

For tank system details, refer to page F 9

SPRAY GUN UNIT LIQUID PRESSURE TANK

The handgun spray system model 125 consists of a liquid pressure tank model 060 and a handgun model 085, connected by 2,5 metre long hoses, attached by quick connecting fittings.

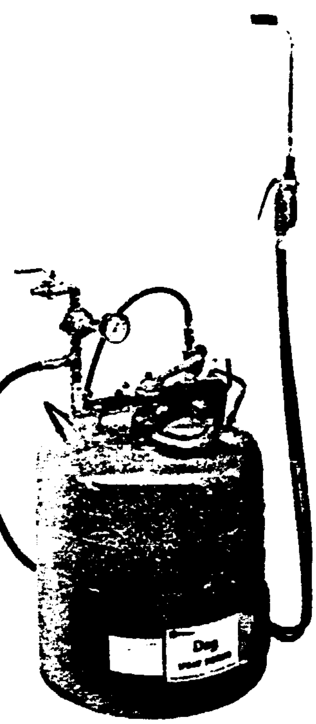
Tanks are available in the following sizes: 7,5, 25, 60 and 200 litre.

For handgun spray systems, the tank is normally equipped with air agitation but the 60 and 200 litre tanks can also be supplied with an air driven paddle wheel stirrer. A single pressure regulator controls the tank as well as the handgun pressure. Operating air pressure ranges from 3 to 6 bars with the air pressure determining the volume of air discharged.

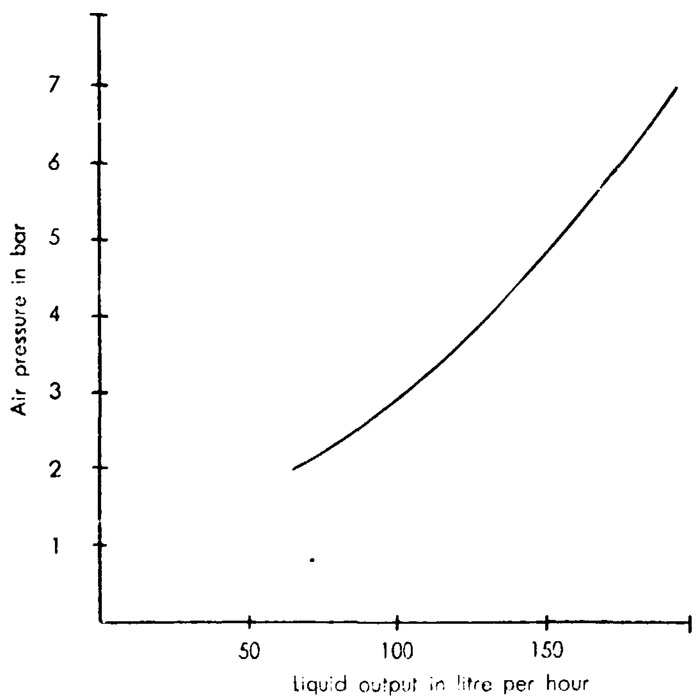
The model 085 handgun has a 2-stage squeeze trigger, the first releases air for cleaning and the second adds a finely atomized spray pattern to the air stream. And adjustable liquid metering screw provides positive flow control.

The standard handgun is equipped with an aluminium 1/4 inch pipe extension tube, furnished with a 90° bend and 30 cm. long. Other lenghts, angles or T-head may be selected for specific application.

For tank details please refer to page C 1 and F 5 and for handgun details to page D 11.



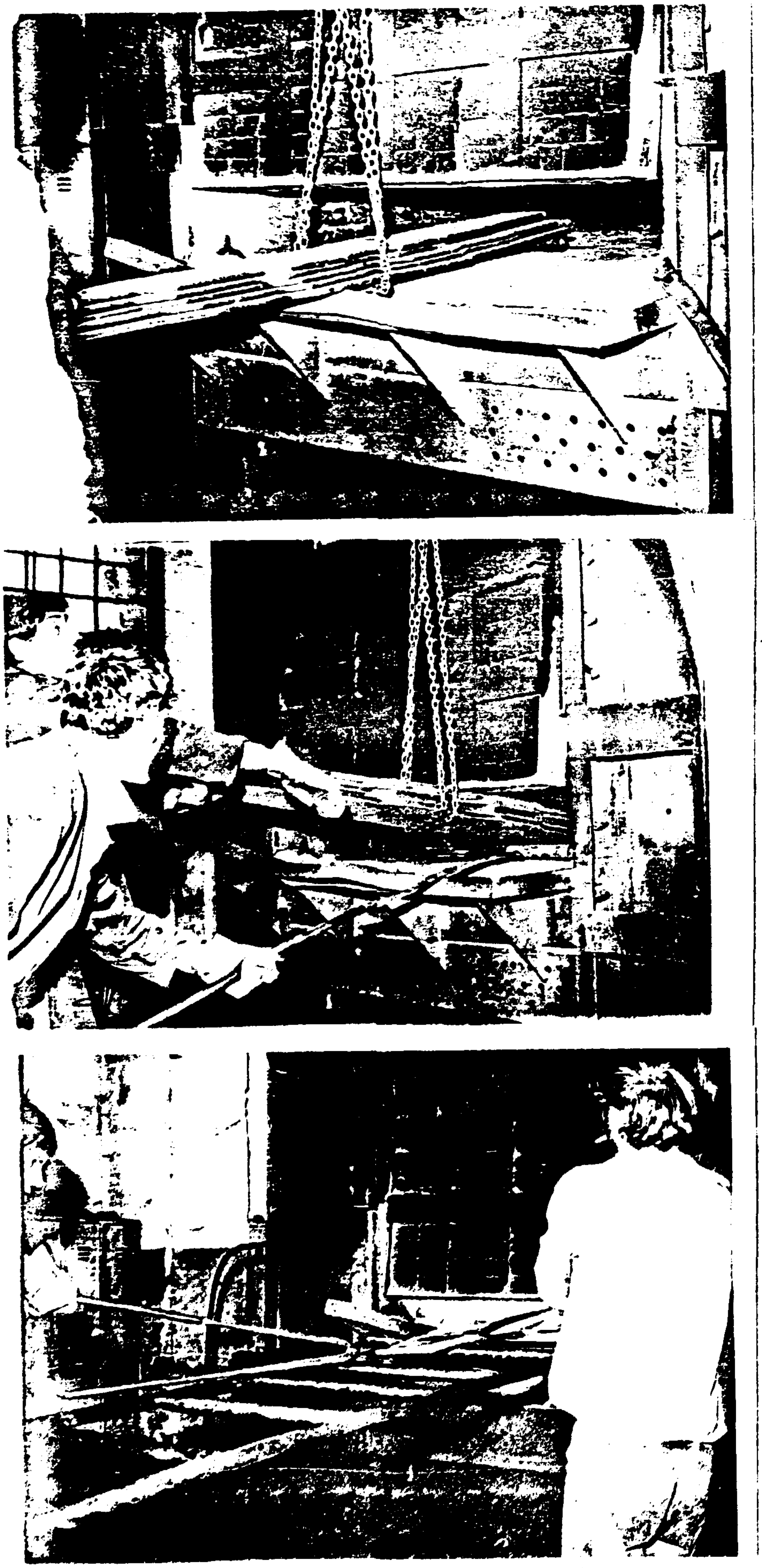
sample shown: 125 - 4030



Capacity curve of handgun 085 - 0030 when liquid pressure 1 bar lower than air pressure.

DESCRIPTION	PART NUMBER handgun with	
Complete system (including standard 085 handgun) and	90° extension	T-head
7,5 l. tank	125 - 1030	125 - 1530
25 l. tank	125 - 2030	125 - 2530
60 l. tank	125 - 4030	125 - 4530
200 l. tank	125 - 5030	125 - 5530

Figure 9.



Photographs showing existing handling of Blanks into and out of Furnace

4.00 CONT'D.

3. HEAT TREATMENT FOR AXLE HOUSING BLANKS

B. (1) cont'd.....

at M.I.N. as it is essential that production continues to meet customer's requirements while the new furnace is being installed, estimated time for installation being two to three months. We are therefore faced with two possibilities:-

(a) To knock down existing furnace and install new furnace on the same site. This would mean that enough half pressings would have to be produced prior to demolishing the old furnace to keep the customer going for three months, plus a contingency of one extra month as insurance against delays and snags, i.e. four months supply of pressings, or alternatively

(b) To re-site new furnace on the other side of the press. In the latter case there will be problems, as a Walking Beam Furnace needs approx. 2 metre pit to accommodate the arms etc., and to facilitate servicing. These underworks will foul the services to the press. We can see no reason why this problem is insurmountable, but feel that the final decision should be left to M.I.N. (Appendix No. 2 refers).

4.00 CONT'D.

3. HEAT TREATMENT FOR AXLE HOUSING BLANKS

C. Recommendations

(1) General

In either case we recommend that the furnace is fed from the front of the press position, discharging onto a roller track at the rear. The height of the press bed from the floor is approx. 889.60 mm. The height of the roller track to feed the press should be approx. 1016 mm, giving a 127 mm drop. This drop will ensure ease of handling, as the blanks will only have to be push. off the track and will slide onto the pressing position on the bed. If the blank is transferred from the track to the press automatically by the addition of two small pneumatic cylinders, the track should be at the same height as the press bed and the blank pushed straight across.

(2) The height of the furnace unload position should be approx. 1219.8 mm and should provide for a drop in the roller track between furnace discharge and transfer to the press of approx. 203.2 mm.

This will also be the height of the furnace with the walking beams in the down position from the floor hearth position plus 25.4 mm, giving a total from the floor of 1245.2 mm.

(3) To facilitate ease in feeding the press, the guide pillars presently positioned in the press bed will

4.00 CONT'D.

3. HEAT TREATMENT FOR AXLE HOUSING BLANKS

C. (3) cont'd.....

have to be removed and repositioned in the ram. This will leave the face of the tools free for positioning the blank. The same procedure should be adopted to facilitate discharge from the press on the opposite side. The length of the roller track for either and the width 400 mm.

5.00 BODY OF REPORT

1. MANUFACTURING OPERATIONS FOR AXLE HOUSINGS

In the immediate future, i.e. within six months, M.I.N. intend to change their welding parameters on the axle case seam. It is intended to use a semi-automatic submerged arc machine and to weld the seam in one pass (currently the seam is welded in three passes by semi-automatic CO_2 plus a final pass by manual arc weld using conventional stick electrodes). While the new intended method will save time and labour, it is felt that porosity will present a very real problem.

During the investigations, considerable interest was expressed in the use of CO_2 automatic welding, but a divergence of opinion was expressed during discussions with the M.I.N. Production Staff, in that some favoured submerged arc process. In this regard, we would comment as follows on submerged arc versus MIG CO_2.

Metallurgically there is very little significant difference. Modern practice on high production plants in Western Europe and North America generally prefer MIG CO_2, as the consumables are considerably cheaper and there is no need for flux handling equipment, de-slagging and the possibility of flux contamination. This reduces mechanical maintenance caused by flux abrasion, and avoids the loss of flux due to spillage around the machine. Against these advantages, MIG CO_2 gives less build up of weld and the appearance is not as good as submerged arc as the reinforcement is not being removed. There is no arc glare from

5.00 CONT'D.

1. MANUFACTURING OPERATIONS FOR AXLE HOUSINGS (Cont'd)

submerged arc, but this is somewhat problematical on accurate butted seams, as it is difficult to judge the exact position of the arc.

However, it is recommended that the following inspection procedures are adopted for seam welds on axle cases using submerged arc machines.

A. Seam Weld Inspection

(1) Each weld must be visually examined by a Senior Inspector to determine the quality of the joint - welds must show characteristics of fusion penetration and soundness of weld deposit.

(2) Weld must be of good appearance and not be subject to excessive weld spatter.

(3) Accuracy of the weld must be measured using fillet gauges.

(4) 100% check on all welds should be carried out using penetrating die in the early stages of production. This could be reduced to normal 5% selection after two to three months of initial production.

(5) Undercutting must not exceed 10% of wall thickness in depth and 15% of weld length.

(6) Penetration of weld should be shown on process drawing.

5.00 CONT'D.

1. MANUFACTURING OPERATIONS FOR AXLE HOUSINGS (Cont'd)

B. Welding Techniques

(1) It is recommended that tacking prior to welding should continue, and that a filler run should be made using Inert Gas CO_2 with 1.2 mm wire prior to final run with submerged arc set. This procedure should allow to some extent for the difficulties which may be experienced in keeping the slave carriage on centre line. If filler weld is not used, then copper backing plate will be necessary.

(2) Recommended welding sequences are shown in Fig. 10.

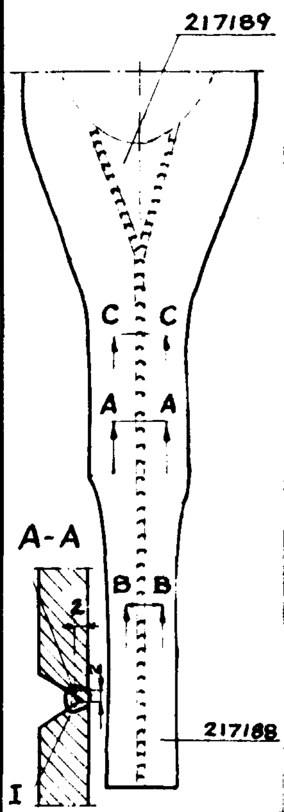
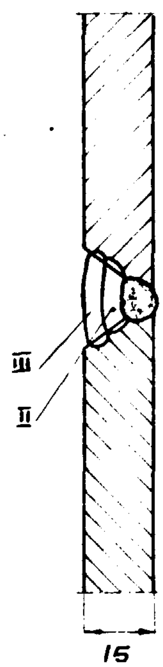
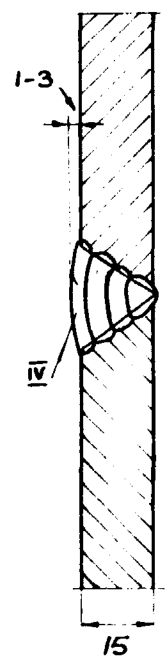
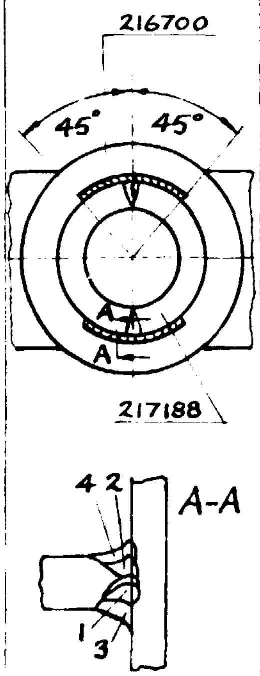
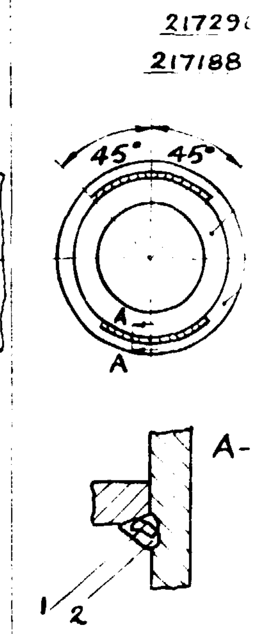
(3) Examples of modern friction welding machines for both banjo and beam type axles are shown in Figs. 11 and 12. The examples are of a 125 Ton machine and a typical double-ended machine that can be used for welding simultaneously spindles on banjo or beam axles. The machines as supplied by Clarke Chapman Ltd, England, are within current budget price range (but excluding automation) of £140,000 Sterling for single ended 125 Ton unit, and the double ended unit at £210,000 Sterling. In addition to the budget prices, shear type flash removal, monitoring, fixed or expanding type bungs for location would be required.

Notes:
1. SEE ALSO TABLES 5.2/B8, B9 & B10.

NORRIS PART[illegible]

Project UN[illegible] CON[illegible]

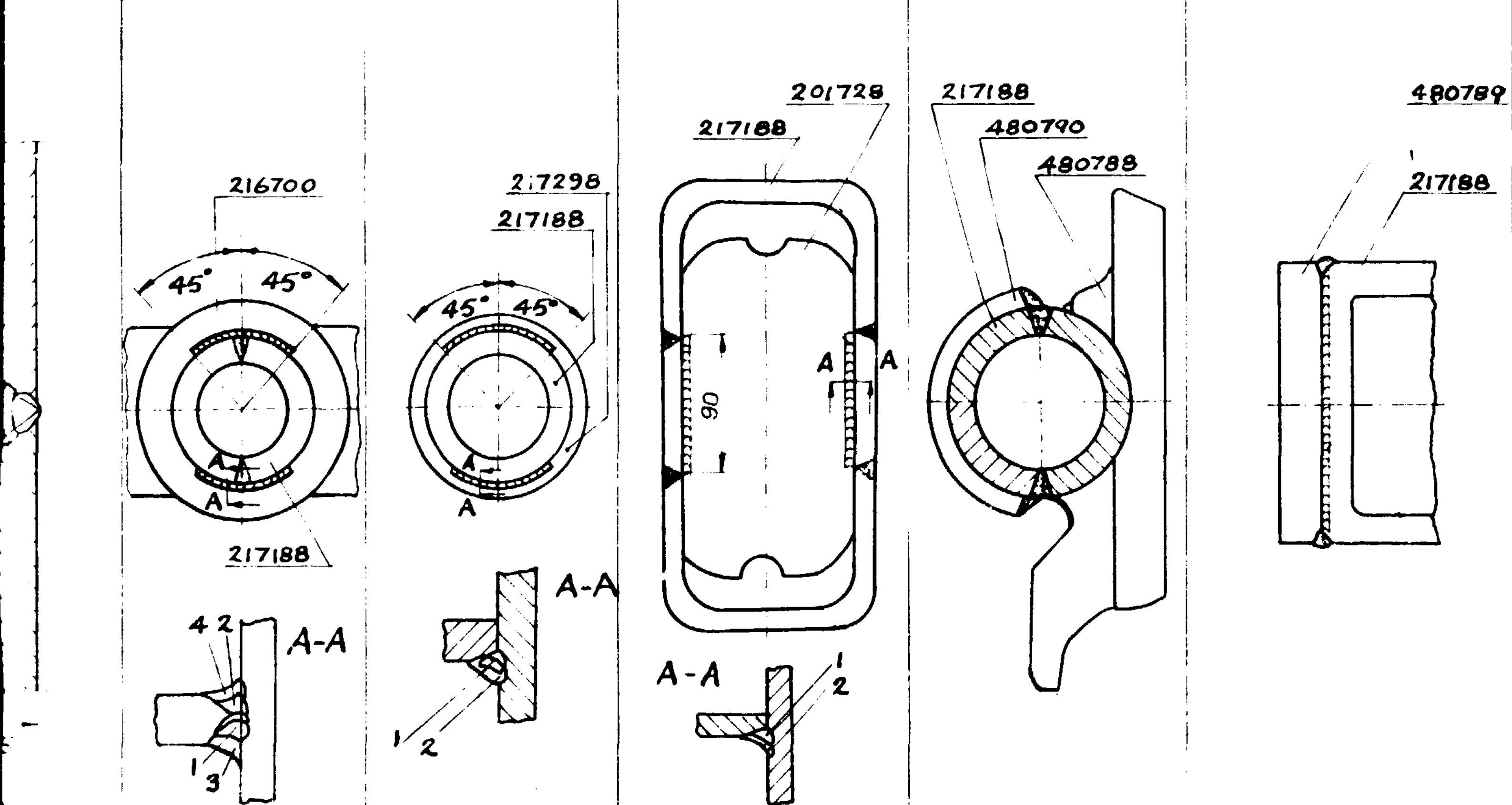
Title AXLE H[illegible] CURRE[illegible]

<table>
<tr><td>OPERATION</td><td>1</td><td>FILLER WELD
WELD DEPTH
3 - 4 mm.</td><td>FILL TWO RUNS
SECTION B-B</td><td>FINAL RUN
MANUAL
ARC - WELD
SECTION C-C</td><td>WELD FLANGE
AS SHOWN
100% PENETRATION
SECTION B-B</td><td>WELD FLANGE
AS SHOWN
SECTION D-[illegible]</td></tr>
<tr><td>DETAILS</td><td>2</td><td>
</td><td>
</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>SEQUENCE OF WELDING</td><td>3</td><td>FILLER WELD</td><td>FILLING IN</td><td>FINAL RUN</td><td>WELD ALTERNATE SIDES AS PER DRAWING</td><td>WELD ALTERNATE SIDES AS PER DRAWING - ON[illegible] RUN AND COVE[illegible]</td></tr>
<tr><td>SHAPE AND LENGTH</td><td>4</td><td>3 - 4 mm DEPTH
4350 mm LENGTH</td><td>8 mm DEPTH</td><td>4 mm DEPTH</td><td>7 mm DEPTH
2x100 mm LENGTH</td><td>5 mm DEPTH
2x47 mm LENGT[illegible]</td></tr>
<tr><td>RECOMMENDATIONS</td><td></td><td>WELD PENETRATION 70% ON SEAM, 100% ON GUSSET. WITH CORRECT PRESSINGS 2 mm GAP ELIMINATED. FILLER NOT REQUIRED.</td><td>WITH CORRECT PRESSINGS, ANGLE WILL BE REDUCED FROM APPROX. 45° TO 27/30° TWO RUNS ONLY 1·6 mm WIRE.</td><td>UNNECESSARY</td><td>TACK AND WELD - ONE RUN ONLY.</td><td>WELD WITH ONE RUN ONL[illegible] NO COVER REQUIRED.</td></tr>
</table>

SECTION 1

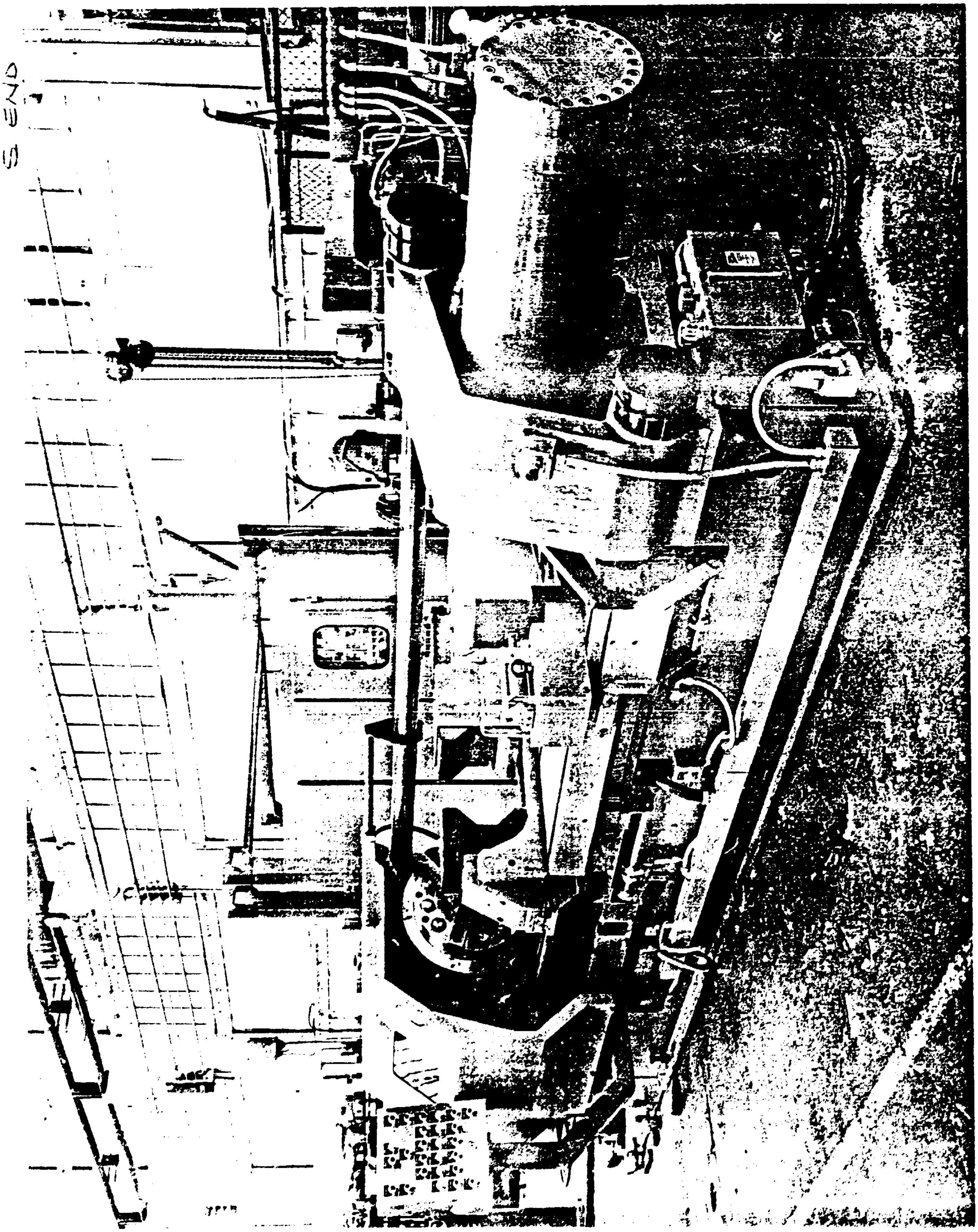
NORRIS PARTNERS LTD	**Figure:** 10
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	**Date:** MAY 1977
Title AXLE HOUSING WELDING SEQUENCES CURRENT AND RECOMMENDED	**Drn. by:** R.T.L.
	Scale:

