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A COLLECTION OF STEEL METALLOGRAPHIES WITH ILLUSTRATION AND DES--ETC(U)
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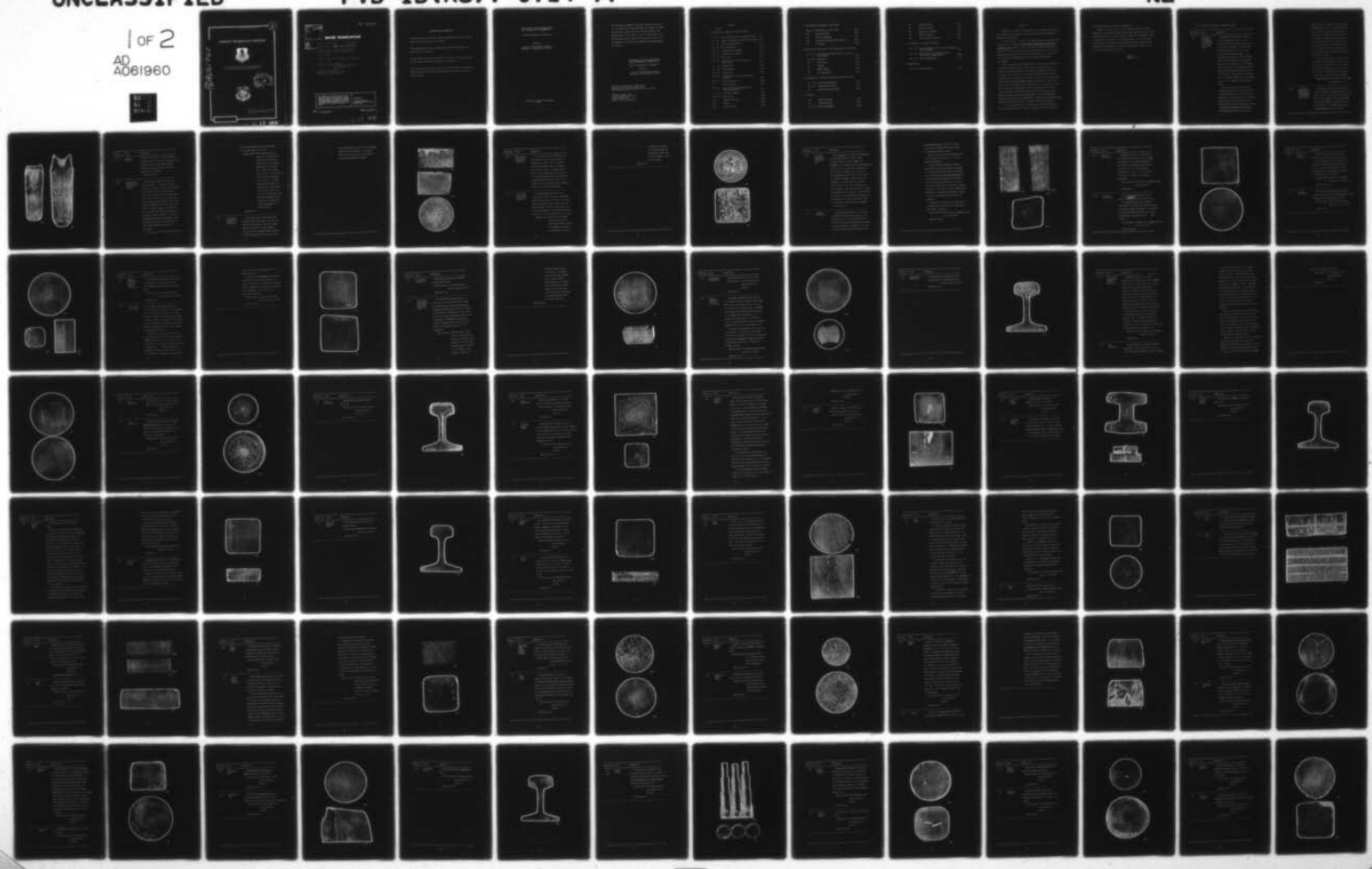