RUN IAL VELD N C-C	WELD FLANGE AS SHOWN 100% PENETRATION SECTION B-B	WELD FLANGE AS SHOWN SECTION D-D	WELD SADDLE WITH FILLER WELD DEPTH 5mm 1 SIDE ONLY 2 RUNS SECTION C-C	WELD - 2 RUNS 7mm DEPTH SECTION E-E	WELD - 2 RUNS 7mm DEPTH SECTION B-B

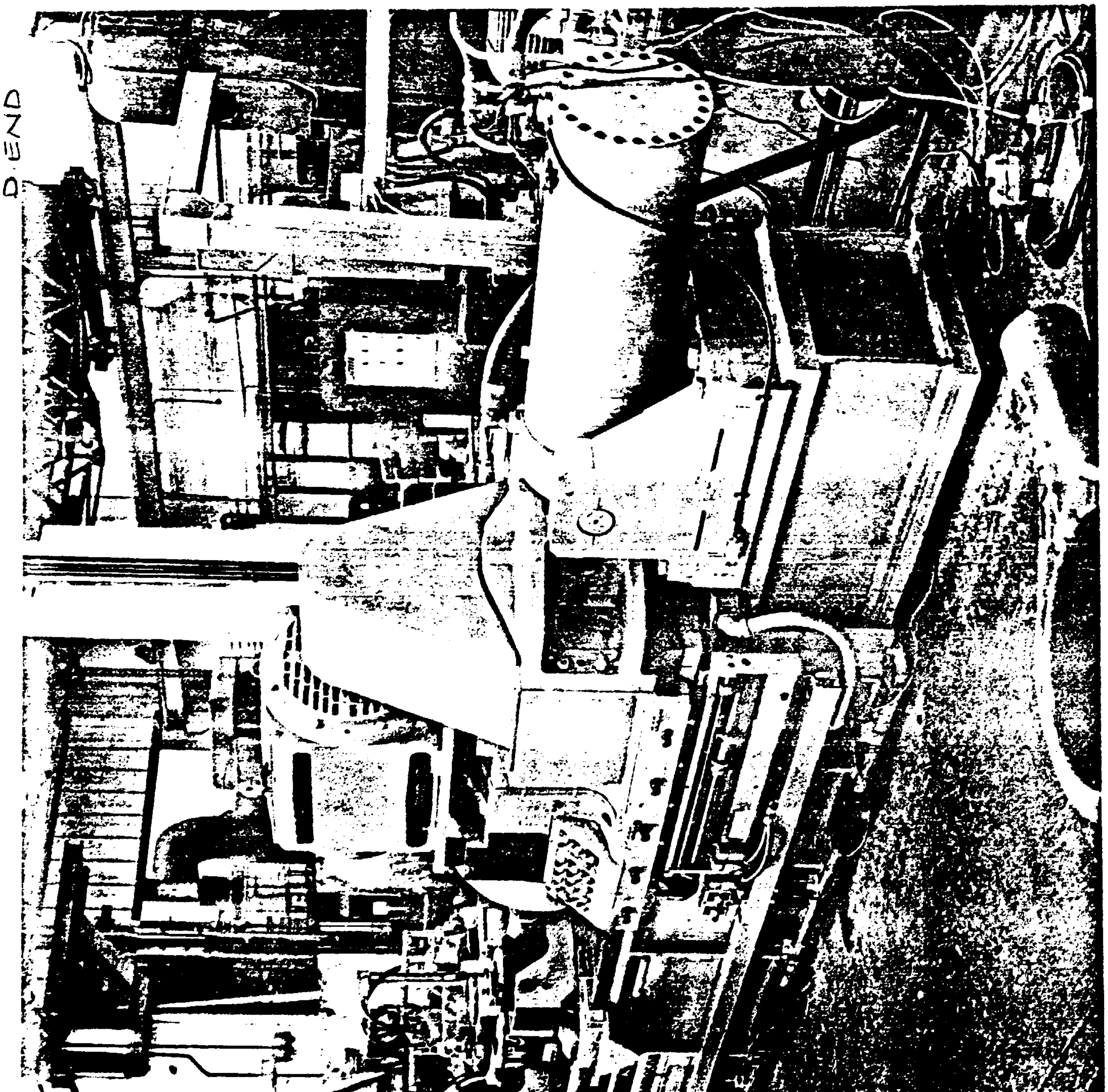


RUN	WELD ALTERNATE SIDES AS PER DRAWING	WELD ALTERNATE SIDES AS PER DRAWING - ONE RUN AND COVER	WELD ALTERNATE SIDES AS PER DRAWING TWO RUNS	WELD AS PER DRAWING TWO RUNS	WELD AS PER DRAWING TWO RUNS
EPTH	7mm DEPTH 2x100mm LENGTH	5mm DEPTH 2x47mm LENGTH	5mm DEPTH 180mm LENGTH	7mm DEPTH 268mm LENGTH	7mm DEPTH 480mm LENGTH
SARY	TACK AND WELD - ONE RUN ONLY.	WELD WITH ONE RUN ONLY. NO COVER REQUIRED.	WEL1 ONE RUN ONLY.	WELD ONE RUN ONLY.	WELD ONE RUN ONLY.

SECTION 2



PHOTOGRAPH OF SINGLE ENDED FRICTION WELDING MACHINE



PHOTOGRAPH OF DOUBLE ENDED FRICTION WELDING MACHINE

5.00 CONT'D.

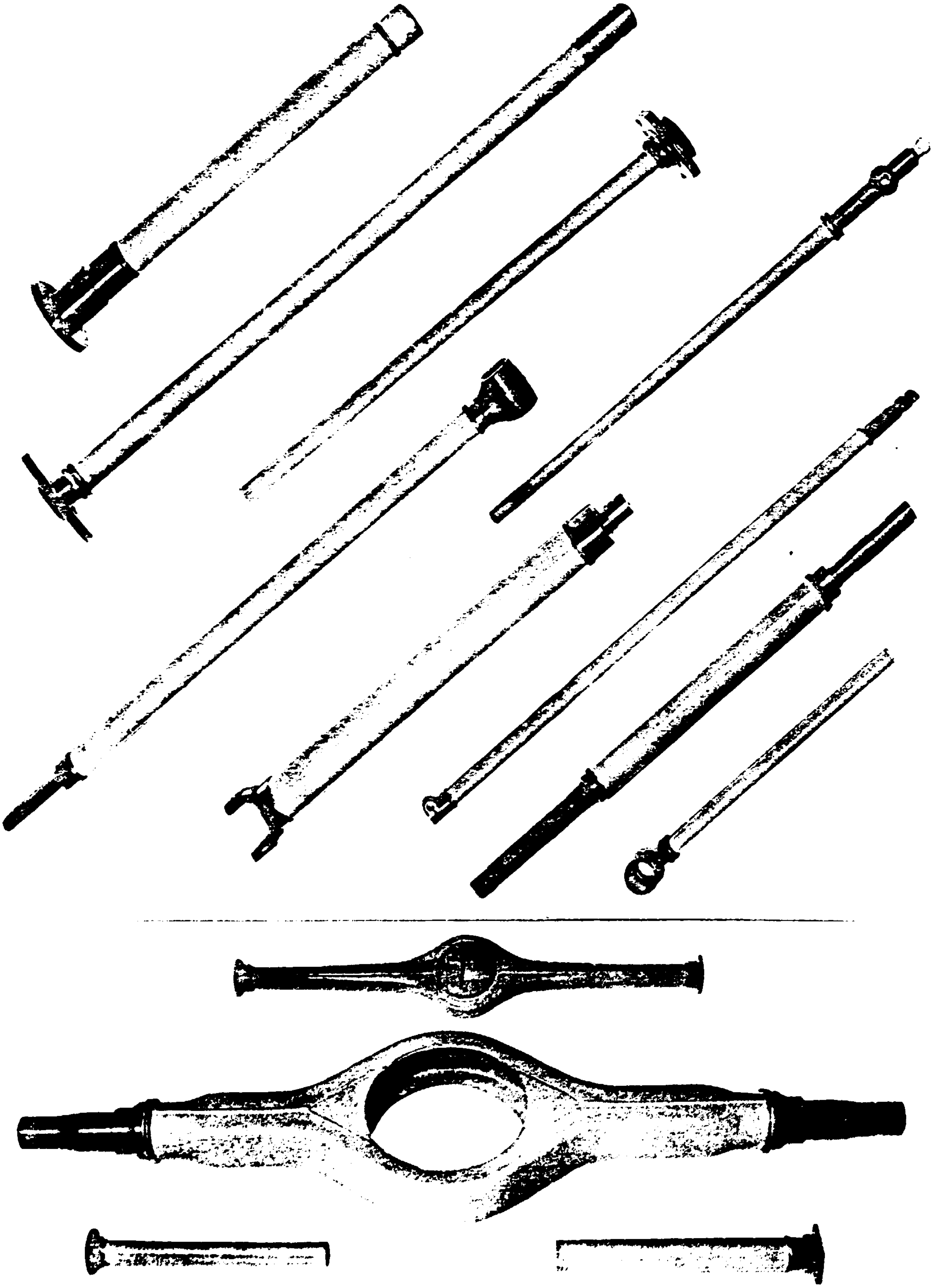
1. MANUFACTURING OPERATIONS FOR AXLE HOUSINGS (Cont'd)

B. (4) On modern axle housing construction utilising spindle enc forgings, welding of the spindle ends is achieved by friction welding techniques (photographs of both single and double ended machines are enclosed - Figs. 11 and 12). We also illustrate typical items of components used in passenger cars and trucks, including Drive Axles, Propeller Shafts, Suspension Links, Steering Shafts and Gear Levers (Fig. No. 13). A single ended machine as illustrated would be ideally suitable for the anticipated production volumes of M.I.N. over the next 10/15 years.

(5) Safety Precautions in Inert Gas Welding

Inert-gas-metal-arc welding processes (MIG) produce intense ultra-violet radiation which is harmful to the eye and skin.

Eye and face protection should be accomplished with a welding helmet which has Shade 10 or 12 welding glass. In addition, the operator should wear No. 2 shade flash goggles beneath the helmet. Skin must be completely covered. Leather gloves are recommended for hand protection. Heavy, dark coloured clothing should be worn to prevent radiation penetration to the skin or reflecting on the neck under the helmet. Light weight leather clothing is recommended because of its durability



A selection of components used for Passenger Cars, including Axle Housings, Drive Axles, Propeller Shafts, Suspension Links, Steering Shafts and Gear Levers.

5.00 CONT'D.

1. MANUFACTURING OPERATIONS FOR AXLE HOUSINGS (Cont'd)

B. (5) cont'd.....

and resistance to deterioration from radiation. Clothing made of cotton will deteriorate rapidly when subjected to ultra-violet radiation. Adequate ventilation should be provided to remove fumes which are produced by this welding process.

(6) Highly toxic gases are formed when the vapour from HALOGENATED (dissolving) solvents are subjected to ultra-violet radiation. Therefore, it is recommended that degreasers and other sources of these vapours cannot reach the welding operation. Much of the protection required in metal arc and the gas shielded processes for continuous welding is not required for arc spot welding IF THE WELDING GUN NOZZLES WHICH FIT WELL OVER THE ARC ZONE ARE USED. Since the arc is completely enclosed by the nozzle, radiation from the arc is greatly reduced. In these cases sufficiently dark flash glasses (flash goggles) will provide adequate eye protection.

C. Considerations: Hot & Cold Pressing

The practicality of the use of Hot or Cold Pressing techniques in the manufacture of axle housings depends on the following criteria:-

(a) The facilities available.

5.00 CONT'D.

1. MANUFACTURING OPERATIONS FOR AXLE HOUSINGS

C. Considerations: Hot & Cold Pressing (cont'd)

(b) Availability of suitable steels.

(c) The quantities required.

Each factor having a major impact on the economics.

Hot Pressing

(1) Imperative that material has grain control McQuaid 5 - 8, and grain in longitudinal direction for pressing. However, some mill marks are permissible parallel to the grain.

(2) Steel can be purchased as rolled strip with medium limit tolerances, and less mill marks than experienced on plate.

(3) Press operation is restricted to single operation on single press with average tonnages, i.e. 800/1000 ton.

(4) Pressing techniques and tool manufacture is comparatively simple, i.e. either close grained nickel/iron in the lighter range of axle housings, and close grained nickel/iron with tool steel inserts for the heavy cases: obviously the quality of the tooling should be based on the production quantities required, i.e. low volume tooling, medium volume tooling, or high volume tooling. The number of times the tools are broken down and re-set must also be taken into consideration, as

5.00 CONT'D.

1. MANUFACTURING OPERATIONS FOR AXLE HOUSINGS

C. (4) cont'd.....
this factor has major impact on tool life and is especially important in small press shops with limited plant, i.e. where one press is used on a variety of jobs.

(5) Hot pressed axle housings tend to be heavier than housings manufactured by cold press methods, since in the latter case better quality steel of thinner gauge can be utilised.

Cold Pressing

(1) Critical that material is grain controlled and mill marks are eliminated (any mill marks will have adverse effects on fatigue under difficult press conditions).

(2) Steel can only be purchased as plate; gauge tolerances are therefore more difficult to control.

Steel is more expensive as tolerances required are $2\frac{1}{2}$% of plate thickness, as against 5% on plate or rolled strip for hot pressing.

(3) Tooling must be of highest quality and expensive.

(4) Press capacity is higher, and two operations are involved, i.e. one 1500 ton and one 1000 ton - presses must be modern, accurate, and in first class condition.

5.00 CONT'D.

1. MANUFACTURING OPERATIONS FOR AXLE HOUSINGS

D. Recommendations

In making recommendations appertaining to M.I.N. as to most suitable methods, the opinion of the investigating team in respect of cold pressing is:-

(1) That no suitable steel is available ex Yugoslavian Mills. In fact, steel will have to be considerably improved to meet satisfactory criteria for hot pressing.

(2) No existing presses are available and new press equipment would have to be purchased - estimated lead time two years. Cost of two oil hydraulic presses, i.e. one 1500 Ton and one 1000 Ton, approximately £350,000 each at today's prices. (Typical example shown at Appendix No. 3).

(3) It is not felt that the required expertise and experience in press shop techniques are available at M.I.N.

(4) It is not felt that tool design and tool manufacturing facilities are available at M.I.N. to cater for high technology presswork.

E. Conclusion

It is judged that cold pressing of axle housings within the M.I.N. manufacturing complex would not be possible and the required ultimate production would not justify the capital expenditure involved.

5.00 CONT'D.

2. <u>CURRENT PRODUCTION METHODS AND RECOMMENDED IMPROVEMENTS</u>

A. Analysis of existing production methods indicated reasonable scope for introduction of changes that would provide improvements in methods and equipment with consequent advantages in reduction of measured time per various operations, better materials handling, improved quality control, and the possibility of either eliminating or combining some elements through the operational sequence.

B. Details of the initial analysis and preliminary recommentations are given in the following tabulated sequence of manufacturing operations, Tables 5.2/B1, 5.2/B2, 5.2/B3, 5.2/B4, 5.2/B5, 5.2/B6 and 5.2/B7.

It is considered that the recommendations could be embodied in the sequence of manufacturing operations at comparatively low cost, other than for Operations 2, 4, 14 and 17. The recommendations are also related to minimum disturbance of existing plant facilities for manufacture of axle housings, other than for Operation 2.

C. As investigations continued to terminal date of field duties at the M.I.N. Plant, further consideration was given to Operations 5, 20 and 23 relative to overall improvement of methods and manning, as displayed on Tables 5.2/B8, 5.2/B9 and 5.2/B10.

CURRENT PRODUCTION METHODS AT M.I.N.

OPERATION	TYPE OF EQUIPMENT	COMMENTS	OP. NO.	RECOMMENDED CHANGES (PRELIMINARY)
Flame Cut Blanks.	Multi cut from Pantograph.	Satisfactory.	1	Try-out to be made using rectangular blank 300 mm wide - if this method proves satisfactory, a saving of approx. 33% in material would be possible.
Heating Furnace for Press	O.S. 3.35 x 2.13 m. Internal 1.45 x 2.35 m. Type not known. Oil fired - no pre-heat for lighting. Doors open 350 mm.	Raise to temperature 2/3 hours. Heating time in furnace 45 mins. Temp. 950^{o} - no temperature control. Blanks stacked two stacks of five.	2	Furnace is not satisfactory and has no temperature control. Blanks are stacked in fives and on checks carried out, temperature variations of up to 200^{o}C were found between the top of the blank and the underside. The handling of the blanks is difficult and a new Walking Beam type furnace is essential. Full recommendations are given in this Final Report.
Press Tools	Heavy Grey Iron Cast-Steel Inserts Punch & Die Mat. Inserts 5740 Size 2.2 x .975 m.	(A) No blank location or shut height stops.	(A)	Being fitted 26-4-77. Not seen in operation.

TABLE 5.2/B1.

CURRENT PRODUCTION METHODS AT M.I.N. (Cont'd)

OPERATION	TYPE OF EQUIPMENT	COMMENTS	OP. NO.	RECOMMENDED CHANGES (PRELIMINARY)
Press.	Ruhard Fernau, Vienna 1000 Ton Water Hydraulic down rated to 800 Ton. Down stroke 1.3 m. Bed size 2.95 x .975 m.	Approx. 40/50 years old. Water leaks. Guides satisfactory. No excessive play on ram through stroke cycle.	3	Not seen in operation. Press satisfactory but not fitted with any means of ejection. Giving consideration to spring ejection, but doubt if this will be possible with current tooling.
Shot Blast Half/Pressing	Gutman. Roller track fed. Good condition.	Satisfactory machine. Used for other components.	4	Feel that this could be eliminated by using Coloidal spray technique. Investigation not complete.
Straightening Press	M.I.N. made. 100 Ton.	Good condition. Used for other components.	5	If clamping pressure is increased at flame cutting, this operation could possibly be eliminated - investigation not yet complete.
ABOVE OPERATIONS 1 - 5 IN FORGING & PRESSING DEPARTMENT UNDER OWN MANAGEMENT				
Flame Cut Chamfer.	Soitaab (Italy). Twin Head. Off Template or Pantograph.	Good condition. Clamps not strong enough to pull down, hence Op. No. 5 Forging & Presswork. Discard 12/25 mm.	6	Increase clamping pressure - raise height of flamecut to centreline plus 0.75 mm to eliminate gap and to give $1\frac{1}{2}$ mm for necessary rounding.

TABLE 5.2/B2.

CURRENT PRODUCTION METHODS AT M.I.N. (Cont'd)

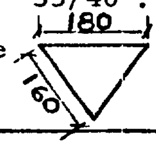
OPERATION	TYPE OF EQUIPMENT	COMMENTS	OP. NO.	RECOMMENDED CHANGES (PRELIMINARY)
Dress Edges	Hand Grind.	To remove oxides prior to welding.	7	No comments.
Assembly and Tack 2 Half Pressings & 4 Gussets.	2 Assembly Stations (tables) using clamps, spacers and rings.	Slow - 4 mm gap left in bottom of "V", no land at bottom of chamfer. Combined angle of "V" 35/40°. Gusset Size 	8	Make hydraulic clamping fixture. Clamping pressure required approx. 40 Tons - this will eliminate gap and will show savings in welding times. Under discussion with M.I.N.
Filler Weld First Run	Inert Gas CO_2 Essab 400 amp used on tilting table.	Length of weld 4350 mm. Depth of weld 3-4 mm. Wire 1 mm.	9	Eliminate gap. Increase wire to 1.6 mm. Penetration on seam weld need be only 70/80% - weld on gusset must be 100% penetration - gusset ends should be double welded.
Weld 2 Runs	Inert Gas CO_2 Essab 400 Amp One Operator on two stations.	Length of weld 4350 mm. Depth of weld 8 mm each run. Wire 1.2 mm each run.	10	Experimenting with 1.6 mm wire. If 2.4 mm wire was used this could be done with one run, but larger CO_2 set would be required, i.e. 600 Amp Machine.

TABLE 5.2/B3.

CURRENT PRODUCTION METHODS AT M.I.N. (Cont'd)

OPERATION	TYPE OF EQUIPMENT	COMMENTS	OP. NO.	RECOMMENDED CHANGES (PRELIMINARY)
Final Cap Weld	Manual Arc D.C. 250 Amp. Yugoslavian made.	Length of weld 4350 mm. Depth of weld 4 mm. Coated Touch Rod 5 mm.	11	Not required if procedure in 10 is adopted.
Visual Inspection		Visual inspection of weld.		
Flame Trim	Hand Torch off mechanical swing guide.	Remove excess metal.	12	O.K.
Straighten	Hydraulic Press built by M.I.N. 100 Ton (est.)	For arms only prior to first machining operation.	13	This operation should be a cold rounding up straightening operation. Op. 16 should be for complete axle housing and not just for arms as at present.
Rough Turn Spindle Ends	Two Gap Bed Centre Lathes 1. 2667 mm B.C. 212 mm Bed/Centre. 2. Potishmorando 2740 mm B.C. 275 mm Bed to Centre.	One lathe very old belt driven. Second lathe geared head Yugoslavian made.	14	Introduction of copy lathe would reduce production time by 80%

TABLE 5.2/B4.

CURRENT PRODUCTION METHODS AT M.I.N. (Cont'd)

OPERATION	TYPE OF EQUIPMENT	COMMENTS	OP. NO.	RECOMMENDED CHANGES (PRELIMINARY)
Cut to Length	Plant as above.	Operation 14.	15	See Op. 14.
Straighten	Hydraulic Press 100 Ton (est.)	For Rear Banjo Face only.	16	Refer to Op. 13 - Arms and Banjo should be done in one operation with simple tooling.
Bore through Face Rear.	Horizontal Boring Machine.	One machine being installed. Both existing and new (secondhand) very light.	17	Very slow - both machines too light. With modern bore/face equipment would reduce times by 80%, i.e. floor to floor 6 minutes.
Fit Oil Seal Ring to Arms	Hand torch to heat forced on by hammer.	No comment.	18	Small muffle furnace should be installed when throughput increases; very little cost.
Fit Baffle.	Manual Arc D.C. 250 Amps.	Locate on tube. Four tacks on each baffle - 5 mm Rutile coated touch rod.	19	Normal method - O.K.
Tack Cylinder Brackets.		Locate on Welding Fixture.	20	Investigating to see whether it can be included in Operation 22.

TABLE 5.2/B5.

CURRENT PRODUCTION METHODS AT M.I.N. (Cont'd)

OPERATION	TYPE OF EQUIPMENT	COMMENTS	OP. NO.	RECOMMENDED CHANGES (PRELIMINARY)
Fit Brake Flange.	Reversible Vertical Press 5 Ton. Inert Gas CO_2	First run in fillet - 2 opposite Back & Front alternate - Weld length 247 mm Depth 5 mm.	21	O.K. - Floor to floor times should be improved.
Assy & Tack Spring Seats	Hydraulic Holding Press. Manufactured M.I.N.	Difficult loading onto locations.	22	Tapered bung location rather than full through bore should be adapted. This would make loading much easier.
Finish Weld all Brackets	Two Stations Manual Arc D.C. 250 Amps.		23	Using two runs - normal one run CO_2 satisfactory - further investigation being undertaken.
Stress Relieve	2 front charged electric furnaces. Depth 2325 mm Door: 1473 mm wide 762 mm open Trolley and Forklift Truck.	Load 8 at a time - raise temp. 800°- 860° approx. 4 hours. Close and soak 1 hour door closed, gradual cool 1 hour door open.	24	Indications that this is doing more harm than good. Full and detailed report after discussions with customer (F.A.P.). At this stage feel that stress relieving should be eliminated.
Straighten	Press (Hydraulic) 100 Ton. M.I.N.	True arms prior to coning and second rough machining.	25	Consideration to be given to new inspection and straightening aids. Time is excessive.