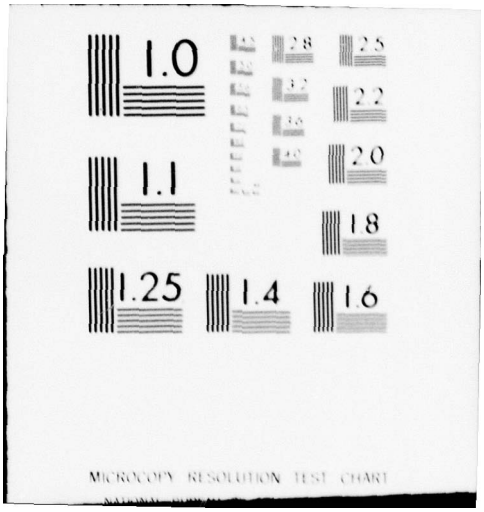
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FOREIGN TECHNOLOGY DIVISION

AD A061960

A COLLECTION OF STEEL METALLOGRAPHIES
WITH ILLUSTRATION AND DESCRIPTIONS

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EDITED TRANSLATION

FTD-ID(RS)T-0714-77 16 November 1977

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A COLLECTION OF STEEL METALLOGRAPHIES WITH ILLUSTRATION AND DESCRIPTIONS

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QUOTATIONS FROM CHAIRMAN MAO

"Ideological and political line is key link. When the key link is grasped everything that hinges on it is in order."

"Be prepared against war, be prepared against natural disasters, and do everything for the people."

"On what basis should our policy rest? It should rest on our own strength, and that means regeneration through one's own efforts."

"The Chinese people have high aspirations, they have ability, and they will certainly catch up with and surpass advanced world levels in the not too distant future."

A COLLECTION OF STEEL METALLOGRAPHIES WITH ILLUSTRATIONS AND DESCRIPTIONS

--Steel Macrostructure and Defects--

Edited by

Steel and Iron Research Institute
Department of Metallurgical Industry

Metallurgical Industry Publication
1975

This Collection includes 156 pictures, which are classified into seven divisions: degasified steel, open steel, continuous casting steel, electro-slag steel, fracture, welding and miscellaneous. Of each picture, there is a brief description. This Collection can be used by steel plants and other units as reference for identifying and judging steel macrostructure and defects.

A COLLECTION OF STEEL METALLOGRAPHIES
WITH ILLUSTRATIONS AND DESCRIPTIONS

--Steel Macrostructure and Defects--

Edited by

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2. The Structure and Defects of Open Steel

3. The Structure and Defects of Continuous-casting Steel Billet

4. The Structure and Defects of Electro-slag Remelted Steel

5. Fracture

Preface

Following the direction of Chairman Mao's proletarian revolutionary line, metallurgical industry in our country has created a vigorous and extremely good situation.

In order to meet the needs of the rapid development of metallurgical industry, we have revised the Steel Metallographies With Illustrations and Descriptions of 1960 edition. In our work of revision, we adopted a mass line and widely solicited opinions and suggestions in regard to our undertaking from workers, technicians and leading cadres. We also went to the fields and visited a number of metallurgical and machinery enterprises.

This Collection contains 156 pictures all concerning macrostructure and defects of steel. Most of these pictures are obtained from the follwoing organizations: Anshan Iron and Steel Company, Tai-Yüan Iron and Steel Company, Capital Iron and Steel Company, Wuhan Steel Plant, Ta-yeh Steel Plant, Tsitsihar Steel Plant, Chungking Special Steel Plant, Shanghai Iron and Steel Research Institute, Shanghai Steel Plant No.1, No.3 and No.5 and Shanghai Diesel Engine Plant (the foregoing five units are affiliated to The Metallurgy Bureau of Shanghai City), Shanghai Boiler Manufactory, Chiangnan Shipyard, Shanghai Steam Engine Boiler Research Insitute, Harbin Boiler Manufactory, Lanchou Petrochemical Machinery Plant, Wuhan Boiler Manufactory, Chungking Heavy Machinary Plant, Kwangchou Heavy Machinery Plant and Peking Metal Structure Works.