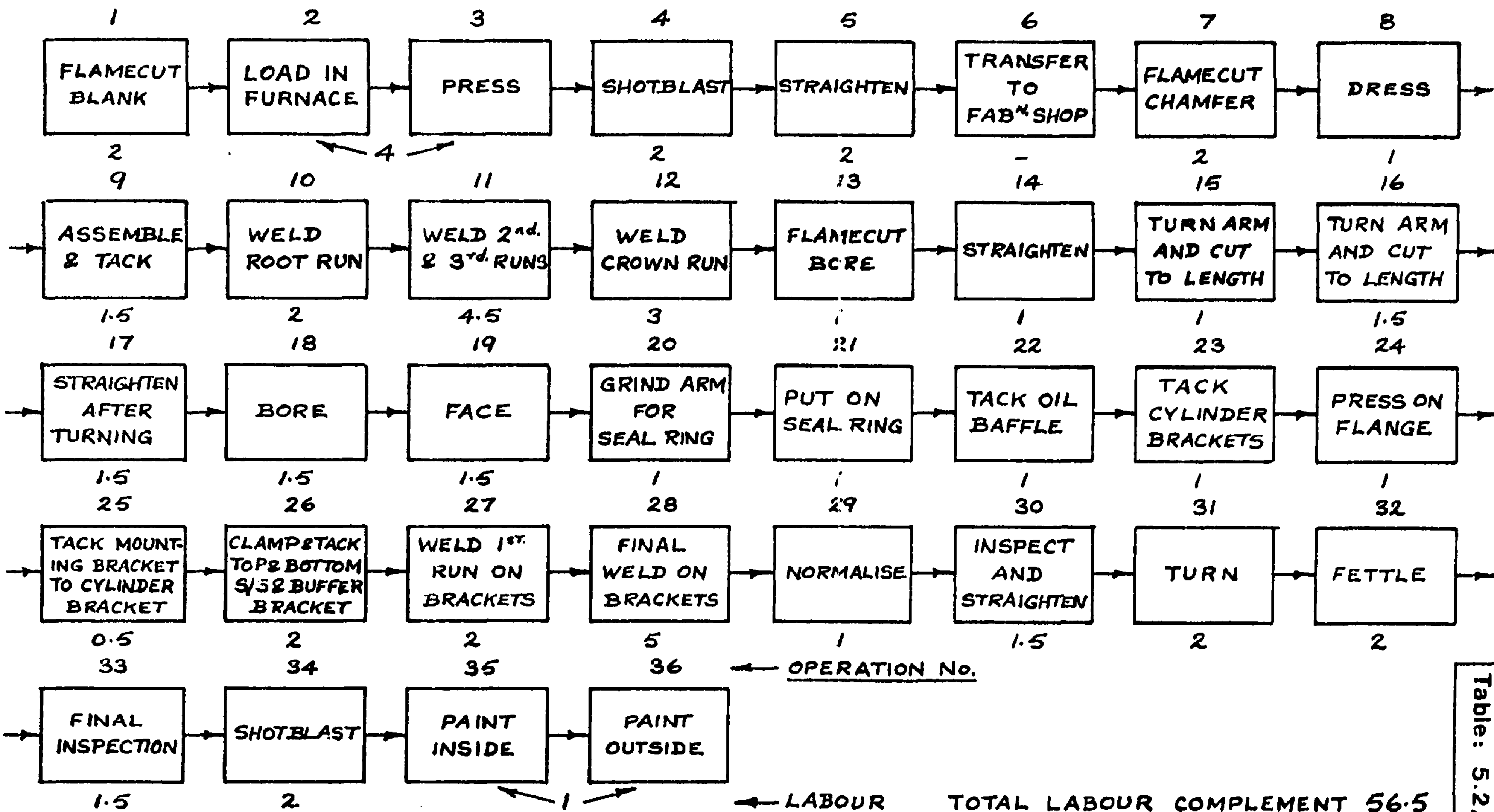
TABLE 5.2/B6.

CURRENT PRODUCTION METHODS AT M.I.N. (Cont'd)

OPERATION	TYPE OF EQUIPMENT	COMMENTS	OP. NO.	RECOMMENDED CHANGES (PRELIMINARY)
Inspection	Table and Standard Equipment.		26	Not seen.
Cone Ends Turn Spindle Ends Brake Flange	Centre Lathe (Wafrum) 2425 BC - 254 Centre to Bed.	Coning badly out of centre on high percentage.	27	Cone badly out of centre. Consider-ation to new techniques.
Shot Blast		Done in another Department.	28	Not seen - but necessary.
Final Inspection	Standard Equipment.	Dimensions & Weld.	29	O.K.
Fettle	Manual.	8 Men Hammer & Chisel.	30	Consider pneumatic hammer or rotary equipment.
Paint.	Manual Brush.	Red Oxide Outside. White Inside.	31	O.K.
PERIODICAL QUALITY CONTROL BY CUSTOMER (F.A.P.)				

TABLE 5.2/B7.

EXISTING SEQUENCE OF OPERATIONS & PLANNED MANNING LEVELS AS AT MAY 1977

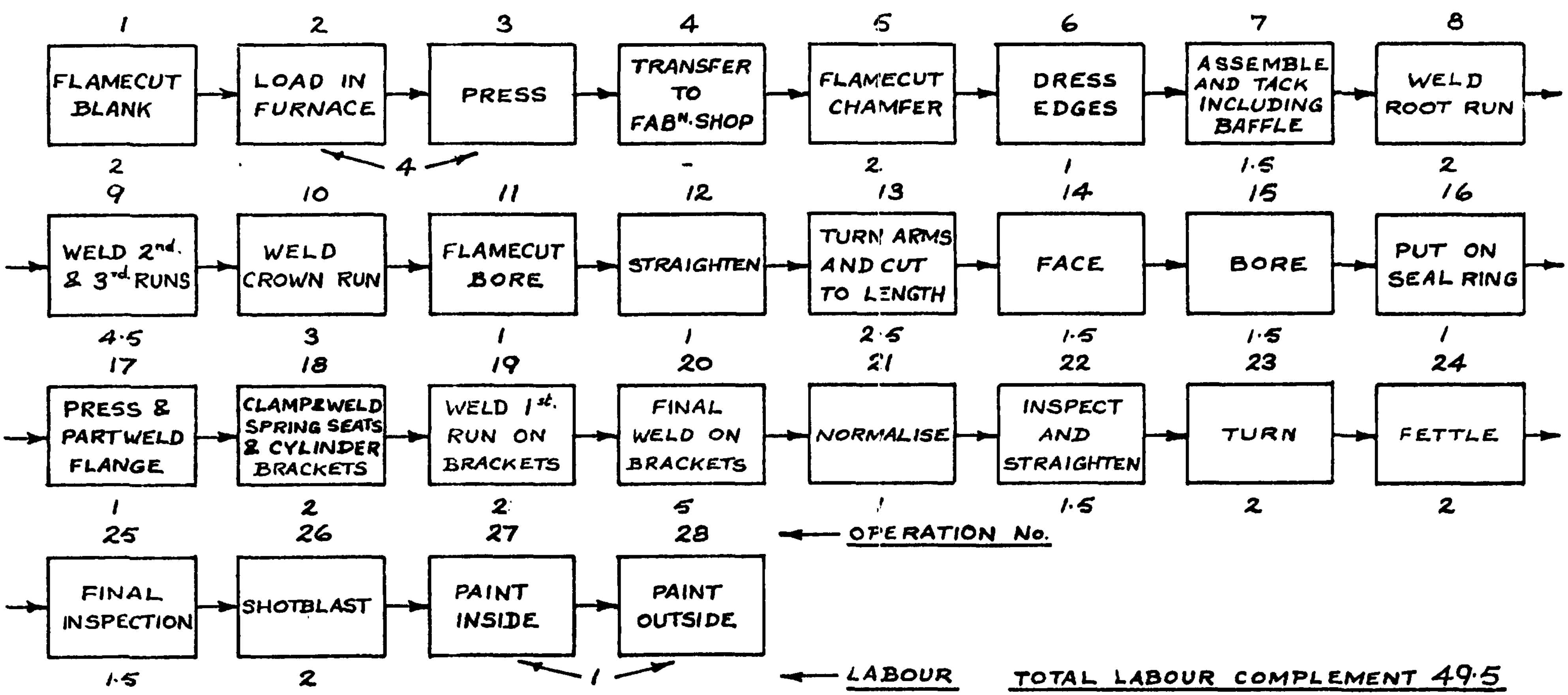


TOTAL LABOUR COMPLEMENT 56.5

BASIS: 500 HOUSINGS PER MONTH WITH ACCEPTANCE OF M.I.N. CYCLE TIME PER OPERATION OF 21.6 MINS. ON A 510 MINUTE SHIFT DAY AND 250 WORKDAYS/ANNUM.

Table: 5.2/B8

SEQUENCE OF OPERATIONS & PROPOSED MANNING LEVELS WITH MINIMAL CHANGES

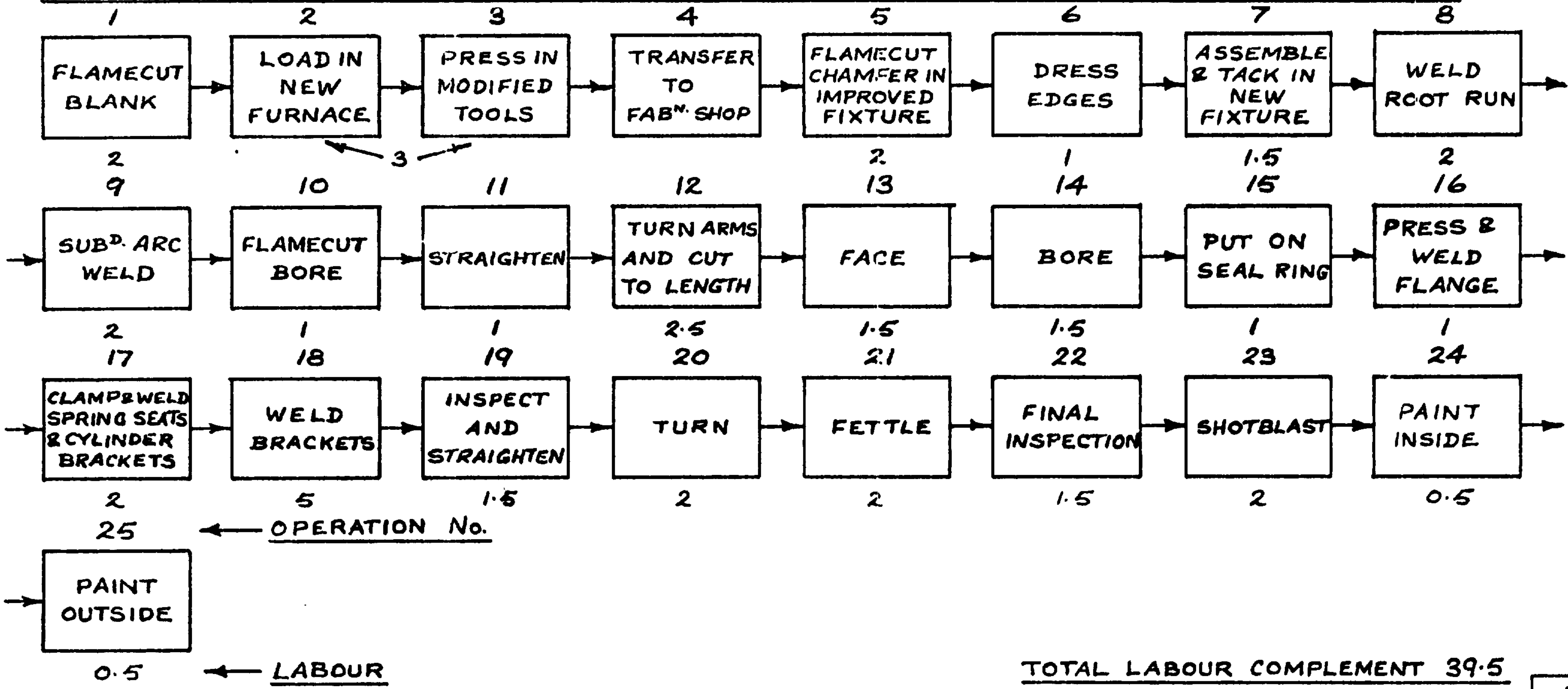


BASIS: 500 HOUSINGS PER MONTH WITH ACCEPTANCE OF M.I.N. CYCLE TIME PER OPERATION OF 21·6 MINS. ON A 510 MINUTE SHIFT DAY AND 250 WORKDAYS/ANNUM.

Table: 5.2/B9

Table: 5.2/B10

SEQUENCE OF OPERATIONS & FORECAST MANNING LEVELS WITH NEW PLATE HEATING FURNACE, MODIFIED PRESS TOOLS, NEW TACK AND ASSEMBLY FIXTURE AND SUBMERGED ARC WELDING.



TOTAL LABOUR COMPLEMENT 39.5

BASIS : 500 HOUSINGS PER MONTH WITH ACCEPTANCE OF M.I.N CYCLE TIME PER OPERATION OF 21.6 MINS, ON A 510 MINUTE SHIFT DAY AND 250 WORKDAYS/ANNUM.

5.00 CONT'D.

2. CURRENT PRODUCTION METHODS AND RECOMMENDED IMPROVEMENTS

D. (1) TABLE 5.2/B8.

Shows the combination of work carried out in the Flamecutting Department and the Press Shop (Operations 1 to 5), and the Fabrication Department (Operations 6 to 36, with the exception of 34).

(2) TABLE 5.2/B9.

Shows the following recommended changes:

A4 - Shot Blasting: It is considered that this is is not necessary, as the amount of scale present would not have a detrimental effect on the welding, as Operation B6 (Dress Edges) would remove the oxides present after flamecutting.

A5 - Straighten: This would not be required, as improved clamping at the flamecutting stage (40 Tonne) would be sufficient to pull down the pressings into the fixture.

A17 - Straighten after Turning: Not required as the facing operation could be carried out by locating directly from the front face (Fig. 14).

A22 - Tack Baffle: This operation to be included with Operation B7.

5.00 CONT'D.

2. CURRENT PRODUCTION METHODS AND RECOMMENDED IMPROVEMENTS

D. (2) TABLE 5.2/B9 (cont'd)

A23 - Tack Brake Cylinder Brackets: It was demonstrated that this operation could be combined with Operation B18 (clamp and tack top and bottom spring seats).

(3) TABLE 5.2/B10.

Illustrates the situation incorporating imminent short-term changes.

(i) A new plate heating furnace.

(ii) Alteration and modification to the press tools (Fig. 6 refers), with consequential improvement in the dimensional accuracy of the half pressings.

(iii) Changes as shown under Table 5.2/B9.

(iv) A new assembly and tacking fixture (Figs. 15 and 16 refer).

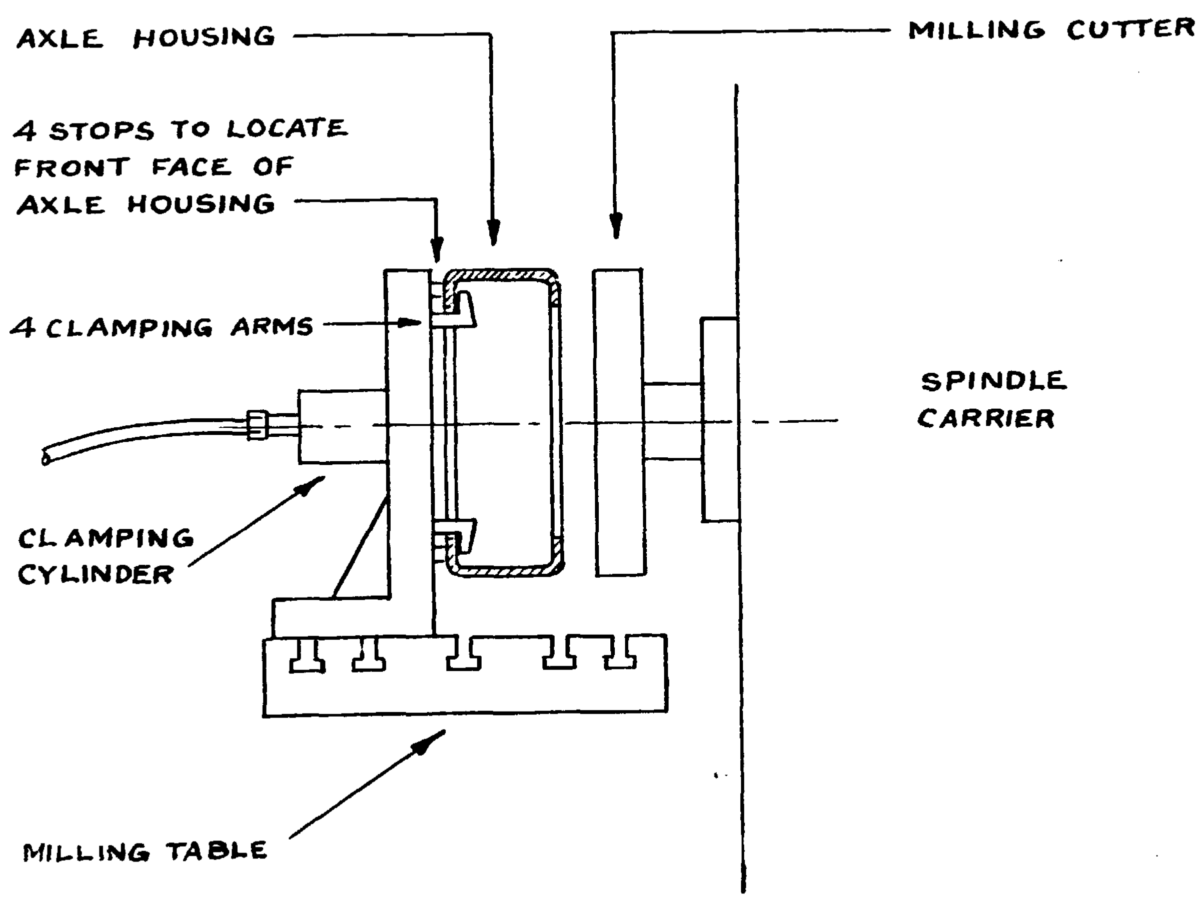
(v) The introduction of semi-automatic submerged arc welding, or alternatively the introduction of fully automatic MIG CO_2.

(vi) Increased wire sizes and transformer sets at Operation C18 with welding carried out at a single pass. (Present procedures can be improved and the same welding carried out in two runs using 1.6 mm. wire with the current transformer equipment).

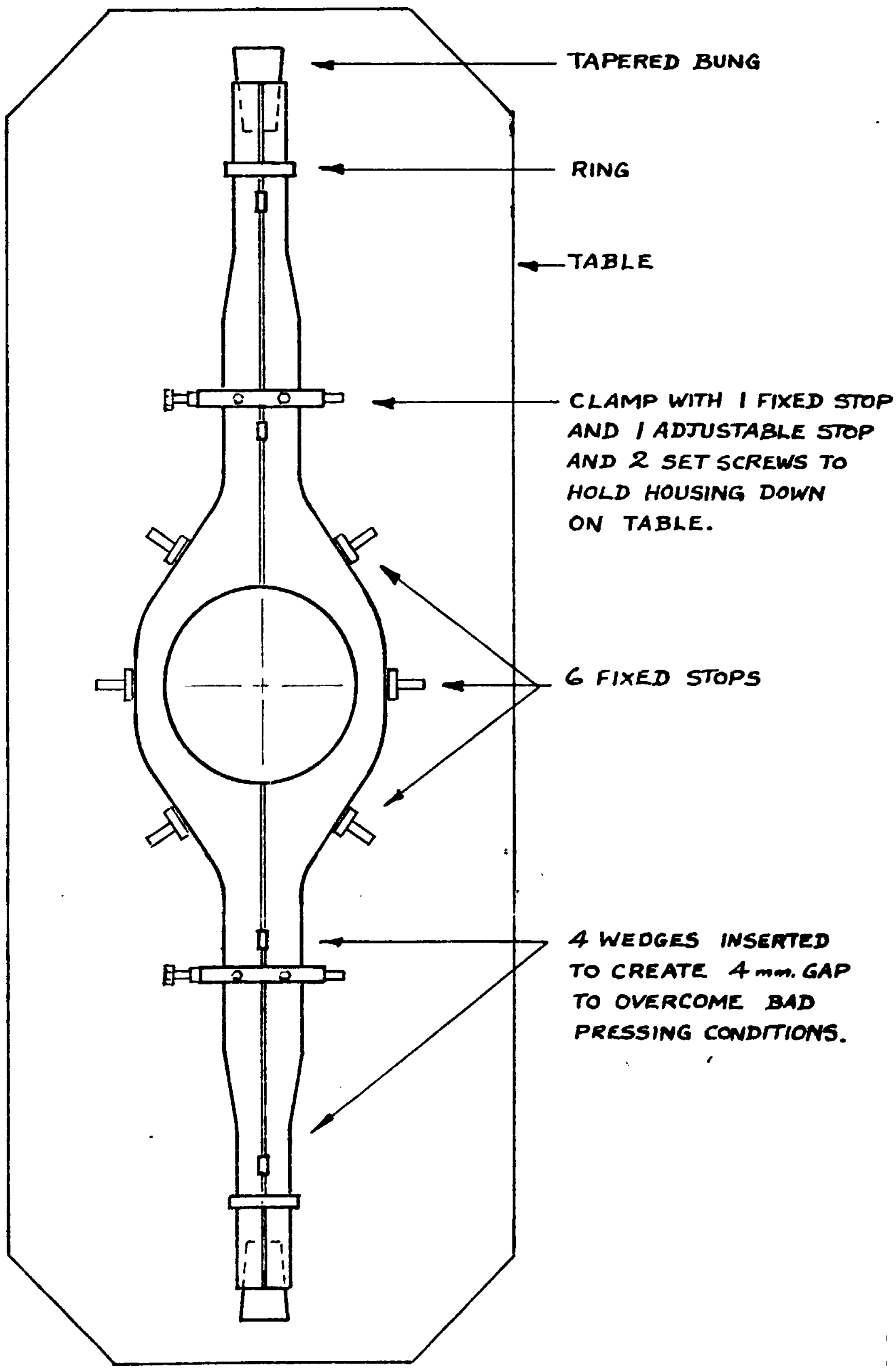
NORRIS PARTNERS LTD	Figure: 14
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title AXLE HOUSING LOCATION & CLAMPING ARRANGEMENTS ON MILLING MACHINE TO ELIMINATE PRIOR STRAIGHTENING OPERATION	Scale: 1:10

REFERENCE :

TABLE ----- 5-2/B5
OPERATION --- 16 - FACE REAR



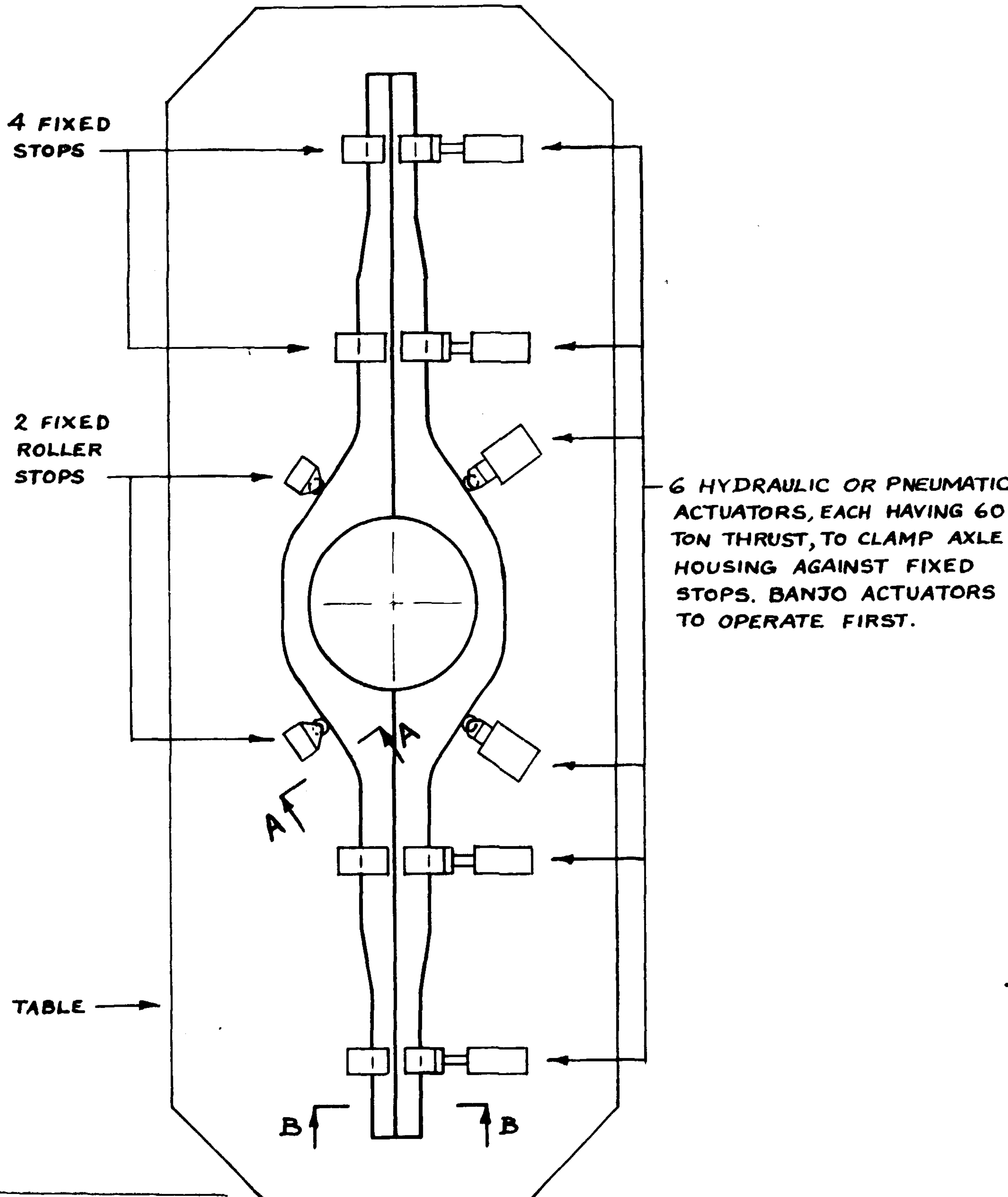
NORRIS PARTNERS LTD	Figure: 15
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title EXISTING AXLE HOUSING CLAMPING DETAILS FOR CURRENT CO_2 MANUAL WELDING	Scale: 1:10