In our preparation for this revision, we received encouragement, support and help from various units throughout the country. To each of

them we here express our heartfelt appreciation.

Because of the limitations in our thinking as well as our work experience, and the lack of sufficient reference materials, we have found some shortcomings in this book, such as the absence of a systematic series of pictures of the changes in hot working process. There may be other errors that we have not discovered. Criticisms and suggestions are all appreciated and we especially welcome contributions of pictures so that we can use them in our next revison.

Editors
December, 1974

1. The Structure and Defects of Degasified Steel

Picture No.	Title	Description
101	The crystal structure and defects of 30CrMnSiNi structural alloy steel ingot	The weight of the ingot is 3 ton, and it is big-end-up with a hot top. The crystalization begins from the mould wall and gradually spreads to the center. From the longitudinal section of the ingot, three crystal zones can be seen. The extremely outside one is a very thin shell layer, which is formed by fine isometric crystals. Next is a rather thick columnar crystal zone and it is formed by coarse and long crystals which stand perpendicular to the mould wall. The one that is connected with the columnar crystal zone is the central zone and it is formed by large isometric grains. In the central zone, there is clear V-shaped segregation. On both sides of the V-shaped segregation, and on the border between the columnar crystal and the central zone, there are some slightly inclined segregation lines, which are usually called inverted V-shaped segregation, and also called A-shaped segregation, "beard" or

"phantom line". The degree of the inversion of V-shaped segregation is determined by the steel chemical composition and the speed of congelation of liquid steel. For example, the degree of inverted V-shaped segregation of alloy steel, of which the nickel content is high, is great, and the small steel ingot or flat ingot because their congelation is fast, the degree of their inverted V-shaped segregation is small.

At the depressed parts on the upper part of the ingot are shrinkage cavities. They are usually limited to the top of the ingot, and they can be scraped out when the ingot is cut open. Otherwise, they remain on the steel piece and are called cavity remants.

Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.

102	The sulphur print on the longitudinal cross-section of heavy rail steel ingot	The chemical composition of the steel is 0.64%C, 0.22%Si and 0.73%Mn. The weight of the ingot is 5.3 ton, and it is big-end-up with a hot top. As a result of having such sulphur prints, it proves that the sulphur content of the steel in the V-shaped and inverted V-shaped segregation parts is high.

101

102

Picture No.	Title	Description
103	Dentrite crystals	This is the situation of dentrite crystal growth at the upper part of a cast piece after quickly pouring out the remaining steel liquid at the time when the casting has been partially congealed. Multiple: 2.4:1
104	Front edge of crystalization and dentrite crystals	These front edges of crystalization, which look like year rings of a tree trunk, are a series of very regular isotherms of congelation. They are almost parallel with the ingot surface. In the sulphur print test, these lines are white in color, and, through microscopic observation, very little sulphide inclusure can be found among these lines. The "year rings" are formed by the very thin pure and hypo-pure metal layers, which move toward the center of the ingot and become congealed layer by layer. These metal layers because of the difference of their etching agents can show white or black color. In the picture, it can be seen that the

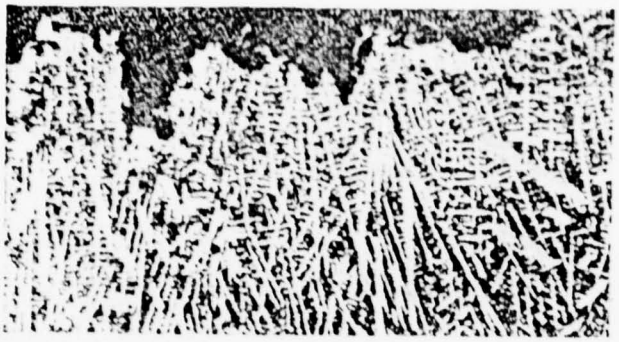
dentrite crystals are mostly perpendicular to the mould walls of the ingot.