NORRIS PAR

Project U
CC

Title ALTER
SUITAE
WELDI

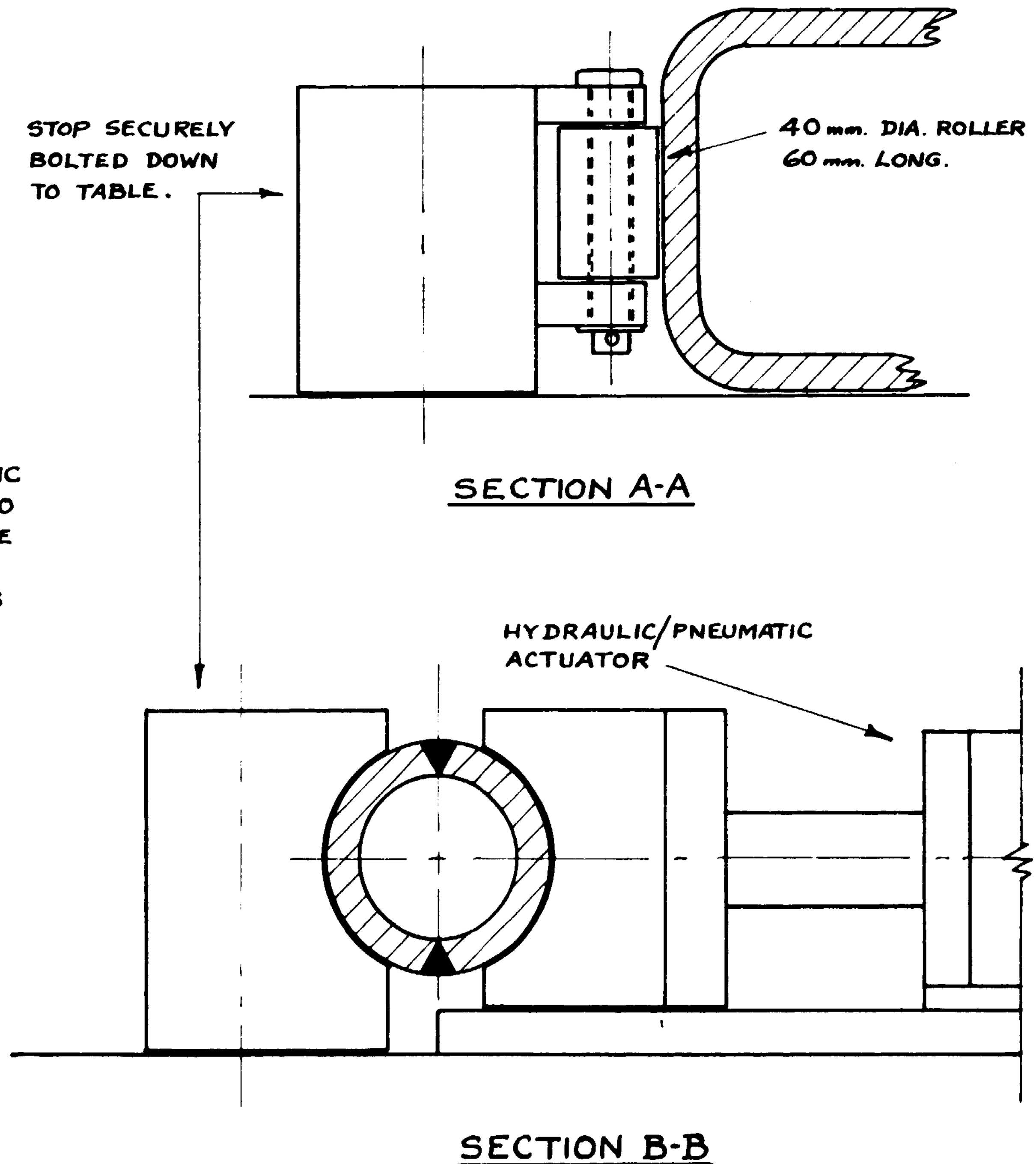


STOP SECUR
BOLTED DO
TO TABLE.

SECTION 1

NORRIS PARTNERS LTD	Figure: 16
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title ALTERNATIVE AXLE HOUSING CLAMPING DETAILS SUITABLE FOR EITHER CURRENT CO_2 MANUAL WELDING OR PROPOSED SUBMERGED ARC WELDING	Scale: 1:10 & 1:2.5

-RAULIC OR PNEUMATIC
-TORS, EACH HAVING 60
-HRUST, TO CLAMP AXLE
-NG AGAINST FIXED
-. BANJO ACTUATORS
-ERATE FIRST.



5.00 CONT'D.

2. CURRENT PRODUCTION METHODS AND RECOMMENDED IMPROVEMENTS

E. Recommended modifications for clamping details for milling machine operations are shown in Fig. 14.

3. DESIGN IMPROVEMENTS OF AXLE HOUSING

A. Change of design details of axle housing components will facilitate improvement of manufacturing methods, quality control, dimensional consistency of piece parts and enhanced reliability and life period of unit assemblies.

B. Investigation of the housing components has indicated that detail design improvements could be achieved and embodied for compatibility with existing plant facilities and relative to item 2 above.

C. The recommendations are displayed in the following list of sketch layouts:-

Fig. 17 : Preparation for Gusset Type Housing - Method A.

Fig. 18 : Preparation for Gusset Type Housing - Method B.

Fig. 19 : Completion of Housing, both types.

Fig. 20 : Proposed Spindle End Forging for Modern Type Axle Housing - Stage 1.

Fig. 21 : Proposed Spindle End Forging for Modern Type Axle Housing - Stage 2.

5.00 CONT'D.

3. DESIGN IMPROVEMENTS OF AXLE HOUSING

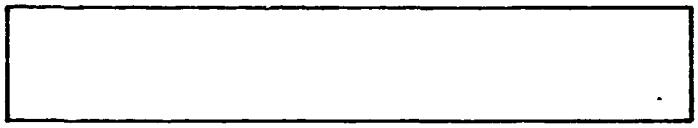
C. Cont'd.....

Fig. 22 : Proposed Spindle End Forging for Modern Type Axle Housing - Stage 3.

Fig. 23 : Proposed Spindle End Forging for Modern Type Axle Housing - Stage 4.

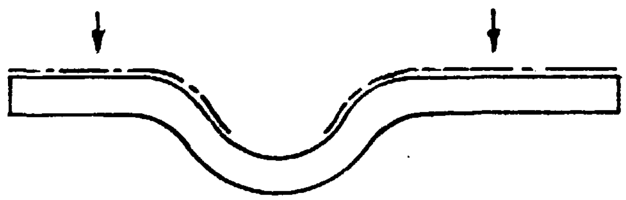
NORRIS PARTNERS LTD.	Figure: 17
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title PREPARATION FOR GUSSET TYPE HOUSING – METHOD 'A'	Scale: N.T.S.

BLANK

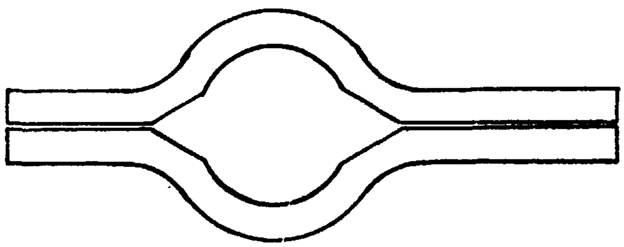


HEAT & FORM

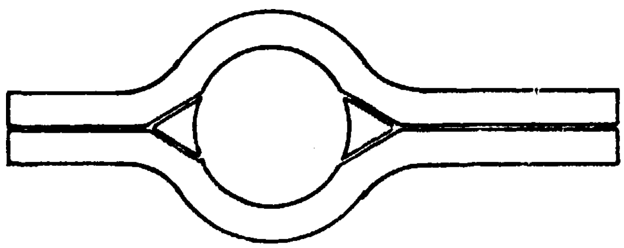
FLAMECUT



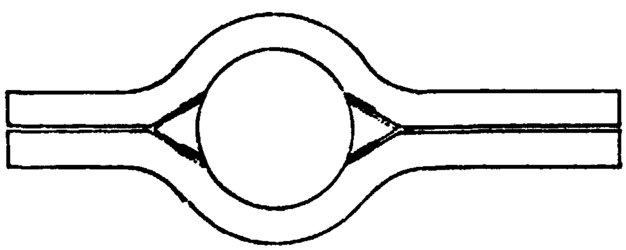
WELD SEAM
70/80% PENETRATION



WELD GUSSET

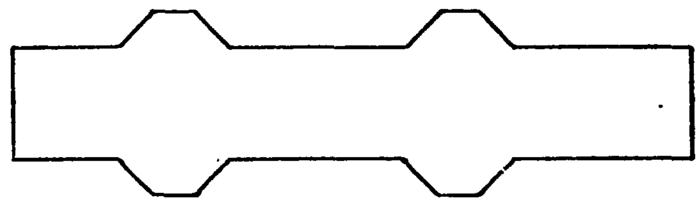


UNDER WELD GUSSET AT CORNERS



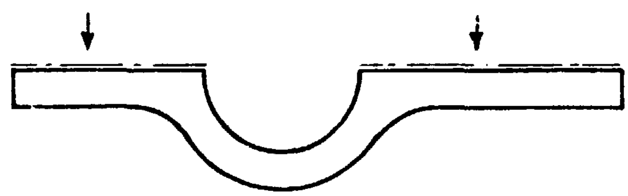
NORRIS PARTNERS LTD.	Figure: 18
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title PREPARATION FOR NON-GUSSET TYPE HOUSING - METHOD 'B'	Scale: N.T.S.

BLANK

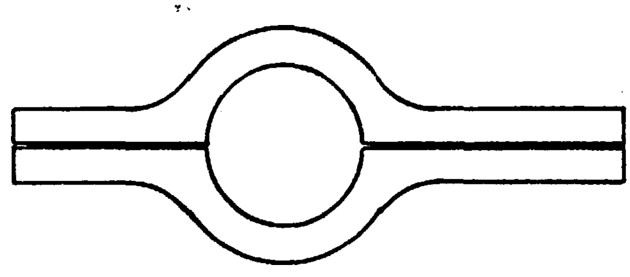


HEAT & FORM

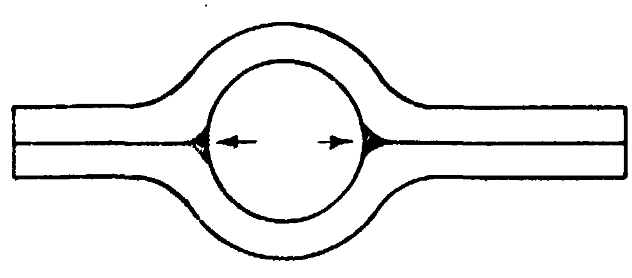
MILL EDGES
OR
FLAME TRIM
EXCESS
MATERIAL
FROM EDGE



WELD SEAMS
INERT GAS
CO_2
AUTOMATIC OR
SEMI-AUTOMATIC
N.B. - FOR FULL
AUTOMATIC REFER
PHOTOGRAPHS.

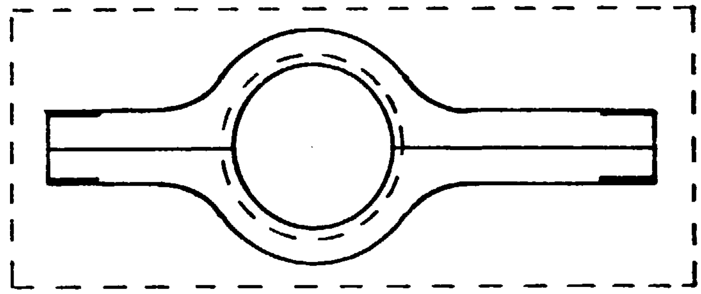


SEAL WELDS
INSIDE BANJO

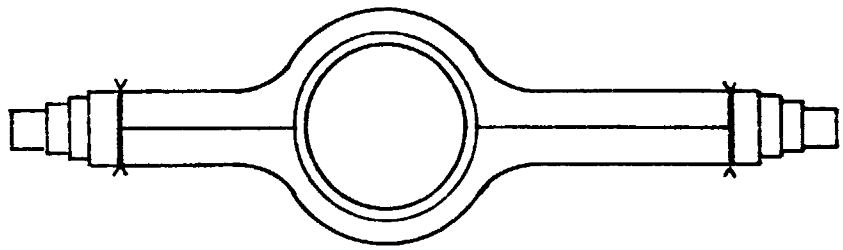


NORRIS PARTNERS LTD	Figure: 19
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title COMPLETION OF HOUSING BOTH TYPES	Scale: N.T.S.

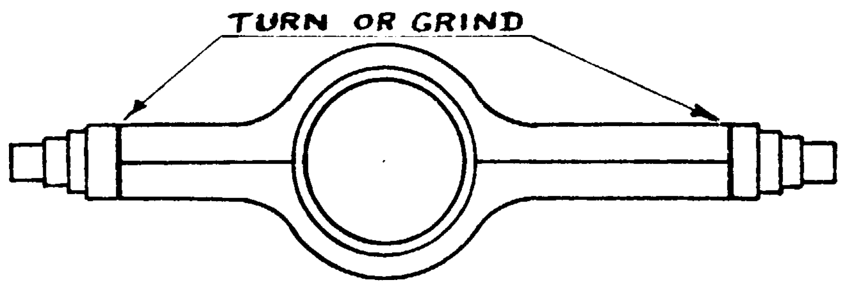
ROUND ARMS



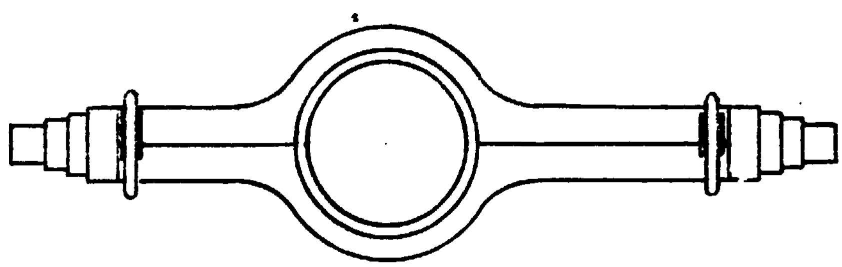
FRICTION WELD



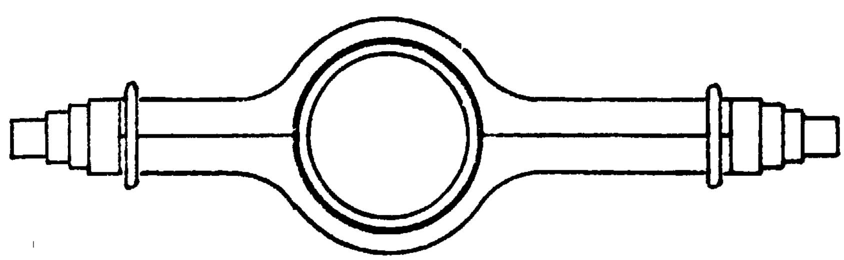
DE-FLASH



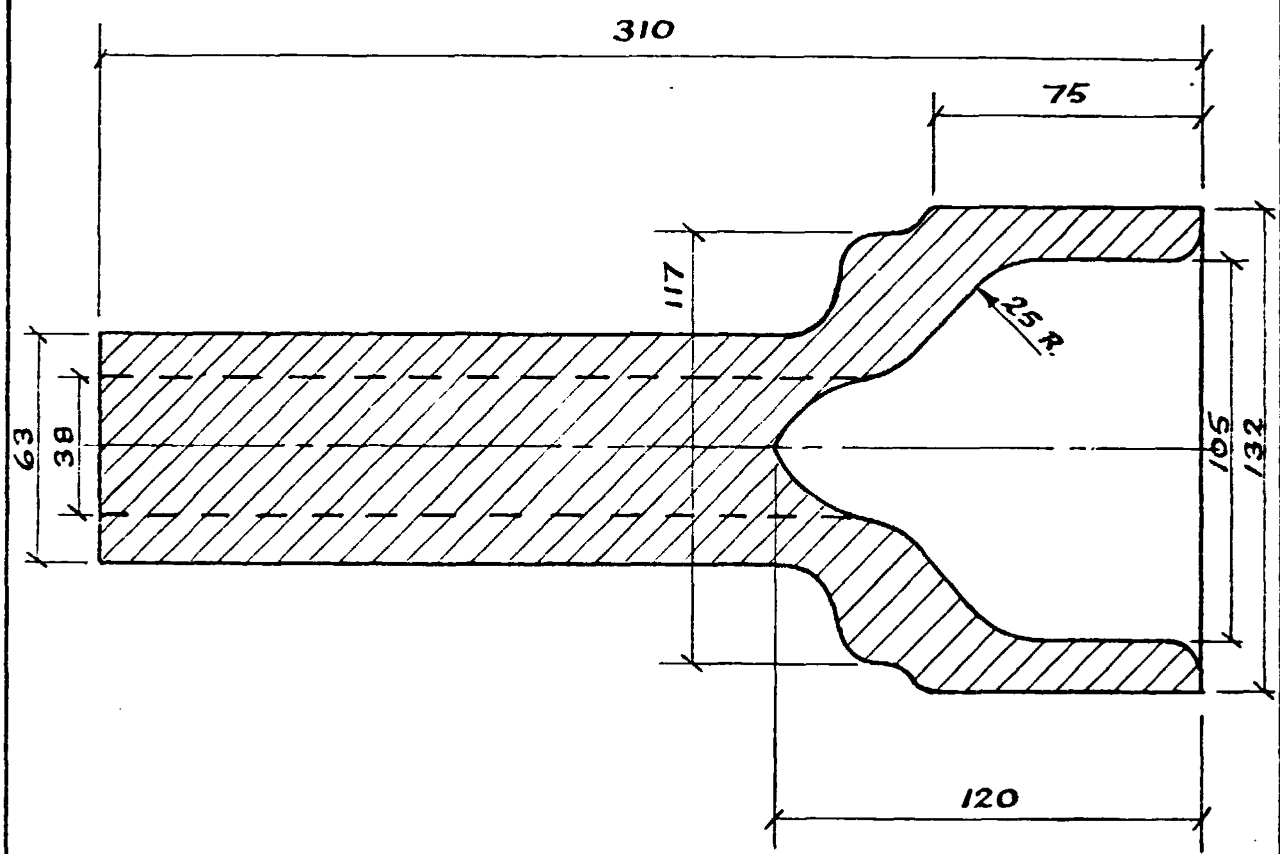
WELD FLANGES



WELD REAR RING
NOT ALWAYS REQUIRED, ONLY ON TANDEM APPLICATIONS.



NORRIS PARTNERS LTD.	Figure: 20
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34.	Date: MAY 1977
	Drn. by: R.T.L.
Title PROPOSED SPINDLE END FORGING FOR MODERN TYPE AXLE HOUSING - STAGE 1	Scale: 1:2

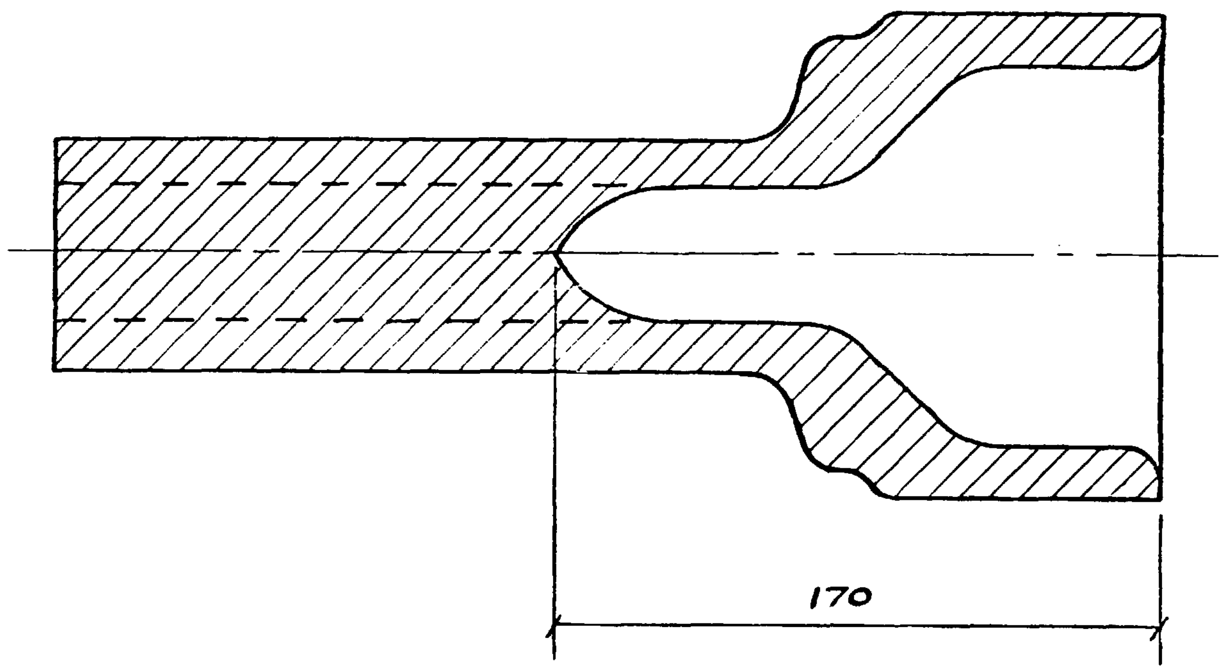


STAGE 1

POSSIBLE INITIAL FORGINGS
FIRST 12 TO 18 MONTHS. CAN BE
PRODUCED ON EXISTING PLANT.
REQUIRE FINISH BORING.

NOTE: FORGING TO BE HEAT TREATED & DE-SCALED
HARDNESS 201 – 255 BRINELL.

NORRIS PARTNERS LTD	Figure: 21
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
Title PROPOSED SPINDLE END FORGING FOR MODERN TYPE AXLE HOUSING - STAGE 2	Drn. by: R.T.L.
	Scale: 1:2

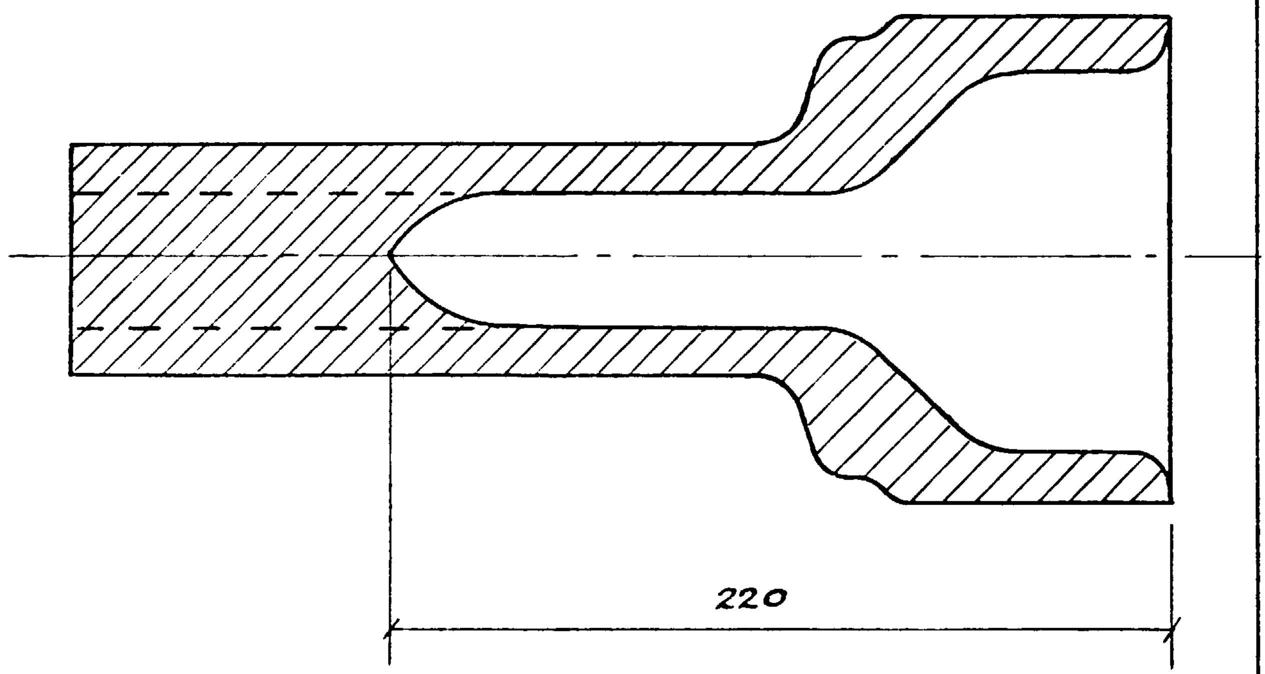


STAGE 2

POSSIBLE SECOND STAGE AS EXPERTISE IS BUILT UP.

NOTE: FORGING TO BE HEAT TREATED & DE-SCALED HARDNESS 201 - 255 BRINELL.

NORRIS PARTNERS LTD.	Figure: 22
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title PROPOSED SPINDLE END FORGING FOR MODERN TYPE AXLE HOUSING - STAGE 3	Scale: 1:2

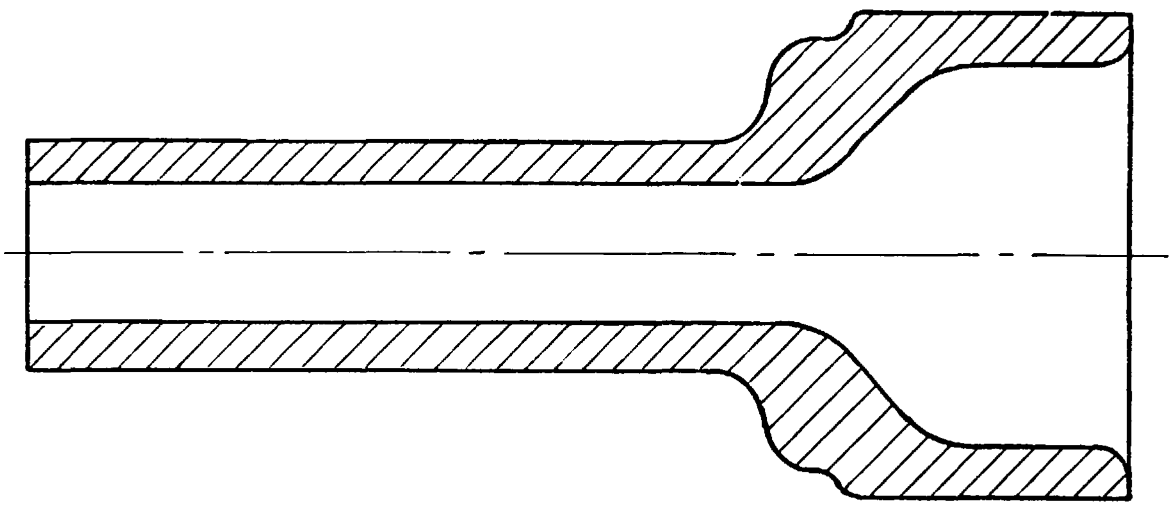


STAGE 3

POSSIBLE THIRD STAGE AS EXPERTISE IS FURTHER BUILT UP.

NOTE: FORGING TO BE HEAT TREATED & DE-SCALED HARDNESS 201 - 255 BRINELL.

NORRIS PARTNERS LTD.	Figure: 23
Project UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
	Drn. by: R.T.L.
Title PROPOSED SPINDLE END FORGING FOR MODERN TYPE AXLE HOUSING - STAGE 4	Scale: 1:2



STAGE 4

ULTIMATE TYPE OF FORGING, FULLY PIERCED. MANUFACTURE WILL ONLY BE POSSIBLE WHEN THE 1000 TON LASCO FORGING PRESS, CURRENTLY ON ORDER, HAS BEEN INSTALLED AT NIS.

NOTE: FORGING TO BE HEAT TREATED & DE-SCALED HARDNESS 201 - 255 BRINELL.

5.00 CONT'D.

4. <u>LABOUR REQUIREMENTS FOR MANUFACTURE OF AXLE HOUSINGS</u>

A. <u>FABRICATION</u> (SCHEME C)

Single Shift - Double for Two Shift Working - Volume 25,000 axle housings per annum Double Shift.

Operation	Operator	Labourer	TOTAL
1(2)	1		1
1(3) 1(4)	3		3
1(5)	1		1
1(6)	1		1
1(7)	1		1
1(8)	1		1
1(9)	1		1
1(10)	1		1
1(11)	2	2	4
1(12)	6	2	8
1(13)	2		2
1(14)	4		4
1(15)	2		2
1(16) Rectify	2		2
General Shop Labour		6	6
Supervision & Inspection			4
			42

5.00 CONT'D.

4. LABOUR REQUIREMENTS FOR MANUFACTURE OF AXLE HOUSINGS

B. MACHINE LINE (SCHEME C)

Operation	Operator	Labourer	TOTAL
(1b)	1		1
(2b)	2		2
(3b)	1		. 1
(4b)	1		1
(5b)	1		1
(6b)	1		1
(7b)	1		1
(8b)	1		1
(9b)	1		1
	General Shop Labour		2
	Forklift Drivers		2
	Supervision & Inspection		4
	Total Machine Line		18
	Total Fabrication		42
	TOTAL SINGLE SHIFT		60
	TOTAL DOUBLE SHIFT		120

5.00 CONT'D.

5. PLANT REQUIREMENTS

Three stages of recommended improvements and modernisation of axle housing production facilities:

A. MINIMUM REQUIREMENTS FOR CURRENT EXISTING PLANT

		£ STERLING
(1)	Modern Walking Beam Furnace to deliver one axle blank to press every 2 minutes. Estimated Cost:	60,000
(2)	Roller track and handling facilities blank to press.	4,000
(3)	Submerged arc semi-automatic	7,000
(4)	Special rails etc., for above to clamp to axle seam.	2,000
(5)	Improvements in general clamping and jigging including clamping pressures up to 40 Tons on flamecutting machine	10,000
(6)	Full automatic heat control on stress relieving furnace if customer requires this practice to continue.	9,000
		£92,000

5.00 CONT'D.

5. PLANT REQUIREMENTS

B. BUILDINGS - EXISTING

All listed prices are based on current U.K. prices late 1976, plus 15% escalation per annum over two years.

		£ STERLING
(a)	Flame cut multi head - Pantograph trace nestled blanks.	1[illegible],830
(b)	Heat Walking Beam	72,000
(c)	Press 1200 Ton Hydraulic, including installation	360,000
(d)	Mill for butt seam weld	59,000
(e)	Seam Weld, submerged arc - 2 machines	14,000
(f)	Weld Ring, hand CO_2 (existing plant)	
(g)	Round up arms - existing plant, but special tooling.	5,000
(h)	Weld CO_2 - 2 Machines 600 Amp, plus Revolving Jig and Clamping.	8,000
(i)	Clean up Weld. Lathe with two saddles (existing).	
(j)	Weld all brackets & flanges - existing fixture with small modification.	2,000
(k)	Full Heat Treatment for thin wall case if required.	198,000
(l)	Two straightening presses with moving tables.	158,000
(m)	Shot Blast & Paint - existing.	
(n)	Roller Track - handling equipment.	50,000
(o)	4 Sets Press Tooling to cover 4 Standard Types - £25,000 each set.	100,000
		£1,045,830

If Machine Line required, see Scheme C.

5.00 CONT'D.

5. PLANT REQUIREMENTS

C. RECOMMENDATIONS BASED ON A NEW PLANT FOR COMPLETE MANUFACTURE OF AXLE HOUSINGS (SCHEME C)

All listed prices are estimated with plus 15% escalation per annum over 2 years forward delivery. Production based on 12,500 Axle Housings per annum Single Shift, i.e. 25,000 per annum Double Shift. Assessments are based on assumed 40 hour work week per shift and 250 work days per annum.

		£ STERLING
1(1)	NEW BUILDINGS WITH SERVICES 30,000 sq.ft.	500,000
1(2)	Flame cut, multi head, Pantograph Tracer nestle blanks	19,830
1(3)	Heat Walking Beam Furnace	72,000
1(4)	Press 1200 Ton Hydraulic, including installation	360,000
1(5)	Mill fur butt seam weld	59,000
1(6)	Seam Weld Automatic CO_2 Machine	65,000
1(7)	Bore and face - clean up seam face to length (special machine)	90,000
1(8)	Weld Ring (special machine)	26,000
1(9)	Round up arms (ends) - special purpose hydraulic press 100 Tons with tooling	29,000
	C/Fwd:	£1,200,830

5.00 CONT'D.

5. PLANT REQUIREMENTS

C. CONT'D.

		£ STERLING
	B/Fwd:	1,200,830
1(10)	Friction Weld (single ended machine)	172,000
1(11)	Trim Flash Lathe with two saddles (second-hand machine)	4,000
1(12)	Weld all brackets & flanges, also dome Manual CO_2 - 2 Stations Tacking 400 Amp Machines. - 4 Stations Finish 600 Amp Machines. Price to include all jigs and fixtures.	21,000
1(13)	N.B. If Mercedes design follows modern square section axle with reduced wall thickness, i.e. a thin wall case, full heat treatment to cover harden and tempering will be required.	198,000
1(14)	Two Straightening Presses 100 Ton with Moving Tables.	158,000
1(15)	Shot Blast and Paint.	40,000
1(16)	Roller Track, handling equipment.	50,000
1(17)	4 Sets of Press Tooling to cover 4 Standard Types of case - £25,000 each set.	100,000
	Total Capital Cost Estimate for Complete Fabrication of Axle Housings	£1,943,830

N.B. A Plant Layout of the above Scheme C is shown on Appendix 4.

5.00 CONT'D.

6. LONG TERM ASPECTS FOR MANUFACTURE OF AXLE HOUSINGS

A. A preliminary meeting was held at M.I.N. Nis on the 9th May 1977 with attendance by F.A.P. to discuss their intent and design, both present and future. Present at this meeting were Dipl. Ing. Radosavjeva Jovica - Chief Development Engineer of M.I.N., Dipl. Ing. P. Pejcic - Technical & Development Engineer of M.I.N., Dipl. Ing. V. Djurovic - Metallurgical Engineer of M.I.N. (and Interpreter), Ing. Herokovic Loupce - Development Engineer of F.A.P., together with Mr. D.H. Barrie and Mr. A.H. Worthy of Norris Partners Ltd.

A further meeting was held at Belgrade on the 17th May 1977 with attendance by both F.A.P. and Zelezarna Jesenice to examine in depth the current problems, possible solutions thereto, future design intent, and finally, but by no means of least importance, the current poor quality of steel and the possibilities of improving the latter. Present at this meeting were the same personnel as previously, with the exception of Ing. P. Pejcic and Ing. Herokovic Loupce, and with the addition of Dipl. Ing. Bura - Head of Inspection & Incoming Material of M.I.N., Dipl. Ing. Hasonovit Ahmed - Chief of Research and Development of F.A.P., and Dr. Techn. Ing. Marin Gabrovsek of Zelezarna Jesenice.

It was soon apparent that there would be no easy or short term answer to the problem of steel quality. The mill used for production of steel plate is 30 years old and is not scheduled for replacement. No immediate improvement can be made to surface finish, but a de-scaling plant for

5.00 CONT'D.

6. LONG TERM ASPECTS FOR MANUFACTURE OF AXLE HOUSINGS

A. Cont'd.....

ingots is included in current 2 year programme. The result of the above situation is that the Steel Company have great difficulty in meeting Yugoslav standards for rolling tolerances, even though these are inadequate for axle housing production. However, it was agreed by the Steel Company that a 100% check would be carried out jointly by their own and M.I.N. Inspectors and all plates with visible bad surface defects and/or excessive rolling tolerances would be accepted for rejection.

Principally from the meeting held on the 9th May, the following information was obtained in respect of F.A.P. planning and development intent over a 10 year period.

(1) F.A.P. the largest truck producer in Yugoslavia currently build under licence fror Sauer, Austria. The truck range is however limite_ in scope, and the design is dated.

(2) F.A.P. currently use three basic axles on a truck volume of 10,000 units per annum. M.I.N. currently manufacture approx. 6000 axle housings on the most popular model, and F.A.P. import a further 2000 housings per annum of the same type as an insurance against a breakdown in supplies from M.I.N. The two low volume axle housings are imported, as the volume is too low to allow for economic tooling cost.

(3) F.A.P. are phasing out the current axle design over the next five years, and the indications are that

5.00 CONT'D.

6. LONG TERM ASPECTS FOR MANUFACTURE OF AXLE HOUSINGS

A. (3) Cont'd.....

volumes will be very low by 1980, and completely run out by 1982. Similar axle designs will however be introduced using heavier gauge material, i.e. 17.5 mm and 20 mm for heavy duty cases on multi axle cross country vehicles.

(4) F.A.P. are currently negotiating licenced manufacturing agreements with Mercedes Benz, and the future production and technical criteria will be based on Mercedes Benz engineering and know-how, but the designs will be modified by F.A.P. to suit their manufacturing resources and local conditions. Little information is available on future production, no drawings or specifications being available.

B. A broad outline of the programme is as follows:

(1) Production of Mercedes Trucks to be phased into the production programme commencing 1980. From 1982 onwards, all F.A.P. Trucks will be based on Mercedes design.

(2) Axle requirements will be four basic types, including a Tandem axle truck which will constitute 33-1/3% of the overall production, i.e. 66-2/3% of axle housing production. F.A.P. will also require low volume production of a housing for heavy front wheel drive steering axles.

(3) Some of the new designs will follow the modern square section cases using welded forged ends.

5.00 CONT'D.

6. <u>LONG TERM ASPECTS FOR MANUFACTURE OF AXLE HOUSINGS</u>

B. (4) The planned truck build is 15,000 in five years, rising to 17,500 in ten years; of the 17,500 33.3% will be tandems, i.e. 23,330 axle housings. Taking into consideration the low volume front drive axle and spares call off, it must be assumed that the F.A.P. planned requirement by 1987 will be approx. 25,000 axle housings.

(5) It is F.A.P's intention that all these housings will be manufactured in Yugoslavia.

C. Discussion took place on the problems of stress relieving. It was pointed out to the F.A.P. representative that stress relieving on axles had been discontinued in some West European plants. It was suggested that M.I.N. manufacture three housings without stress relieving and submit to F.A.P. for testing. If it should be F.A.P's wish that stress relieving of the fully welded case should be continued, it is essential that this should be done accurately in heat controlled furnaces based on the steel manufacturer's recommendations, and it is felt that suitable temperatures should be in the range 450/500^{o}C for 40 minutes, followed by a slow cooling in air.

6.00 TERMINAL SECTION

1. M.I.N. ORGANISATION STRUCTURE

A. It is regarded as an advantage for an appraisal of the operational format at M.I.N. to be included in this section as an updated statement of the current organisation structure and the range of products as follows.

The Mechanical Engineering Industry (Masinska Industrija) Nis - MIN was established in 1884 as a railway workshop. In 1963 the factory took its present form through the merging of the Stanko Paunovic factory and the Bridge and Railway Crossing factory which later were joined by Milos Dimanic of Vlasotinci, Napredak of Svrljig and ZITOGRADNJA, a light structures plant. Out of these mergers one of the largest mechanical engineering firms in Serbia was created, with wide production programmes:

- freight cars for various uses
- cranes and steel structures
- railway crossings and track accessories
- machine tools
- iron and non-ferrous metal castings
- processing equipment
- machine units and parts
- engine overhauls

6.00 TERMINAL SECTION

1. M.I.N. ORGANISATION STRUCTURE

A. Cont'd.....

In future, special emphasis will be laid on programmes covering processing equipment, forgings, pressings, lifts and components for commercial vehicles.

Due to the breadth of its programme, MIN co-operates closely with scientific organisations and institutes, as well as with other firms in the country and abroad. The enterprise has well-established business relations with the buyers-users of its products to whom it furnishes efficient help during the guarantee period, spare parts, services and technical assistance.

B. During the period of duties in the project area, Mr. D.H. Barrie and Mr. A.H. Worthy held meetings and informal discussions with Senior Management Executives and Engineers of M.I.N. Nis, which enabled technical investigations to proceed satisfactorily in accordance with the work plan. The executives and engineers who participated in the various discussions are as follows:-

Ing. Slavco Jovic	- Director and General Manager.
Ing. Poovidar Jocic	- Deputy General Manager
Dipl. Ing. D. Stefanovic	- Technical & Development Director.
Dipl. Ing. P. Pejcic	- Technical & Development Engineer.
Dipl. Ing. V. Djurovic	- Engineer on Metallurgy (Interpreter)

6.00 TERMINAL SECTION

1. M.I.N. ORGANISATION STRUCTURE

B. Cont'd.....

Dipl. Ing. Mikovic Drajutin	- Director Pressing and Forging.
Ing. Mikovic Krkic	- Tooling Engineer.
Ing. Zdravkovic	- Side Beam Manufacture.
Ing. Nikodijevic	- Housing Fabrication Welding.
Ing. Kucicki Branko	- Chief Welding Development.
Ing. Njgulovic	- Housing Fabrication Machining.
Dipl. Ing. Bura	- Head Inspection & Incoming Material.
Dipl. Ing. Radosavjeva Jovica	- Chief of Development Rolling Stock (including axles)
Ing. S. Duric) Ing. S. Kostic)	- Tool Designers

C. The current organisational format of the Masinska Industrija-Nis Plant is displayed on the chart layout, Fig. 25.

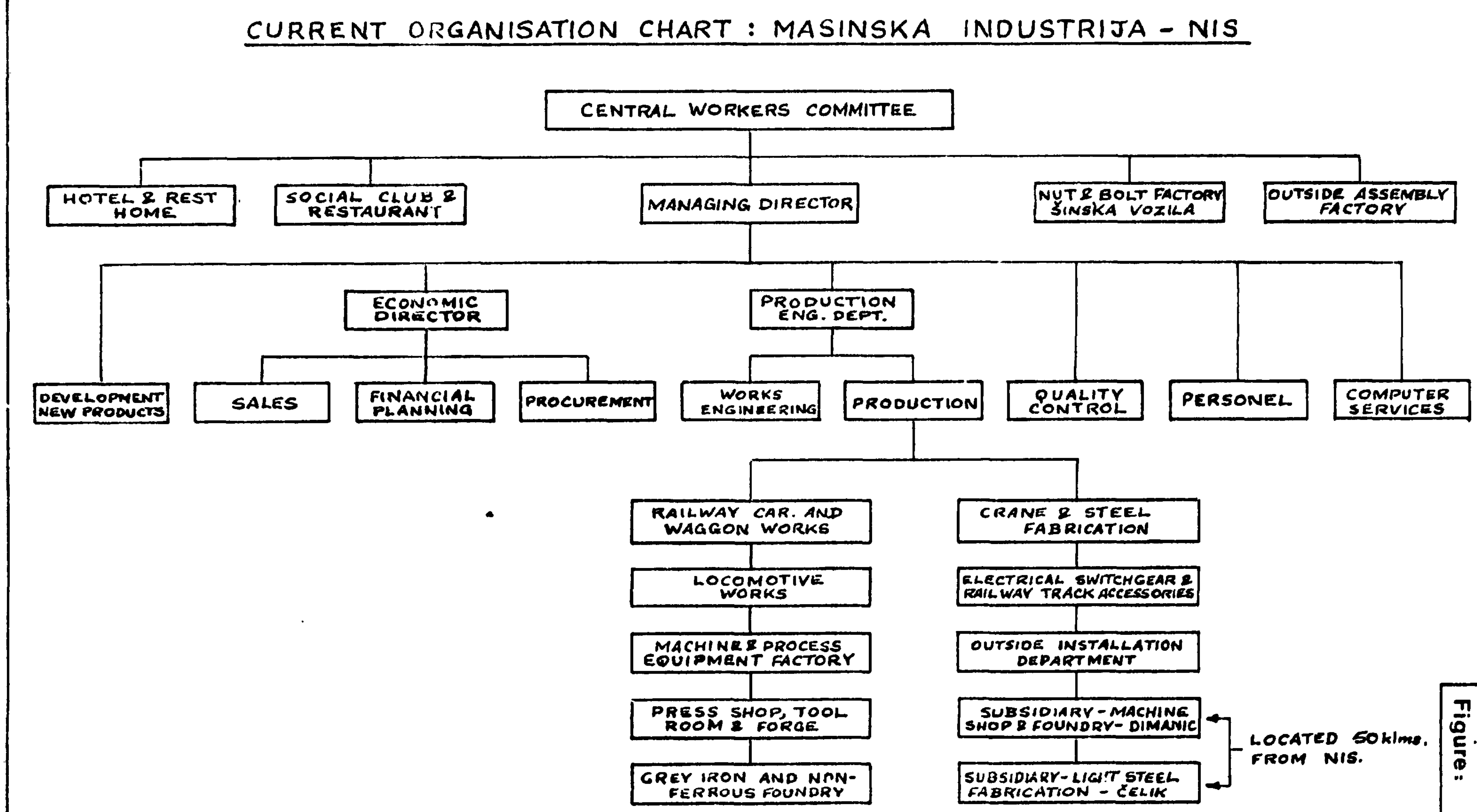

CURRENT ORGANISATION CHART : MASINSKA INDUSTRIJA - NIS
CENTRAL WORKERS COMMITTEE
HOTEL & REST HOME
SOCIAL CLUB & RESTAURANT
MANAGING DIRECTOR
NUT & BOLT FACTORY ŠINSKA VOZILA
OUTSIDE ASSEMBLY FACTORY
ECONOMIC DIRECTOR
PRODUCTION ENG. DEPT.
DEVELOPMENT NEW PRODUCTS
SALES
FINANCIAL PLANNING
PROCUREMENT
WORKS ENGINEERING
PRODUCTION
QUALITY CONTROL
PERSONEL
COMPUTER SERVICES
RAILWAY CAR. AND WAGGON WORKS
LOCOMOTIVE WORKS
MACHINE & PROCESS EQUIPMENT FACTORY
PRESS SHOP, TOOL ROOM & FORGE
GREY IRON AND NON-FERROUS FOUNDRY
CRANE & STEEL FABRICATION
ELECTRICAL SWITCHGEAR & RAILWAY TRACK ACCESSORIES
OUTSIDE INSTALLATION DEPARTMENT
SUBSIDIARY - MACHINE SHOP & FOUNDRY - DIMANIC
SUBSIDIARY - LIGHT STEEL FABRICATION - ČELIK
LOCATED 50 klms. FROM NIS.

Figure: 25

6.00 TERMINAL SECTION

2. BASIC CONCLUSIONS

A. M.I.N. is an organisation employing approximately 8500 workers. The traditional manufacture for the past 100 years has been based on Railway Rolling Stock, and the repair of steam and later diesel engines. The Yugoslavian Railways, like many other systems in the world, is losing its dominance to road haulage, hence the necessity for M.I.N. to diversify into other product ranges. The plant and buildings are old, and they have the added problem of traditional labour wedded to a traditional product.

(1) The introduction of the manufacture of axle housings over the past seven years has therefore been both difficult and expensive, as the M.I.N. Production Staff have had to learn to a large extent from experience. The total labour force engaged in axle housing manufacture is estimated to be about 70 - very small compared to the overall labour force. Even so, there is a growing appreciation of its importance to the future of the Company.

(2) A further difficulty in the manufacturing process is that it is fragmented over a number of different existing departments, each department with its own problems on existing production. We consider <u>it is absolutely essential that the manufacture</u>

6.00 TERMINAL SECTION

2. BASIC CONCLUSIONS

A. (2) cont'd.....

of axle housings should be brought under one roof, and put under its own Management with complete authority for the finished product. This problem has been discussed with the M.I.N. Management along these lines, but they regard such a step as impossible within the present framework of the Company. Even so, we believe very serious consideration must be given to this problem in the near future.

(3) Regarding steel procurement, here again M.I.N. face great difficulty. Steel is in short supply in Yugoslavia. Deliveries are protracted, and forward scheduling of requirements up to a minimum of twelve months is required. The tolerance on rolling and finishing following current practice is far short of M.I.N's requirements for difficult presswork. With a seller's market available, the steel companies are not keen to introduce more difficult conditions for themselves, and the impression was obtained that the steel procurement staff at M.I.N. are often faced with a "take it or leave it" attitude. The rejection of steel back to the Mill as unsatisfactory appears to be an unknown phenomenon at Nis.