Etching agent: 120ml hydrochloric acid added 100ml distilled water and 90g cuprous chloride. Before etching, the testing piece must be heated from 200 to 250°C for 5-30min, then cool it off and polished. In the process of etching, the surface of the testing piece must be rubbed with a piece of water-soaked gauze or cotton cloth until the structural lines become clear. The copper sediment on the surface can be removed by using liquid ammonia or a light polishing.

Multiple: 1:1

105	The crystal zone of heat-resistant steel ingot	The crystal zone of 23%Cr-23%Ni heat-resistant steel ingot. When the pouring temperature is appropriate, there will appear three crystal zones: the fine isometric crystsl zone, the columnar crystal zone and the coarse isometric crystal zone. If the

pouring temperature is too high, the columnar crystal zone will stretch to the central part of the ingot,and the coarse isometric crystal zone there will d'sappear.



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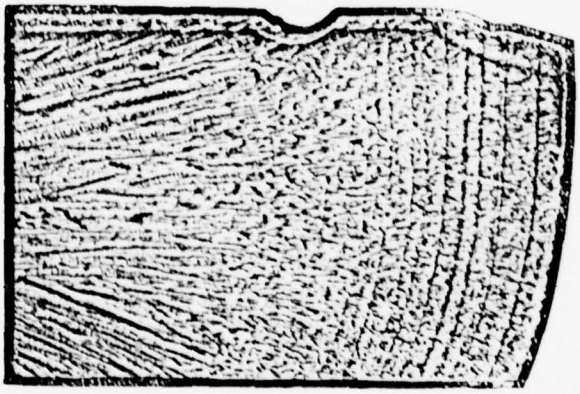

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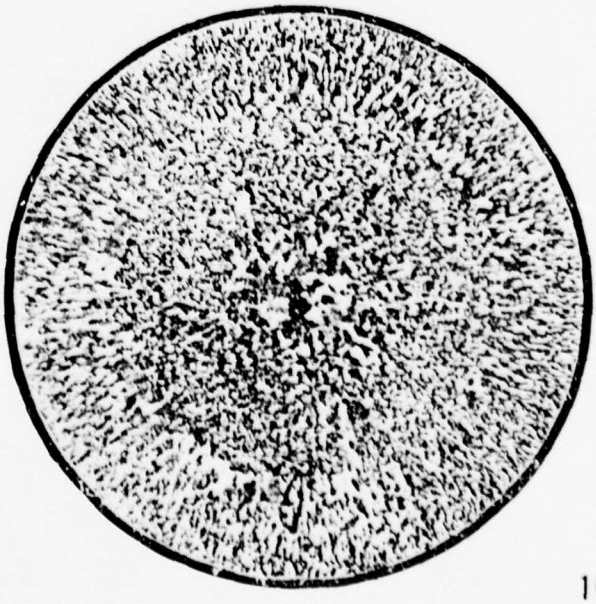

105

Picture No.	Title	Description
106	The crystal zone of heat -resistant steel ingot	The crystal zone of 23%Cr-23%Ni heat-resistant steel ingot. When the pouring temperature is appropriate, there will appear three crystal zones: the fine isometric crystal zone, the columnar crystal zone and the coarse isometric crystal zone. If the pouring temperature is too high, the columnar crystal zone will stretch to the central part of the ingot, and the isometric crystal zone there will disappear.
107	The crystal zone of heat -resistant steel ingot	The transverse cross section of a testing ingot, which is made of 25%Cr-20%Ni heat-resistant steel, and its weight is 15kg. The four columnar crystal zones, which are perpendicular to the ingot mould walls, meet at the intersection of the diagonal planes of the ingot. This is the weak link of the ingot. Etching agent: 10ml oxalic acid added 100ml distilled water is used as electrolytic liquid, and platium or stainless steel is used as anode to

do electrolytic etching.
The distance between the
electrodes is 25mm., the
voltage is 6volt and time
is 5-20 minutes.

Multiple: 1:1

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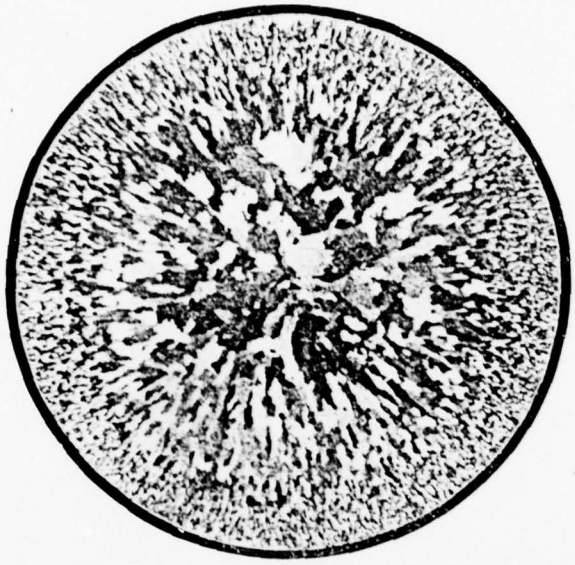

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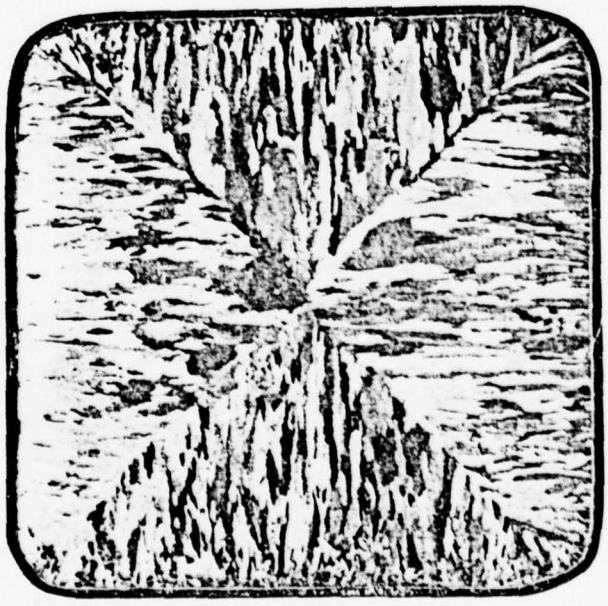


107

Picture No.	Title	Description
108	The effect of chemical composition to crystal zones	When the content of silicon and manganesium steel of 30CrNiMo is normal (0.32%C, 0.30%Si, 0.62%Mn, 1.03%Cr, 1.50%Ni, 0.29%Mo and 0.061%Al), the columnar crystal zone approximarely constitutes 80% of its whole volume (see the left picture). Otherwise, when the silicon and manganesium content is low (0.32%C,0.07% Si, 0.34%Mn, 1.01%Cr, 1.48%Ni, 0.31%Mo and 0.025%Al), the columnar crystal zone will constitute 99% of the ingot volume (see the right picture). The aluminum content of these two different kinds of steel is also different, but,according to the findings of research, it is known that the effect of aluminum content is not so great as silicon and manganesium. Multiple: 1:2
109	General unsolidness	The general unsolidness of forged billet of 18CrMnTi structural alloy steel. Before acid etching, it is generally unvisible. On the hot acid etching transverse testing piece, the loose porosity is generally in the shape of polygon. When the narrow concaves on the

bottom become severe, they tend to connect together and become something like sponge. The crevices are black in color.

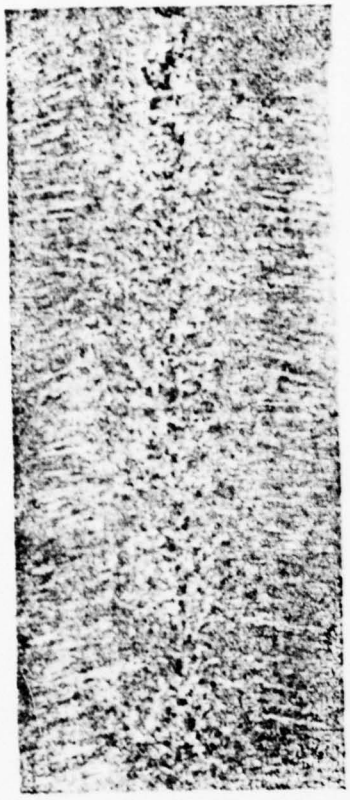
When the loose crevices are evenly spread over the whole cross section, it is called general unsolidness.