6.00 TERMINAL SECTION

2. BASIC CONCLUSIONS

A. (4) It is essential that under present conditions the help and the co-operation of the Steel Company is sought and every endeavour is made to establish standards for axle housing production, i.e. rolling tolerances must be - 0 + 5% of plate thickness maximum.

(5) M.I.N. should introduce new order techniques whereby chemical composition, mechanical properties, and tolerances are clearly stated; a typical format is shown in Fig. 24. Only under these conditions will the incoming material inspection staff have the necessary criteria to work to.

(6) M.I.N. have a good forging facility. They also have on order from Germany a 1000 Tonne LASCO Forging Press which, in our opinion, is first class special application forging equipment. M.I.N. should have no difficulty after experimentation in producing the fully pierced spindle end forgings which will be necessary as they move into production with the modern types of square section case.

(7) The forging facility is housed in a separate factory some 3 kilometres from the main plant. Attached to the forging plant is a well-equipped tool room for the manufacture and re-sinking of forging dies.

Figure 24

STEEL PROCUREMENT FORM

DATE ______________ No. __________

TO:

FROM: M.I.N.
P.O. BOX 112
18000 NIS
YUGOSLAVIA
Telephone No.
Telex No. 16187

Our Enquiry Dated ____________________	Reference No. __________________
Your Quotation Dated _________________	Reference No. __________________

QUANTITY kg.	NOMINAL SIZE			Type of Steel	Condi- tion	DIN. Ref. No.	Maker's Ref. No.	Date Req'd
	Thk. mm.	Length mm.	Width mm.					

CHEMICAL COMPOSITION

ELEMENT	C	Si	Mn	Nb	V	Al	S	P
Percentage: Maximum Minimum								

MECHANICAL PROPERTIES

Rolling Tolerances % of Plate Thickness	Tensile Strength kp/mm^2 min.	Yield Stress kp/mm^2 min.	Elongation % Min.		Brinell Hardness	Limiting Ruling Section mm.
			Longi- tudinal	Trans- verse		

OTHER SPECIAL REQUIREMENTS

WE WILL/WILL NOT WISH TO WITNESS MANUFACTURER''S TESTS.

SIGNED BY ________________________________ FOR & ON BEHALF OF M.I.N.

6.00 TERMINAL SECTION

2. BASIC CONCLUSIONS

A. (7) cont'd.....

The tool room is equipped with jig boring facilities under temperature controlled atmosphere. We would stress however that the facilities are too light for the press tools which M.I.N. will be called upon to manufacture for axle housing production in the foreseeable future, and additional facilities will be needed.

(8) It is also emphasised that, whereas there is a wealth of knowledge on the design of forging dies, there appears to be only limited knowledge on the design of press tools. This aspect should be given consideration.

(9) It is considered that M.I.N. should aim at producing a fully machined axle housing (with their customer's co-operation). They must strive to become the acknowledged experts in their field of manufacture, and this is always difficult if half the production, i.e. the Machine Line, is out of their control. In general it is our opinion that M.I.N. Management must give greater consideration to detail: not bad, is not good enough when dealing with life and limb components such as truck axles. Only a first-class product, backed by first-class Management know-how and plant will ensure their continued success. All heating

6.00 TERMINAL SECTION

2. BASIC CONCLUSIONS

A. (9) cont'd.....

equipment must be temperature controlled and accurate.

(10) We believe that it is essential to provide heating in the workshops to maintain winter temperatures of not less than 10°C - under present working conditions, winter temperatures drop to -5°C regularly. Apart from the comfort of the workers, such conditions make for problematical welding techniques, and if a modern machine line was introduced in the future, it would be imperative to have balanced heating conditions in the workshops.

(11) It was noted that M.I.N. have first-class engineering and chemical laboratory facilities. These were fully up to Western European standards for a company of similar size. These facilities however appear to be seldom used, and are certainly not making their full contribution to recommendations on quality control and the formulation of special standards suitable for the new techniques in manufacture which are slowly being introduced at M.I.N.

(12) Following a meeting with senior staff in charge of Research and Control of the Steelworks at M.I.N. it became apparent that the steel problem

6.00 TERMINAL SECTION

2. BASIC CONCLUSIONS

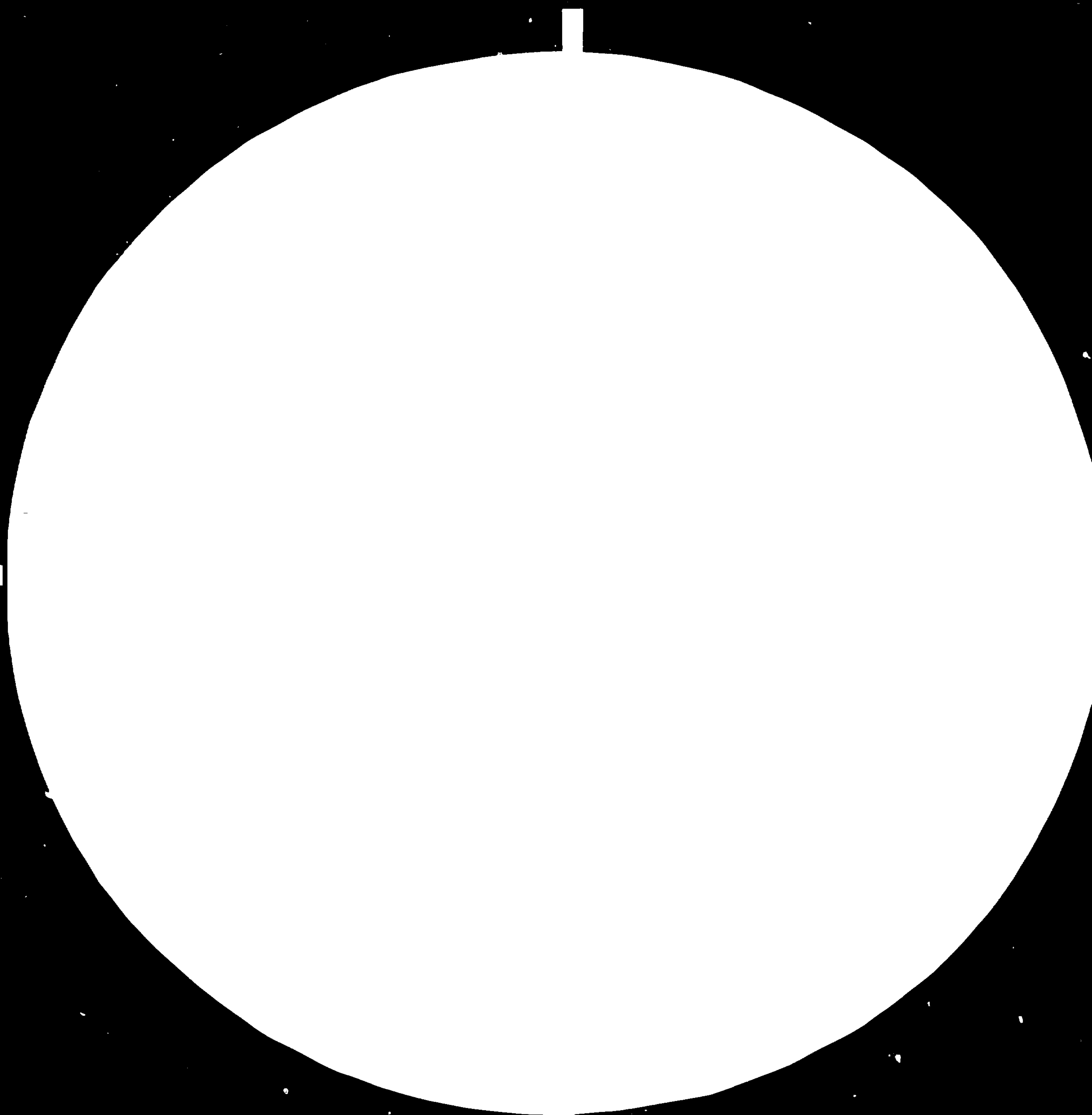
A. (12) cont'd.....

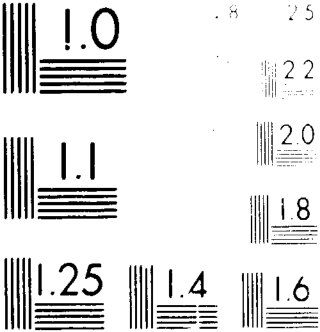
of M.I.N. is not short term and it is a problem they will have to live with for many years.

(13) It was explained by senior staff of the Steel Company that the only plate mill available is an old German triple roll machine installed at Jesenice in 1947. There are no plans to replace this mill, as the future development at Jesenice is towards the manufacture of stainless steel sheet for both home consumption and the export market. All available financial funding has been earmarked and channelled for this type of future development.

(14) The Steel Company Staff fully admit that they have the greatest difficulty in holding the Yugoslav Standards for rolling tolerances based on ordinary commercial quality plates. These Yugoslav Standards are taken from the old German D.I.N. Specifications of 1947 and are very much wider than those required for specialised production such as axle housings.

(15) The Steel Company also advise that they can do nothing to improve surface finish and the cleanliness of the steel in the immediate future, but on this aspect there is a little hope in the medium term as they are considering putting in a 500




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5

6.00 TERMINAL SECTION

2. BASIC CONCLUSIONS

A. (15) cont'd.....

Atmosphere Plant to clean scale from the ingots prior to rolling. This capital expenditure has been included in their current 2 Year Programme, and they expressed their intention to go ahead with the installation of the equipment.

(16) Taking all these factors into consideration, we reached agreement that the Steel Company would allow M.I.N. Inspectors to carry out 100% inspection in conjunction with their own inspectorate at the Steelworks from each cast and completed rolling. They would accept rejection on all plates with visible bad surface defects and with rolling tolerances in excess of the laid down Yugoslav Standards. It is felt that this form of selection is a great step forward and we recommend that M.I.N. make the most of this concession and implement the procedures immediately. We would emphasise that M.I.N. will have to agree with the Steel Company regarding a uniform laid down inspection procedure, both parties using identical measuring equipment. In the case of surface rolling defects and dirt inclusions, an acceptable plate should be agreed between both parties and a sample kept in the Steelworks for comparison purposes and future reference.

6.00 TERMINAL SECTION

3. PRIMARY CONSIDERATIONS

A. However, the emphasis to be placed on conclusions for primary consideration are:-

(1) The existing manufacturing facilities at M.I.N. have potential capability for improved volume of annual production to the extent listed in section 3.00, item C. (10) of this report, always providing that the specified recommendations are implemented.

(2) An early increase in the volume of annual production could be achieved by improvement of the axle housing detail design characteristics.

(3) Comparatively low cost investment for improvement of manufacturing methods and production line equipment will also give further impetus to the early rate of increase of the volume of annual production.

(4) Other recommendations for improvement of process plant in the manufacturing line will ensure attainment of the maximum volume of annual production forecast in section 3.00, item C. (10). In this instance, however, it will be necessary to budget for a high scale of capital investment for specific items of plant, e.g. Walking Beam Furnace for heating axle housing blanks, for which two preliminary quotations have

6.00 TERMINAL SECTION

3. PRIMARY CONSIDERATIONS

A. (4) cont'd.....

been received from U.K. sources at approximately £70,000 Sterling and £74,000 Sterling, respectively.

(5) The costs contained in the preliminary quotations received for all specific items of plant which have been recommended for inclusion in the revised layout of existing facilities have been included in Section 5.00, Item 5 - Plant Requirements.

(6) There is considerable scope for improvement in the quality and dimensional consistency of axle housings, and these important factors have been given utmost emphasis in section 4.00, items 2. A, B and C of this report.

(7) In reverting to the Walking Beam Furnace for heating the axle housing blanks, it must be emphasised that this is an essential feature of manufacturing line improvement to ensure integrated results for the final product.

(8) It is also emphasised in section 5.00, item 1, that apart from the expressed intention of the M.I.N. Management to install improved welding equipment and methods later this year, there is

6.00 TERMINAL SECTION

3. PRIMARY CONSIDERATIONS

A. (8) cont'd.....

nevertheless a contingent necessity to improve and extend inspection for seam welding and for the M.I.N. Management to secure provision of the specified safety precautions for operating staff responsible for the welding process. These latter factors are given emphasis in section 5.00, items 1. A and B.

(9) Investigation and analysis of the alternative conditions required for hot and cold pressing for the axle housing blank has clearly indicated that the cold pressing technique is not compatible with existing manufacturing resources within M.I.N. and that the specified ultimate volume of production would not justify the necessary extent of capital expenditure.

(10) Important recommendations are given in section 5.00, items 3. A, B and C of this report for detail design improvement of the axle housing components. The detail design changes are regarded as a significant contribution for attainment of the forecast volumes of annual production with consistent reliability and a pre-determined life period of unit assemblies.

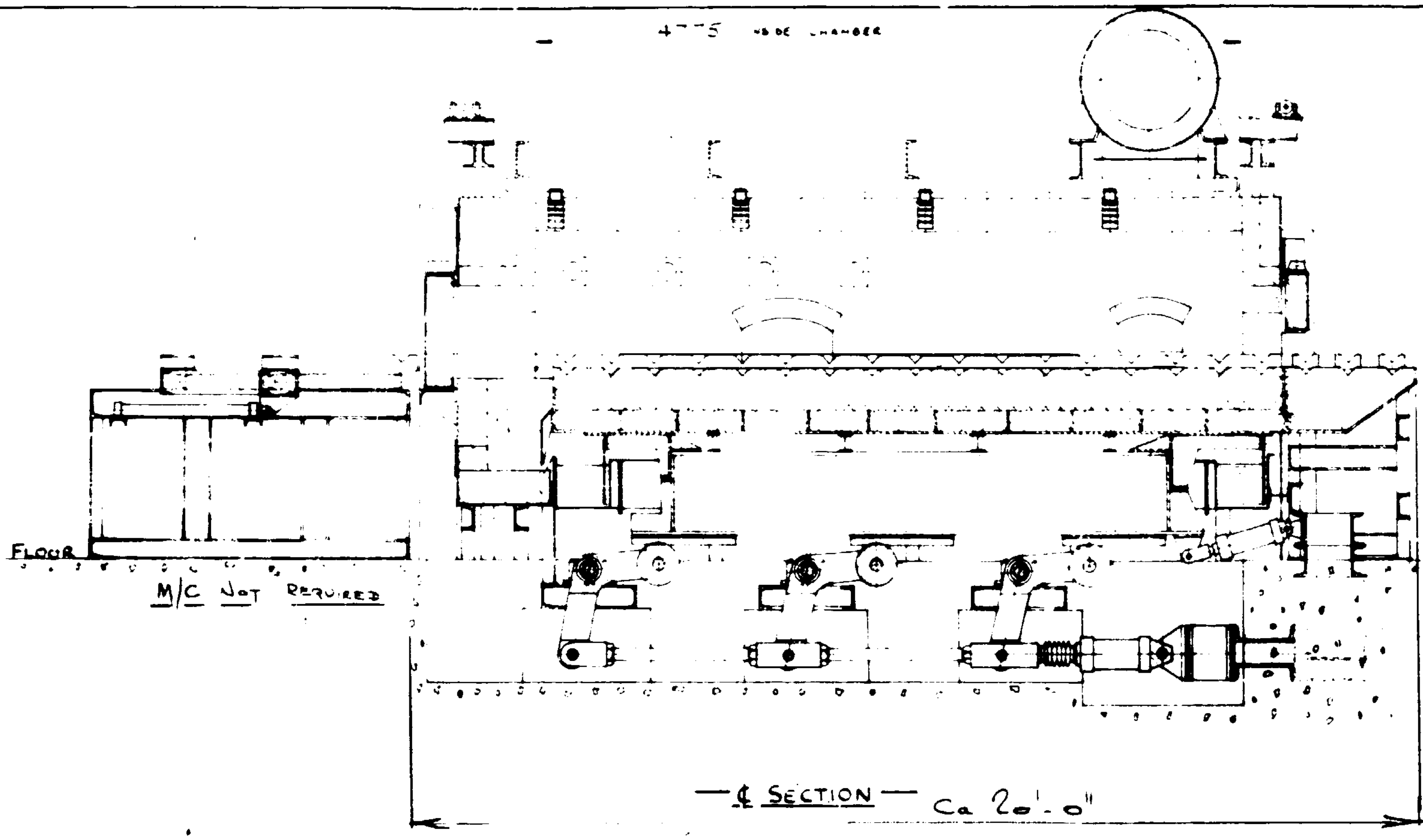
6.00 TERMINAL SECTION

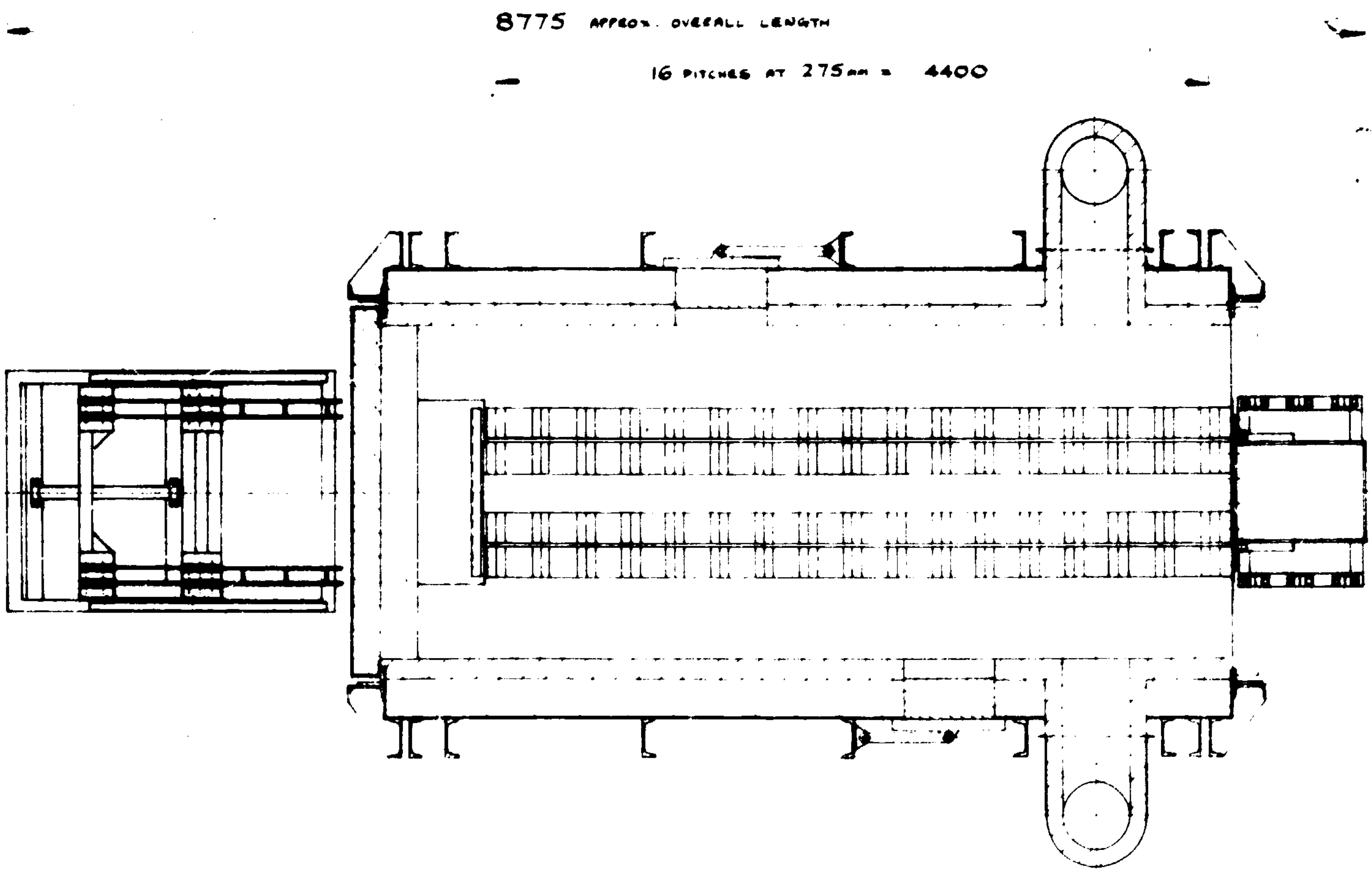
4. PRODUCTIVITY POTENTIAL

A. (1) In view of the age of the existing plant and equipment presently operating in the M.I.N. manufacturing line for production of axle housings, there is serious justification for full implementation of all recommendations specified in this report.

(2) Consequently, it is apparent that the operating staff at the Nis Plant have a restricted productivity factor not consistent with their performance potential.

(3) The prevailing circumstances and effects of the existing manufacturing line are heavily inhibiting the real time performance capabilities of the operating staff responsible for the manufacturing line, so that it is anticipated full implementation of recommendations will be justified by the subsequent improvements in the ratios of productivity, unit costs, amortisation of capital costs, and quality of product.

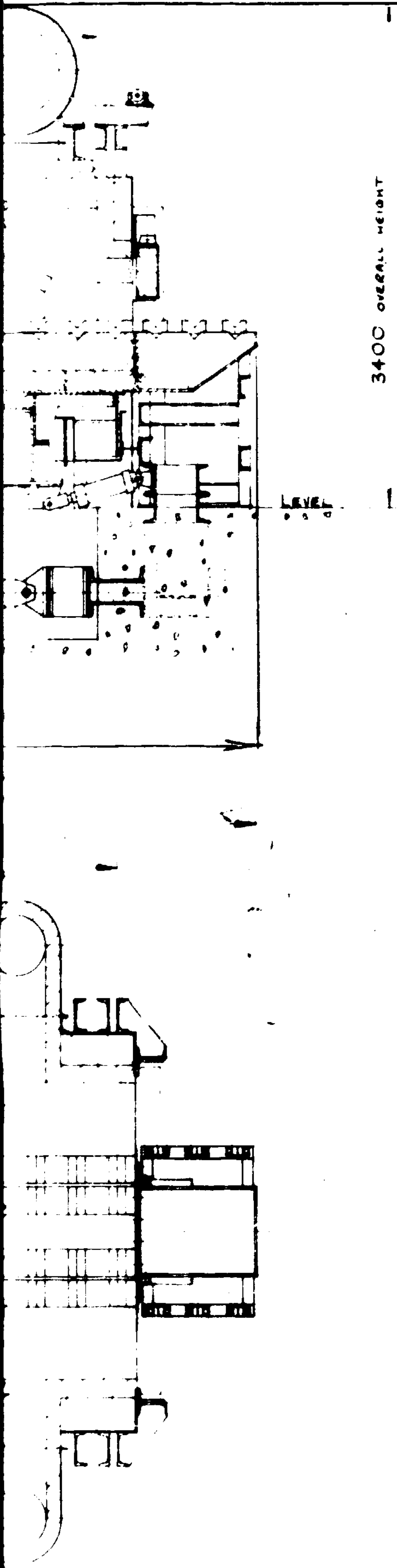


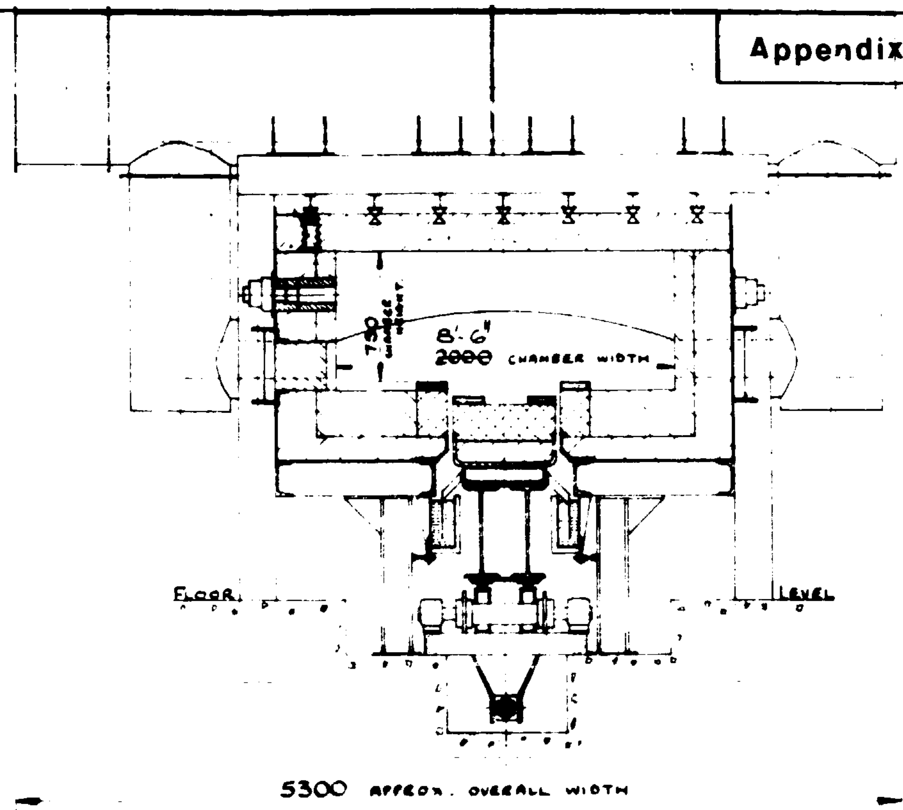


SECTION 1

SECTIONAL PLAN

Appendix: I





— CROSS SECTION THRO' FURNACE —

TYPICAL ONLY

SECTION 2

WELLMAN INCANDESCENT
FURNACE COMPANY LIMITED
CORNWALL ROAD, SMETHWICK, WARLEY, WORCS.