The cause that produces unsolidness is that when the steel liquid begins to congeal in the shape of dentrite crystal, the liquid among the dentrites containing impurities is of low melting point and begins to shrink in the final stage of congelation. At the same time, the undissolved gas comes out and makes crevices. It may also be that the non-metallic inclusion in the steel was eaten away by acid in the hot acid etching test and left those crevices.

The effect of unsolidness to steel quality is determined by the size of the loose spots, their amount and density.

Etching agent: Hydrochloric acid water solution of 1:1 at 60-70°C.

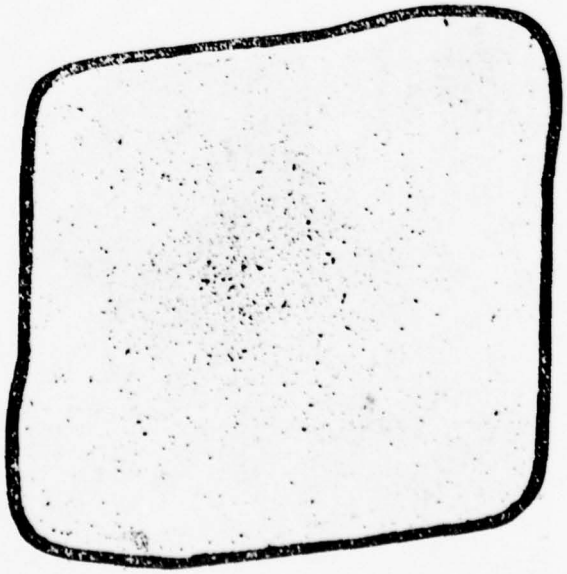
Multiple: 1:1.4



Left

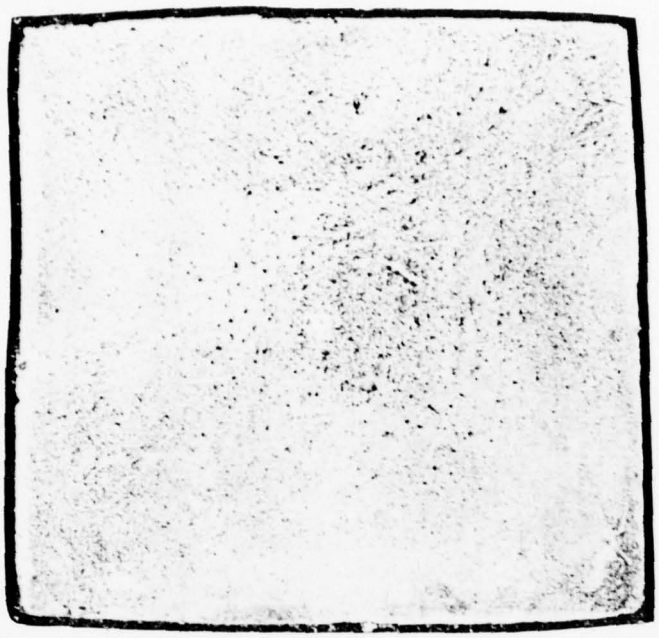
Right

108



109

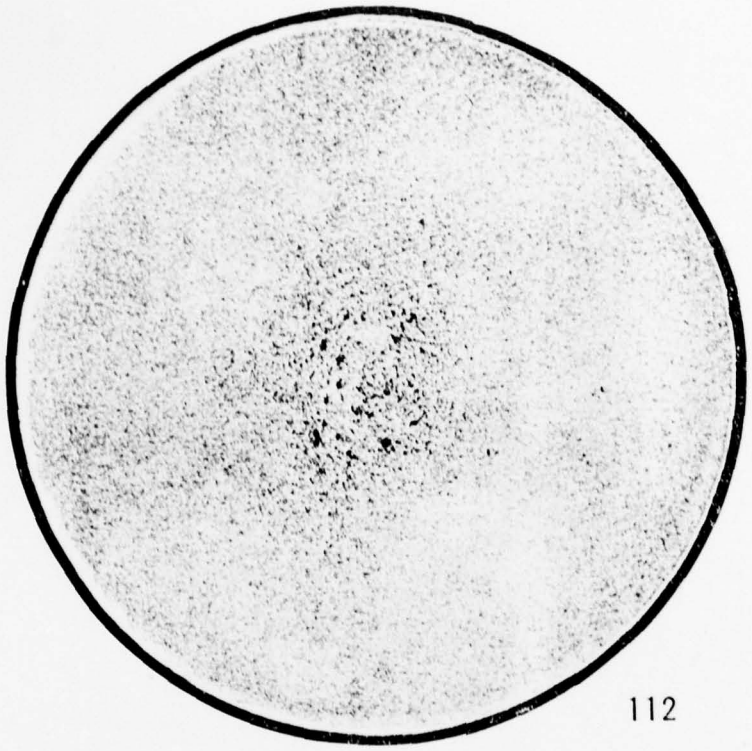
Picture No.	Title	Description
110	General unsolidness	General unsolidness of forged billet of 40CrNiMo structural alloy steel. In some steel plants, the general unsolidness of large steel bloom because of the large size of the loose spot is called "particle looseness", but in many other steel plants, they think it is better to call general unsolidness. Etching agent: Hydrochloric acid water solution of 1:1 at 60-70°C. Multiple: 1:4
111	Central unsolidness	Light central unsolidness of steel billet of ~~40CrNiMo~~ Cr-MnMoVR structural alloy steel. The characteristics and the cause of the formation of central unsolidness are same as those of general unsolidness. It is called central unsolidness because the unsolidness concentrates on the axis part of steel billet. Etching agent: Hydrochloric acid water solution of 1:1 at 60-70°C. Multiple: 1:1.2



110

111

Picture No.	Title	Description
112	Central unsolidness	Severe central unsolidness of steel billet of CrMnMoVR structural alloy steel. The characteristics and the cause of the formation of central unsolidness are same as those of general unsolidness. It is so called because the unsolidness concentrates on the axis part of the billet. Etching agent: Hydrochloric acid water solution of 1:1 at 60-70°C. Multiple: 1:1.2
113	Central unsolidness	The form of central unsolidness in the longitudinal (right) and transverse(left) testing samples cut off from D60 steel billet. Etching agent: Hydrochloric acid water solution of 1:1 at 60-70°C. Multiple: 1:2.5



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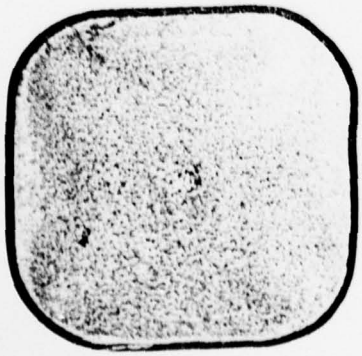

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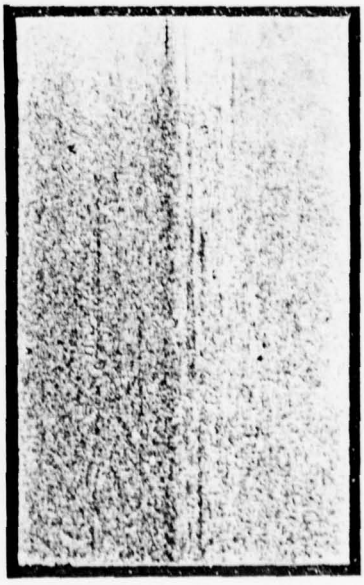