~~GAS~~ OIL - FIRED, BELL CRANK, ~~1800 Kg~~
WALKING BEAM FURNACE

DRAWN BY.	PJB	SCALE. 1/30
CONTRACT No.		DRG. No. Q1-3875

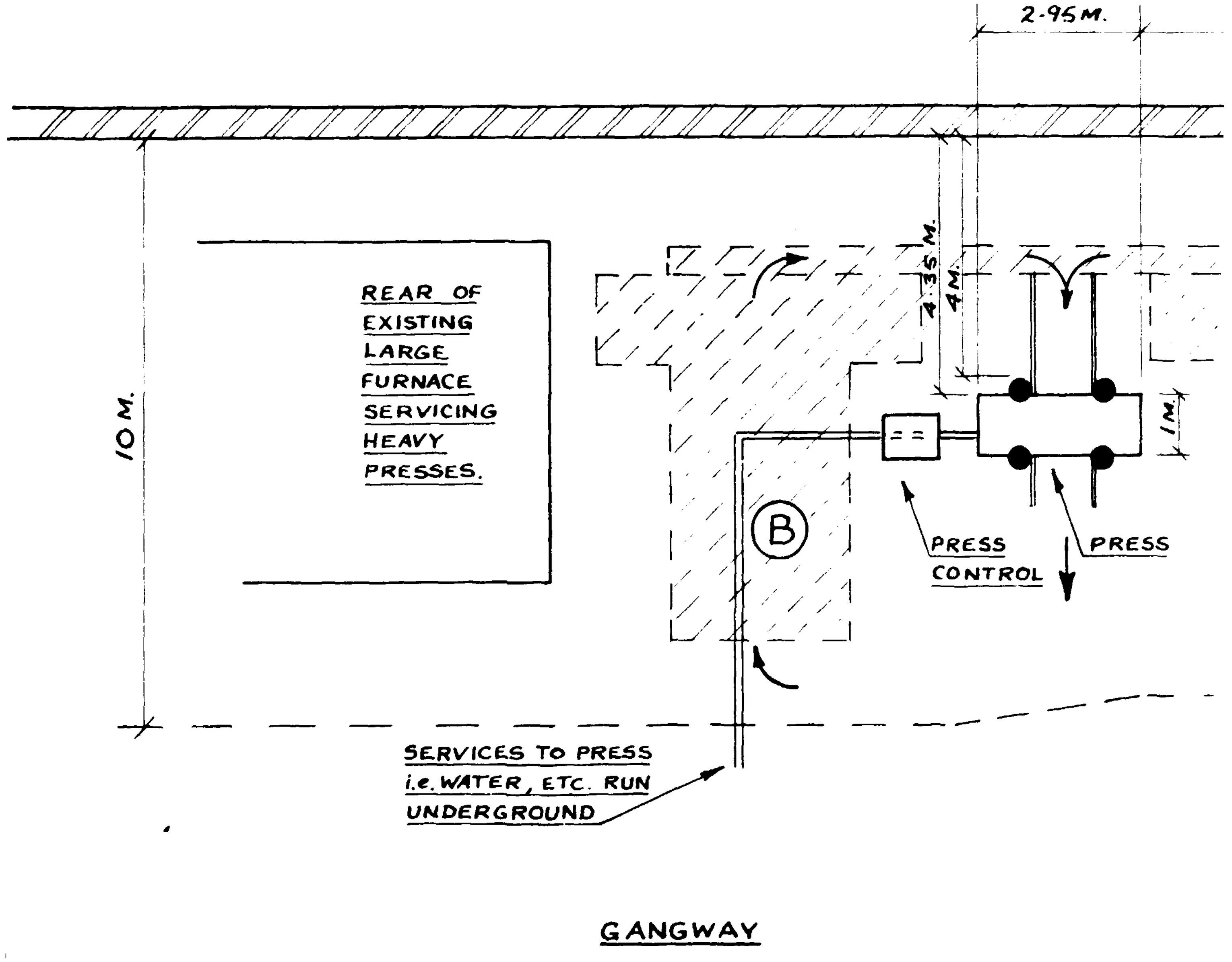
Notes:

1. LENGTH OF FURNACE INCLUDING LOADING SILL AND UNLOAD POSITION MUST NOT EXCEED 7·9 M.
2. BLANK CAN BE EITHER PUSHED ON TO PRESS OVER RAILS - RAILS TO BE 25 mm. THICK WITH A DROP OF 125 mm. <u>OR</u> CAN BE FED WITH CYLINDER.
3. DO NOT SCALE OFF THIS DRAWING.

NORRIS PARTN

Project UNI
CONT

Title PLAN S
(A & B)



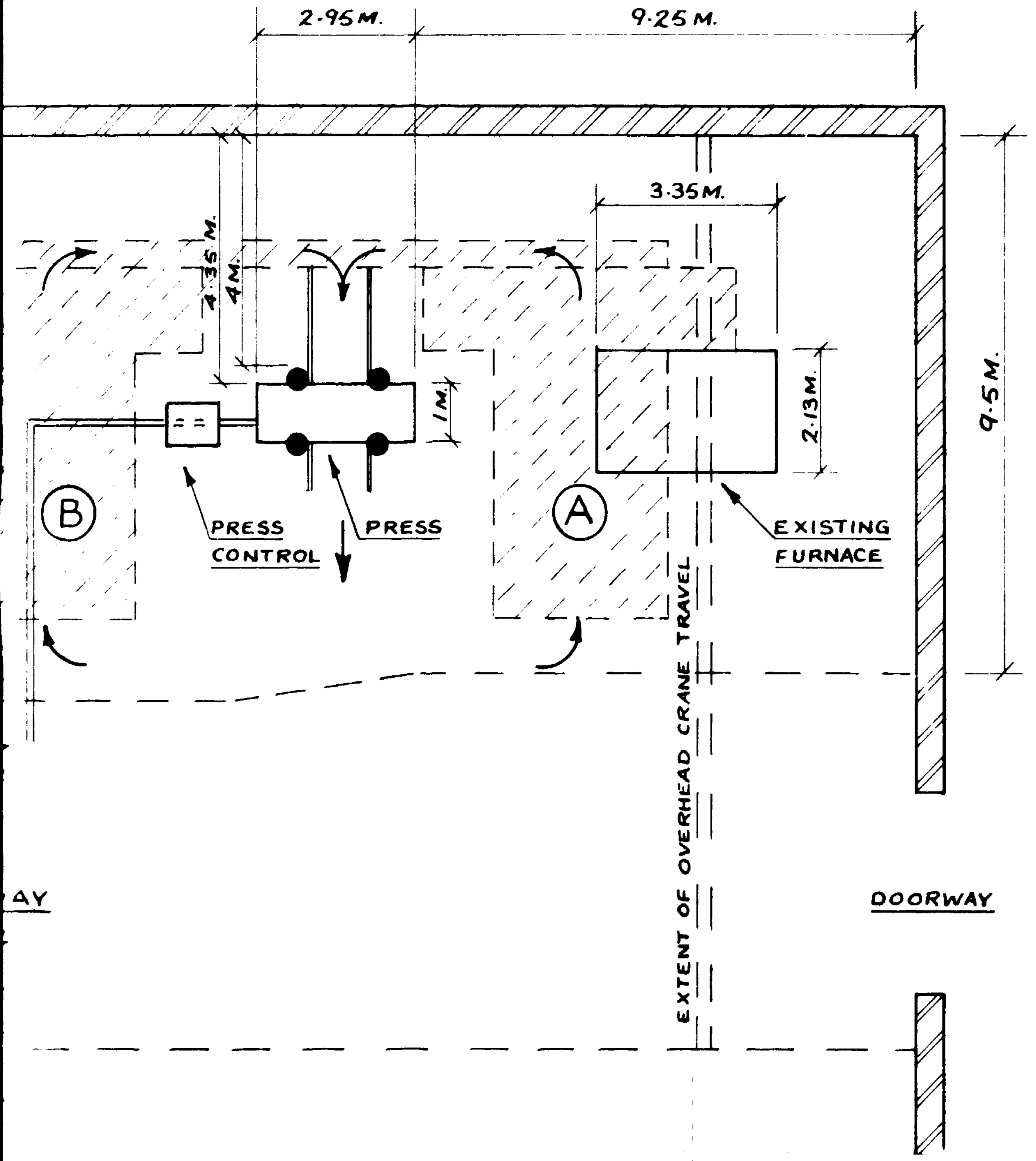
SECTION 1

NORRIS PARTNERS LTD.		Appendix: 2
Project	UNIDO YUGOSLAV PROJECT CONTRACT No. 77/34	Date: MAY 1977
		Drn. by: R.T.L.
Title	PLAN SHOWING ALTERNATIVE POSITIONS (A & B) FOR WALKING BEAM FURNACE	Scale: 1:100

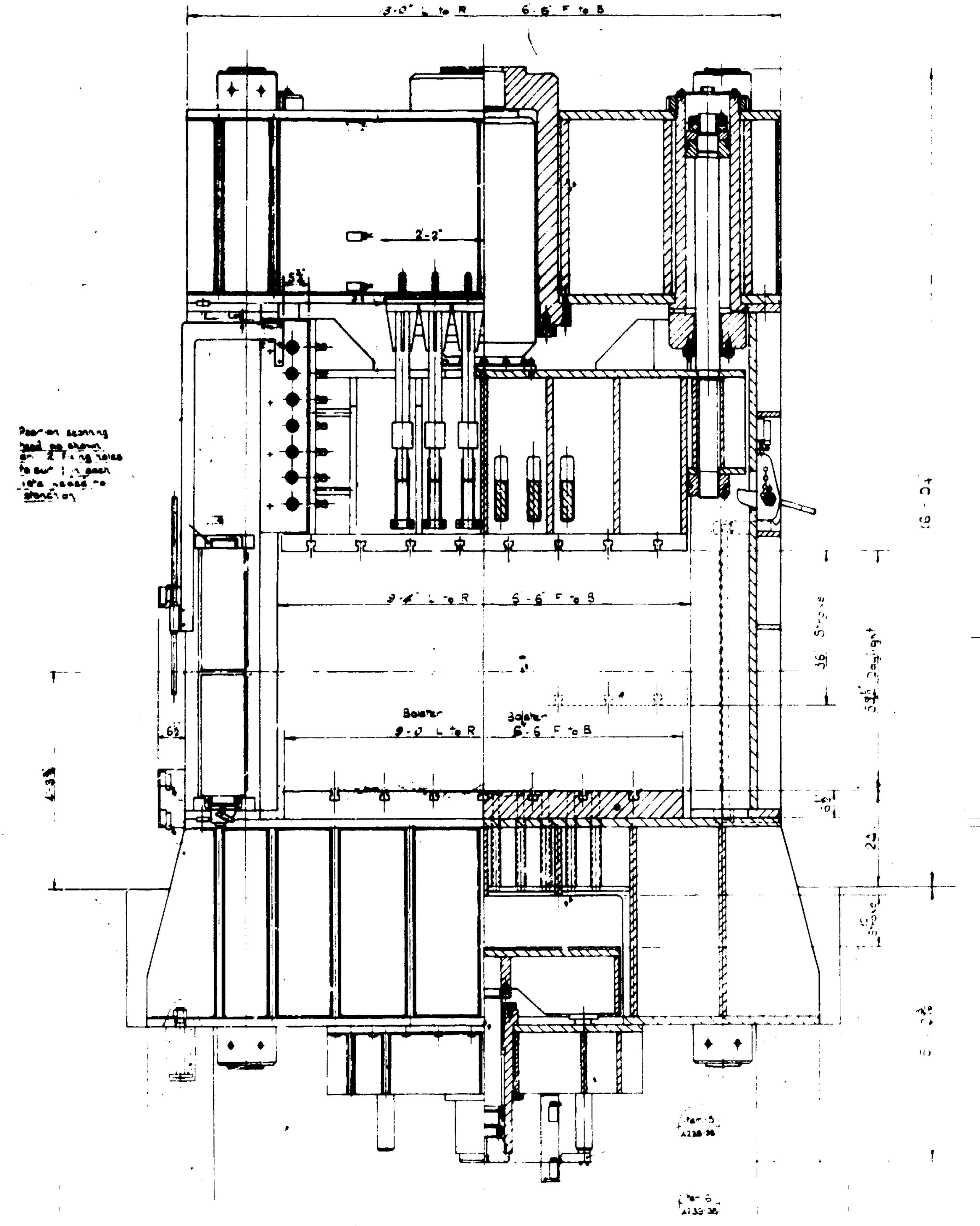
AND UNLOAD

...VER RAILS - RAILS

...N BE FED WITH

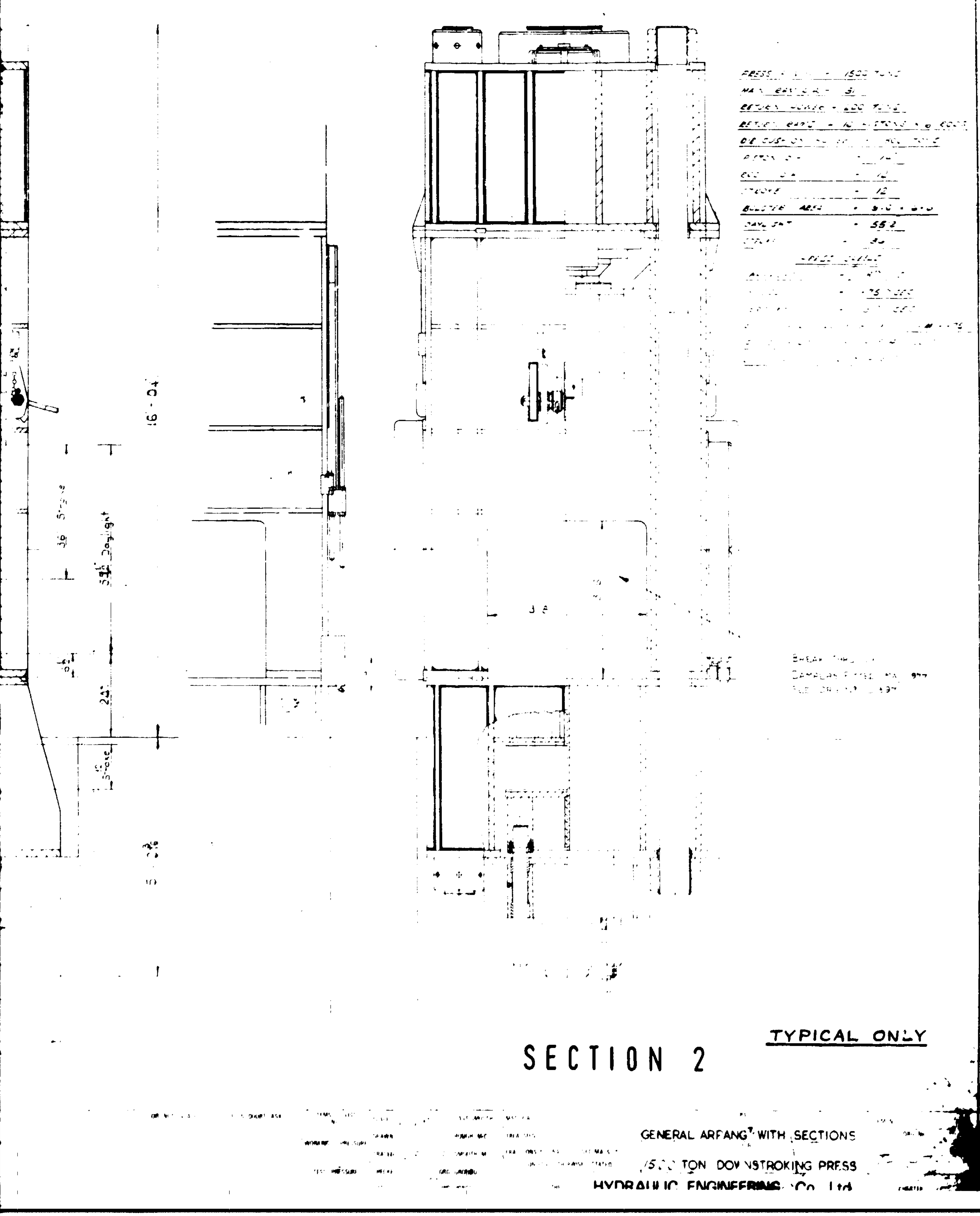


SECTION 2


3'-0" L to R 6-6" F to B
2-2"
Position scanning head as shown and fixing holes to suit 1 in each side needed to stanchion
9-4" L to R 6-6" F to B
36" Stroke
39½" Daylight
Bolster 9-0" L to R
Bolster 6-6" F to B
4-3⅜
24
16-0¼

SECTION 1

Appendix: 3


36" Stroke
Daylight
TYPICAL ONLY
SECTION 2
GENERAL ARRANGT WITH SECTIONS
TON DOWNSTROKING PRESS
HYDRAULIC ENGINEERING Co. Ltd.

M. Gabrovšek[x]
Coauthor – I.Rak[xx]
Coathor – F.Šlibar[xxx]

DEVELOPMENT OF PRODUCTION OF FINE – GRAIN STEELS AT JESENICE IRON AND STEEL WORKS – PROBLEMS OF WELDING AND WELDED STRUCTURE STRESS ANNEALING

Introduction

Owing to the requirements of the domestic metal-working industry, „Jesenice" Iron and Steel Works included into its production programme a wide assortment of fine–grain micro–alloy steels. Particular attention was paid to the production of fine–grain microalloy steels, with the minimum yield point of 461 N/mm^2 (5.8 N/mm^2) intended for the fabrication of sturdy steel structures.

Thus, Nioval 47 quality steel, with the minimum yield point of 461 N/mm^2 (47 kp/mm^2), was used in the construction of the Perućica Hydroelectric Power Plant Pipeline. The pipeline basic characteristic are:

> length: 1931 m, wall thickness: 12–35 mm, diameter: 2650–2500 mm, test specimen ϕ 2500 (6 x 1200 mm), static pressure: 552 mm, singledirectional dynamic load coefficient: Ψ = 0.8, material yield point utilization: 0.6, safety factor: S = 1.67.

In view of the fact that these steels are used to make high yield point utilization structures, extensive tests of steel, as a parent and filler metals, were conducted, in order to answer the following questions:

- what are interactions between elements Nb, V, and N in transient zone.
- what is optimal welding technology of this fine–grain micro–alloy steel.
- selection of filler metal for manual and automatic welding.
- setting up of Nioval 47 steel pipeline welding technology.
- is structure stress annealing necessary and what is its meaning in the manufacture of structures from high–quality Nioval 47 steel.

Owing to the volume and the different character of the testing of particular phases, in addition to „Jesenice" Iron and Steel Works and the „Metalna" enterprise of Maribor, as structures contractors, the research work was joined also by the Ljubljana Metal Structure Institute which made calculation checks and stress testing.

Development and Characteristics of Nioval 47 Steel

The Nioval 47 is a type of steel with the minimum 461 N/mm^2 yield point level. This high strength steel, in addition to its mechanical properties also guarantees weldability and toughness at low temperatures.

The yield point serves as the basic calculated parameter in the selection of steel, and as the steel weldability depends on its chemical composition, favourable influence exerted by certain elements on the yield point level has negative effect on the steel weldability. Thus, added quantities of carbon, manganese, chrome, etc., reduce ciritical cooling rates and increase austenite and martensite transformation in the transient zone.

The yield point is equally influenced by the presence of displacement densities and crystal lattice deformation.

The elements of the interstitial and substitution types can, as a consequence of varied atomic diameters or individual element metallic bond, influence crystal lattice deformation; equally, this deformation is affected by fine–dispersed precipitated particles which block displacement, influencing the yield point.

The linking of the yield point with the steel physical parameters is defined in the Pitch formula:

$$\sigma_s = \sigma_o + k \cdot d - 1/2$$

[x] M.G. Dr. Eng., Director, „Jesenice" Iron & Steel Works Technical Control & Research Sector, Jesenice, Yugoslavia.

[xx] I.R. Grad. Eng., Director, „Metalna" Institute, Maribor, Yugoslavia.

[xxx] F.Š. Grad. Eng., Senior Consultant, Metal Structure Institute, Ljubljana, Yugoslavia.

where:
- σ_o is crystal lattice displacement movement resistance.
- d is crystal grain medium size.
- k is material constant.

The crystal lattice displacement movement resistance as well as grain size can be influenced by the following factors:

- interstitial type elements, e.g., C and N, which directly influence the forming of the Cotrell displacement form
- such elements as Nb and V which in the form of carbide or carbonitride influence the structure fixing.

substitution_type elements, e.g., Mn, Si, Mo, and Cr which influence the crystal structure change and the lamellar perlite–ferrite ratio.

The interstitial and substitution element influence on the yield point is shown in the Pickering–Gladman diagram, Fig. 1.

In addition to the yield point, the material weldability is equally very important.

One of the approximate sizes used to determine the material weldability is 'Cequivalent' (Cekv) which limits adding of certain elements to steel:

$$C_{ekv} = \%C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

in such a way that the reduced carbon and manganese quantities increased 'Cekv' value from 0.40 to 0.45, i.e., to the value where the steel weldability would become possible only via use of preventive measures, such as pre–heating, etc.

In view of the enumerated factors, „Jesenice" Iron and Steel Works used two chemical elements — Niobium and Vanadium — in the development of the fine–grain steels with the minimum yield point of 467 N/mm^2. The Č–0562 quality steel, with the minimum yield point of 353 N/mm^2 was used as parent metal.

*Both of these elements (Nb and V) create carbo-*nitride, in the presence of carbon and nitrogen, in th sizes of 200 to 500 A, thus greatly influencing the strengthening of ferrite, i.e., displacement blocking.

The optimal size of individual particles is produced by thermomechanical material treatment i.e., by rolling, at the temperature of 800 to 830^o, creating higher displacement density, resulting in the appearance of carbonitride Nb and V in desired sizes. During thermo–mechanical treatment precipitated particles are arranged properly, providing for optimal yield point and optimal added element utilization.

The example of the precipitated Nb–carbonitride, following thermomechanical treatment, is shown in Fig. 2 (x 500,000).

Today, fine–grain micro–alloy steels, with Nb or V, in the rolled, i.e., non–heat treated state, are produced, usually. In practice, this means that the thermo–mechanical treatment secures a maximum displacement density, as well as optimal sizes of Nb or V–carbonitride, resulting in the high steel yield point.

„Jesenice" Iron and Steel Works developed Nioval 47 quality steel, with Nb and V added, delivered heat treated.

The steel chemical compostition is shown in Tables I.

The steel mechanical properties are shown in Tabels II.

The minimum steel toughness is shown in Tables III.

We supposed that the parallel adding of Nb and V. plus Al, will exert positive influence on the nitrogen bonding and the appearance of aging, and that the added thermo–mechanical treatment will in turn influence coagulation of the precipitated particles, reducing the internal lattice stress, thus improving the steel weldability. In fact, we intentially lowered the added element (Nb and V) utilization level, forthe purpose of stabilizing mechanical properties and improving the steel weldability.

Problems of Welding Nioval 47 Steel

A welded joint is the most sensitive part of a welded structure. The appearance of martensite and bainit structures on the transient zone exert considerable influence on the steel mechanical properties, i.e., welded joint.

If we are to add micro–alloyed elements, the bahviour ofcarbonitride would pose a problem in the transient zone. The welding technological processes are tied in closely with the introduction of primary and secondary energy. Depending on parameters, varied transient zone can be formed; brought in energy influence the formation and distribution of carbonitride and thus the toughness of the transient zone.

At the metal melting point, during welding, nitrides and carbonitrides are transformed into solid solution. This process is tied in with the time element, i.e., diffusion processes; and it can be said that the dissolving [illegible] and carbonitride is also connected with the [illegible]rbonitride particles.

According to the free energy tests (conducted by different authors (Mayer, Ruhler, and Heiterkampf), nitrogen stability in a nitride depends on vanadium and via niobium to aluminum. These tests prove that the stability of niobium carbide is greater than that of vanadium carbide. In practice, this means that we can, along with the presence of Nb, V, and Al, plus nitrogen, expect to see the appearance of the forming of nitrides and carbonitrides, depending on the steel thermo–mechanical treatment. In turn, this means that with aluminum present, we can hardly expect to see the formation of vanadium carbonitride, i.e., in the narrow temperature interval of 650° to 800°C; the niobium bond in niobium carbonitride is more stable, so depending on Nb and C concentration, complete dissolving of carbonitride is to be expected even at temperatures above 1250°C.

The appearance of V and Nb–carbonitrde is tied in with the forming temperature. During our tests, we wanted to get a picture of the Nb and V–carbonitride bond, with the presence of both the Nb, V and Al [illegible] wanted to tests the influence of the thermomechanical treatment on the formation of carbonitride, niobium, and vanadium. Based on this, we can observe the behaviour carbonitride in the transient zone where the different doses of energy also exert influence on carbonitride cristallization.

The testing of the charges poured in the high–frequency furnaces was made, as shown in Tabels IV.

Al these charges were homogenized for 60 minutes at the temperature of 1300°C and then heat treated, as follows:

Treatment A: normalizing for 30 minutes at the temperature of 910°C; airstill cooling.

Treatment B: normalizing at the temperature of 910°C; furnace cooling at the temperature of 750°C; annealing for 30 minutes at the temperature of 750°C; airstill cooling.

Treatment C: normalizing for 30 minutes at the temperature of 910°C; airstill cooling re–annealing at the temperature of 750°C; airstill cooling.

Thourgh the above–mentioned heat treatment, we wanted t[illegible]ermine the interaction of certain chemical elements, [illegible] combination of micro–alloyed elements, at different temperature intervals most suitable for the carbonitride forming.

The heat treatment influence on the bond of certain elements in nitride, i.e., carbonitride, in percentages, is shown in Tables V.

In view of the fact that as with aluminum we attain a maximum of 77% of the component parts bonded into aluminum nitride, we believe the normalizing process to be too short and that no chemical balance was created. This result is ever more important, because through it we can evaluate more properly the influence of other elements added, i.e., microalloyed, on nitrogen bonding.

With Nioval 47 steel, where all of the microalloyed elements (Nb, V, and Al), we attained a relatively high bonded nitrogen content during the normalizing treatment itself; but what is interesting is that during heat treatment, B and C portion of the bonded niobium content jumped to 91, i.e., 90%. The results of the tests conducted by K. Nishida++ show that the niobium carbonitride precipitation at the temperature of 650°C requires a period of more than 20 hours, confirming the specific nature of the Nb and V interaction on the bonded niobium in the presence of vanadium, proving that the interaction of vanadium and niobium, as far as bonding with nitrogen is concerned, depends entirely on the heat treatment, for which no proper explanation canbe given. At any rate, this experiement proves that combined with Nb, V, and Al we can expect to get a very strong nitrogen bond, influencing both the basic mechanical properties of the parent metal, as well as welded joint – transient zone. In view of the heat treatment normalizing process, the carbonitride microalloyed particles have the size of over 500 A.

This means that if the welding was performed with a relatively low energy input, carbonitride will not dissolve completely in the tansient zone, due to lack of sufficient time, and carbonitride will again be formed during the weld cooling process; but, if the welding was done with a relatively high energy input, all carbonitrides will dissolve partially. If, on the other hand, we are to apply welding with weaving, formation of cabronitride and nitrogen–niobium bond, as with „C" experimental charge heat treatment, will occur, influencing to some extent the physical weld, i.e., transient zone properties.

Nioval 47 Steel Welding Technology

In order to check the supposition of the dependance of cabronitride dissolving on the time element, i.e., energy input, the following practical experiments were conducted:

a) testing of spot welded joints on the changing dynamic loads; the results have shown that compared with the „normal" steel spot welds, the steel containing niobium has longer lasting strength, meaning that no diffusion, dissolving of carbonitride, or formation of brittle structure, occured during welding.

b) tests with the welding of an experimental 30 mm steel plate pipeline, performed partially with manually coated electrodes and partially by automatic submerged method.

The experimental pipeline was constructed of 30 mm steel plate and vessel diameter of 1000 mm and was closed off on one side by a cup–edged cover, with the pipeline connection covers reinforced.

K.J. Irwin, F.B. Pickering, Journal of the Iron and Steel Institute, Nov. 63

M.Economopulos, T.Greday, N.R.M. No. 1, 1964.

++ K. Nishida, Nippon Kinzoku, 1959 No. 9 1077–1085.

The chemical steel plate composition is shown in Tables VI.

The mechanical steel plate properties are shown in Tables VII.

In order that the welding technology could be mastered, numerous tests on the quality of filler material, input energy parameter, and slot shape, were conducted. Finally, it was established taht 2/3 X slot shape and the plate pre–heating temperature of 170–200°C were most suitable.

The optimal results of the welded joint mechanical properties were arrived at through the use of the special basic type EVB Ni electrode.

The chemical composition of the pure weld metal is shown in Tables VIII.

The toughness of the pure weld metal is shown in Tables IX.

The experimental pipeline automatic welding was performed with EP40 flux and EPP 2 Ni ϕ 4 mm wire, under the following conditions:

Electric current:	620–700 A
Voltage:	34 V
Welding rate	62–67 cm/min.
Number of runs:	15

The toughness of the welded joint is shown in Tables X.

The toughness of the electric arc welding joint is shown in Tables XI.

Determining of Pre–heating Temperatures

In order to determine the pre–heating temperatures, maintain temperature between runs, and keeping up the heating temperature level after the welding process, we used ITA and BESSYA high strength steel formula, also applicable when the weld hydrogen content stands at 3 ccm/100 gr., recognized by the IIW.

$$C = 1440\,P_C - 392$$

$$Pc = C + \frac{Si}{300} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B + \frac{t}{600} + \frac{H}{60}$$

where:
– t is plate thickness
– H is diffused H_2 (ccm–100 gr. of weld)

The minimum 35 mm plate pre–heating temperatures are:

– automatic submerged welding: 185°C.
– manual electric arc welding: 145°C.

Evaluation of susceptibility of weld material, transient zone, and parent metal toward brittle fracture

In order to determine the birttle fracture transient temperature, we employed the Drop– Weight–Test, as per ASTM 208–69. The experimental test pieces P3 were cut out from 35 mm thick samples, so that for every transient temperature five test pieces were used.

The experimetnal crack starter, where the V–shaped notch was made, was so welded that the fracture could appear at the crack starter, transient zone, and the parent metal.

The diagram in Fig. 3 shows NDT automatic submerged welding temperatures.

The diagram in Fig. 4 shows manual electric arc welding temperaturs.

If NDT temperatures are entered onto Pellini diagram, used to determine the appearance of brittle fracture, and if we consider that the lowest pipeline operational temperature is plus 5°C, we can then arrive at the required difference between NDT and the working temperatures, i.e., 35°C, applicable to all types of welding, and this would guarantee that no brittle fracture will materialize.

Question of after–welding stress relieving application

The transient zone test results, before and after stress relieving, are used to determine after–welding structure stress relieving applicatio[n].

The transient zone toughness test results, before and after annealing, are shown in Fig. 5.

The weld hardness, i.e., transient zone hardness, covering example No. 10, measured on the last crack starter, after–annealing, is shown in Fig. 6. These tests reconfirmed the data from professional journals, i.e., that the stress relieving in different types of steels is manifested differently. Thus, it was noticed that in Nioval 47 steel, depending on the test temperature, there is a weakening of the plate, i.e., welded joint properties.

We abandoned stracture stress annealing also because the stress unrelieving welded high strenth steel joints can catch and arrest a brittle fracture much faster, same of which was also verified by the tests conducted on large welded test pieces, per Robertson.

If we follow such a test, we can notice that the crack in the stress unrelievingweld joint or weld transient zone moves initially vertically in the exterior load direction, to be direction changed afterwards, arresting at the parent metal. The reason for this are the weld longitudinal stresses caused by welding, bigger thant he exterior loads, causing the weld stress.

If the stree relieving did materialize, the welding stresses are then reduced, resulting in a higher exterior load, preventing the crack from changing the direction of expansion, i.e., moving in not so tough part of a weld or transient zone. This could be applicable only if a plate is tougher than weld or transient zone and provided the structure was not loaded above the yield point.

Further on, additional arguments influencing the decision not to stress anneal the pipeline after welding will be presented.

Experimental Pipeline Model Testing

In order to justify the welding technology selected, we conducted static and explosion tests on a separate experimental pipeline model made of 30 mm plate where the stress relieving process was not applied. The dimensions and the shape of the model tested are shown in Fig. 7.

a) Static Test

The pressure of up to 225 atmosphere was tested in the first phase of operations. The experimental model had 20 stress and deformation strain gauges (Fig. 8) placed on both the individual welds, as well as casing.

b) Explosion Test

This test was conducted in a special area. In order that the wall pressure could be spread evenly, explosive was placed vertically and seven kilos of trinitrotoluene were used. The experimental model was filled up with 3 m^3 of water at the temperature of 8°C. In order to be able to check on the notch influence, both on the weld (Fig. 9) and the transient zone, approximately 30 mm long and 3 mm deep notches were made.

The model prior to explosion is shown in Fig. 10.

The model after explosion is shown in Fig. 11.

The tests showed taht the fracture on one spot had initially deformation characteristics (Fig. 12), and strong plate contraction was noticed. It can be seen that the crack expansion (Fig. 13) did not follow any set pattern, i.e., spread on the parent metal in many different directions. The man made notches did not influence the crack, i.e., fracture movement.

Based on the laboratory tests of the temperature, prior to entering into brittle state, and based on the experimental model tests, it can be concluded that an appropriate welding technology provides a structure made of fine–grain micro–alloy Nioval 47 quality steel with good technological characteristics.

All the tests conducted up to now, show that the str[illegible]ing process in a structure made of N[illegible]7 quality steel did not give positive results as far as metallurgical properties are concerned.

The results of the experimental model tests failed to provide any support to the stress relieving process.

Experimental Model Stress Measuring Analysis Results

Based on the results of the previously conducted tests, where we checked the influence of the stress relieving on the notch toughness, it was decided not to relieve the pipeline. This d[illegible]sion was also justified by the pipe model static and explosion test results. When the pipe model was tested to pressure (Fig. 14), what was done was to measure specific pipe casing deformation in dependence to the pipe overpressure. The measurements were performed with some 20 odd strain gauges placed on both the interior as well as exterior of the casing, in two cross–sections, in the direction of the volume (x) and longitudinal direction (φ), as shown in Fig. 14.

The specific deformation measured values (Tables XII) $\epsilon_{\vartheta i}$ and ϵ_{xi} depending on the pipe overpressure (p), i.e., on the stress σ_{ϑ} and σ_x and equaling overpresssure p:

$$\sigma_{\vartheta} = \frac{pD}{2t}$$

$$\sigma_x = \frac{pD}{4t}$$

On each measuring point, deformations were checked on both the exterior (v) and the interior (u) casing surface and the indicated medium values are shown in Tables XII.

$$\epsilon_{\varphi i} = \frac{\epsilon^{v}_{\varphi i} + \epsilon^{\varphi}_{\varphi i}}{2}$$

$$\epsilon_{xi} = \frac{\epsilon^{v}_{xi} + \epsilon^{\varphi}_{xi}}{2}$$

and then compared with the calculated values:

$$\epsilon_{\varphi} = \frac{pD}{2tE} \left(1 - \frac{\vartheta}{2}\right)$$

$$\epsilon_x = \frac{pD}{4tE} \quad (1 - 2\vartheta)$$

For illustration purposes, some of the results were shown graphically. Thus, specific deformations ϵ_{φ}, measured on the point No. 1, depending on overpressure p, i.e., the stress σ_{φ}, are shown in Fig. 15; while deformations ϵ_x measured on the point No. 5, are shown in Fig. 16.

From the diagram in Fig. 15, it can be seen that specific deformations, in the direction of the volume, are [illegible]tional to [illegible] overpressure p, i.e., to the stress σ_{φ}.

In fact, via cold pipe bending process, residual casing stresses are caused (Fig. 17), which are added up with the load stresses, i.e., caused by interior overpressure; this brings about, with the initial pipe load, a partial pipe casing cross–section plasticising – even under small loads – reflected in the pipe inflexible behaviour in the direction of the volume; with the subsequent loads, which do not overstep the previously maximum attained loads, the pipe reverts to its original flexibility; however, each overstepping of the previous maximum load, brings about the lasting inflexible deformation. The final pipe capacity was not reduced, but it is evident that the residual cold plate bending stresses increase pipe deformation, increased with the degree of the plate bending deformation (D/t).

With the defined assumptions, such as the Narairov hypothesis on flat cross–sections during bending (ideally flexible – ideal plastic material, etc.), we have also determined the calculated ratio between specific deformations ε_T and the stress σ_T, taking into consideration the plate bending residual stresses (Fig. 1[illegible]).

In the diagram (Fig. 15), where the calculated curve thus made (broken curve) was compared with the measure values, it can be seen that the calculated results agree fully with the values arrived at experimentally.

Table XIII shows the difference in values measured on particular exterior and interior casing surface points. While these differences on the casing itself are not great – measuring point No. 1 – these differences can be very great on the longitudinal welds, as is the case with the measuring point No. 4. If the weld in the cross–section is not level with the surface of the metal, then in addition to the normal stresses, bending stresses too will appear; however, despite these great deformation differences, pointing to geometrical departures, no damaging influences, or a reduction in the weld joint capacity, in both the static as well as explosion tests, proving on this point too the appropriate welded joint quality.

Conclusions

Based on the results of the tests on the influence of the micro–alloy niobium and vanadium additions on the behaviour in the incresed steel yield point, and based on the test results made on the Nioval 47 steel, the following conclusion can be singled out:

1. By combining microalloy steel with Nb and V elements, in the presence of A., it is possible to get optimal N bonding, both in the normal as well as other heat treatment states, resulting in the satisfactory steel mechanical properties.

2. The following preventive measure should be adhered to when welding Nioval 47 quality steel:
   – input energy should be proportional to plate thickness and number of runs.
   – plates should be pre–heated prior to welding, as well as during welding, if necessary; added heat and welded joint slow cooling is recommended.
   – filler metal should be dried up, to keep hydrogen content at 3 ccm/100 gr. level

3. Input welding energy influence Nb, V, & Al – carbonitride cristallization, i.e., nitride in the weld and adjacent zone.
   In view of the fact that high strength steel is used to construct important structure, the welding process must be suited to carbonitride and nitride formation process, although this may not always be the most economical.

4. residual pipe stresses caused by the plate cold bending increase the pipe deformation in the direction of the volume, at the initial load, in the form of a lasting deformation; with the subsequent loads, which do not overstep the maximum, the pipe stays flexible; however, if the overloads become too great, as when a water shock is experienced, the increased deformation acts as a kind of „shock–absorber". From this reason, the pipe stress relieving, as well as increased pressure above the nominal level, during the pipeline pressure testing, is not useful, as the favourable residual stress influence on the pipe deformation is lost.

Equally, pipe stress relieving represents a problem, metallurgically, necessitating the examination of the influence of stress relieving on every type of steel, separately. In our concrete example, we have, based on the results of the tests of metallurgical and mechanical properties, as well as tests conducted on the experimental model, abanadoned the pipe stress relieving process.

BIBLIOGRAPHY:

1– L. Meyer – F.Schmidt – C.Strassburger: Einfluss von Niob und Vanadin auf das Gefuge und Eigenschaften perlitarmer aluminiumberuhigter Stahle. Stahl u. Eisen No. 22–1966.

2– W. Dahl – H. Hengstenberg – H.Adrian: Ainfluss von Legirungszusatzen auf die Festigkeitseigenschaften von hochsten schweissbaren Baustählen im normalgeglühten und luftvergüteten Zustand. Stahl u. Eisen No. 12 1970.

3– J.M. Gary – W. Webster – J.H. Woodhead: Precipitation in mild steels containing small additions of niobium. Journal of the Iron and Steel Institute, August 1965.

4– F. Vodopivec, M.Gabrovšček, A.Osojnik, L.Kosec: Nitride Balance Sheet in structure steels, Metalurški Institut, Ljubljana, 1972.

5– W.E. Duckworth: New Steels and their applications, Steel Times Annual Review & Centenary Number 1966.

6– H.Vogel – P.Konig – K.Heinz: Einfluss der Abbindung von Stickstoff duch Aluminum und Vanadin auf die mechanischen Eigenschaften von hochfesten Baustählen. Archiv fur das Eisenhutten wesen 1964 No. 4.

7– P. Mandry – R.Namdar – C. Wache: Précipitation de carbonitrures de niobium dans les aciérs de construction soudables. Révue de Métalurgie No. 7 – 8 1969.

8– M. Economopoulos – T.Greday: Récherches sur les aciérs de construction soudables a haute resistance. C.N.R.M. No. 1 1964.

9– B. Morrison – H. Woodhead: The influence of small niobium additions on mechanical properties of commercial mild steels. Journal of the Iron and Steel Institute No. 1. 1963.

Table I – Nioval 47 Steel – Chemical Composition

C%	%Si	%Mn	%P	%S	%Nb	%V	%Al
max. 0,20	cca 0,35	cca 1,40	max. 0,030	max. 0,030	cca 0,04	cca 0,06	cca 0,030

Table II – Nioval 47 Steel – Mechanical Properties

Yield Point N/mm^2	Strength N/mm^2	Elongation 5 d%	Bending 180°
min. 431	559–755	min. 18	3a

Table III – Minimum Steel Toughness (Test specimen V–Notch) Joul

	Non – aging state					Aging state		
	+20	0	–20	–40	–50°	+20	+5	–20°
Longitudinal	48	41	34	47	24	41	35	24
Cross	41	41	31	23	24	41	35	24

Table IV – Chemical Compostion of Charges Poured in High Frequency Furnace

Chg	Steel Type	%C	%Si	%Mn	%V	%Nb	Al	N
3319	Al 1	0,18	0,36	1,25	–	–	0,029	0,0063
3320	Al 1	0,18	0,45	1,27	–	–	0,030	0,0092
3321	Al 2	0,17	0,42	1,23	–	–	0,091	0,0082
3322	Al 2	0,17	0,39	1,25	–	–	0,090	0,0032
3324	Nb	0,15	0,43	1,13	–	0,075	0,004	0,0039
3325	Nb	0,17	0,43	1,23	–	0,064	0,002	0,0078
3405	Nb–Al	0,20	0,53	1,50	–	0,075	0,042	0,0113
3331	V	0,18	0,41	1,24	0,088	–	0,003	0,0072
3332	V	0,19	0,45	1,29	0,080	–	0,003	0,0113
3334	V–Al	0,14	0,36	1,03	0,070	–	0,019	0,0099
3404	V–Al	0,21	0,52	1,45	0,072	–	0,043	0,0135
3363	Nb–V–Al	0,17	0,46	1,33	0,073	0,071	0,037	0,0176
3333	Nb–V–Al	0,17	0,47	1,28	0,072	0,070	0,035	0,0092

Table V – Binding Share of Single Elements in percentages

Alloyed Elements	N			Nb			V		
Heat Treatment	A	B	C	A	B	C	A	B	C
Steel Type									
Al 1	77	80	74						
Al 2	64	71	61						
Nb				41	55	52			
Nb–Al	73	94	85	47	45	44			
V							18	32	41
V–Al	65	100	100				13	10	11
[illegible]	93	87	84	45	91	90	10	9	17

Table VI – Plate – Chemical Composition

%C	%Si	%Mn	%P	%S	%Al	%V	%Nb	%N
0,19	0,33	1,50	0,017	0,006	0,015	0,07	0,04	0,0102

Table VII – Plate – Mechanical Properties

Jield Point N/mm²	Strength N/mm²	Elongation 5d	Toughness[x] Joul
464,9	629,1	26,8	41,4–49,6

[x] Toughness in aged state deformation 5%, sharp notch test, test temperature 0°C

Table VIII – Pure Weld Metal (electric arc welding) – Chemical Composition

%C	%Si	%Mn	%Ni
0,06	0,50	0,95	1,10

Table IX – Pure Weld Metal Toughness (test specimen V–Notch)

Temperatura	20	0	–20	–40	–60°
Joul	82	55	41	34	27
	124	96	82	69	55

Table X – Welded Joint Toughness (automatic welding–Joul)

Weld	Transient zone	Weld Aged State
60	68	38
64	54	37
58	78	39

Test Specimen V–Notch
Test temperature 0°C

Table XI – Welded Joint Toughness (electric arc welding)

Weld	Transient zone	Weld Aged State
97	71	83
85	99	53
82	95	64

Test specimen V–Notch
Test Temperature 0°C

Table XII

p kp/cm²	Measure Specific Deformations $\epsilon_{\varphi 1}.10^{-6}$	$\epsilon_{\varphi 2}10^{-6}$	$\epsilon_{\varphi 3}.10^{-6}$	$\epsilon_{\varphi 4}.10^{-6}$	$\epsilon_{\varphi 5}.10^{-6}$	$\epsilon_{\varphi 6}.10^{-6}$	$\epsilon_{\varphi 7}.10^{-6}$	$\epsilon_{\varphi 8}.10^{-6}$	$\epsilon_{\varphi 9}.10^{-6}$	$\epsilon_{\varphi 10}.10^{-6}$	Calculated Values^x) $\epsilon_{\varphi}.10^{-6}$	$\epsilon_x.10^{-6}$	σ_{φ}	σ_x
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	335	351	328	337	87	345	344	366	318	95	337	79	833	417
60	436	433	434	441	104	451	458	423	383	126	405	95	1000	500
100	743	757	746	735	166	765	769	712	641	196	675	159	1667	833
0	60	59	73	68	−1	69	80	26	6	8	0	0	0	0
100	753	759	743	739	170	766	769	703	633	191	675	159	1667	833
150	1346	1313	1332	1294	269	1366	1366	1245	1030	299	1012	238	2500	1250
184	1841	1785	1822	1740	319	1871	1861	1693	1283	353	1241	292	3067	1533
0	544	468	545	512	4	547	541	396	110	18	0	0	0	0
190	1878	1823	1860	1778	319	1904	1896	1731	1303	355	1282	301	3167	1583
200	1984	1921	1960	1833	335	2009	1993	1833	375	375	1349	317	3333	1667
0	718	639	717	650	19	731	719	536	197	54	0	0	0	0
208	2138	2073	2117	1973	351	2166	2150	1970	1434	385	1403	330	3467	1733
220	2387	2313	2359	2138	360	2406	2377	2213	1523	396	1484	349	3667	1833
230	2637	2538	2604	2290	380	2650	2610	2438	1610	413	1551	365	3833	1916
230	2766	2651	2726	2355	392	2769	2716	2545	1637	417	1551	365	3833	1916
0	1167	1063	1155	862	16	1143	1102	966	221	17	0	0	0	0

$$\sigma_{\varphi} = \frac{p \cdot R}{t} \qquad \epsilon_{\varphi} = \frac{p \cdot R}{t \cdot E}\left(1 - \frac{\nu}{2}\right)$$

$$\sigma_x = \frac{p \cdot R}{2t} \qquad \epsilon_x = \frac{p \cdot R}{2\,tE}\,(1 - 2\nu)$$

Table XIII

p kp/cm²	σ_φ kp/cm²	Measuring Point: 1		4 (longitudinal weld)		9 (longitudinal weld)		Calculated
		$\epsilon^u_{\varphi 1} \cdot 10^{-6}$	$\epsilon^v_{\varphi 1} \cdot 10^{-6}$	$\epsilon^u_{\varphi 4} \cdot 10^{-6}$	$\epsilon^v_{\varphi 4} \cdot 10^{-6}$	$\epsilon^u_{\varphi 9} \cdot 10^{-6}$	$\epsilon^v_{\varphi 9} \cdot 10^{-6}$	$\epsilon_\varphi \cdot 10^{-6}$
0	0	0	0	0	0	0	0	0
50	833	346	325	573	102	432	204	337
60	1000	443	429	780	103	527	250	405
100	1667	768	719	1303	168	847	435	675
0	0	65	56	219	−80	16	−3	0
100	1667	782	725	1317	162	843	434	675
150	2500	1401	1292	2400	188	1273	787	1012
183	3067	1906	1777	3196	284	1502	1076	1241
0	0	578	511	1282	−257	−37	257	0
190	3167	1951	1806	3266	291	1500	1107	1282
200	3333	2054	1915	3398	329	1560	1176	1349
0	0	756	631	1525	−225	+38	355	0
208	3467	2207	2069	3566	381	1612	1256	1403
220	3667	2466	2308	3806	471	1646	1410	1484
230	3833	2719	2556	4025	555	1690	1531	1551
230	3833	2859	2673	4109	601	1678	1597	1551
0	0	1211	1123	1841	−116	−133	580	0

Calculated Values:

$$\sigma_\varphi = \frac{pD}{2t} = \frac{pR}{t} = 16{,}6 \cdot p \quad (\text{kp/cm}^2)$$

$$\epsilon_\varphi = \frac{pD}{2tE} = \left(1 - \frac{\nu}{2}\right) = 6{,}746 \cdot 10^{-6} \cdot p$$