Right

113

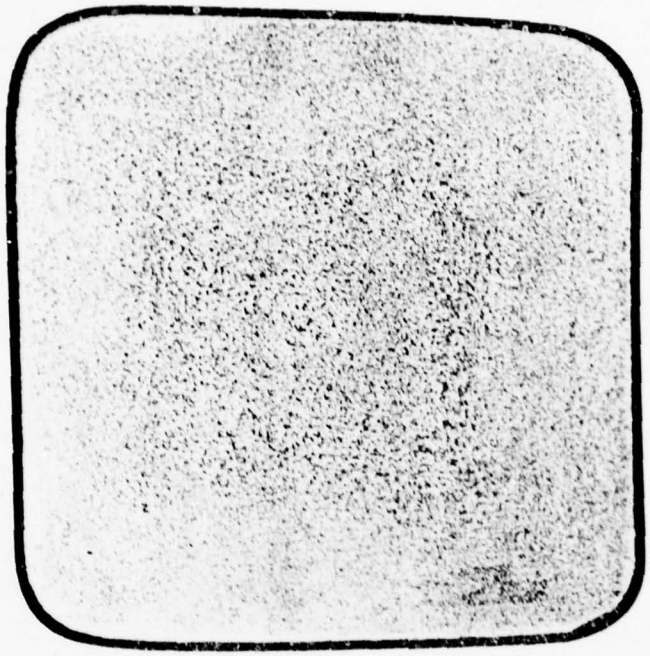
Picture No.	Title	Description
114	Central unsolidness and ingot-shaped segregation	In a 65Mn structural carbon steel billet of good quality, central unsolidness and ingot-shaped segregation appear at the same time. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.
115	Ingot-shaped segregation	The laminar ingot-shaped segregation in a forged billet of W18Cr4V high speed steel. The ingot-shaped segregation on a hot acid etched transverse testing piece gives a sight of deep corrosion. The segregation band, which is made of a cluster of dark spots, is of the shape of transverse section, so it is called ingot-shaped segregation. Ingot-shaped segregation is located at the joining point of columnar crystal zone and isometric crystal zone. It is formed at the final stage of steel liquid congelation because the liquid has a certain quantity of sulphide and silicate inclusion. The more is the inclusion, the clearer is the segregation

and the looser is the structure of the segregation region.

The effect of ingot-shaped segregation to the quality of steel is determined by the degree of clearness of segregation framework, namely the degree of aggregation and closeness on the framework, and the width of the segregation framework.

Etching agent: 1:1 hydrochlroic acid water solution at 60-70°C.

Multiple: 1:1



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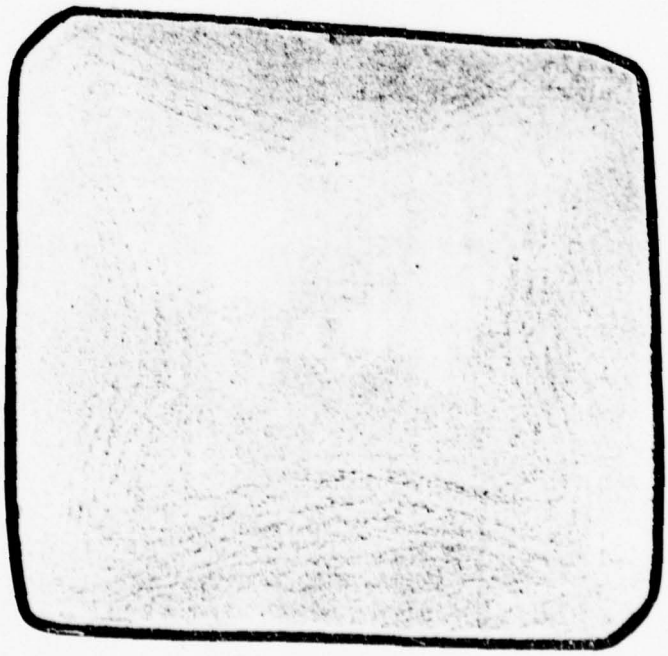

115

Picture No.	Title	Description
116	Ingot-shaped segregation	Ingot-shaped segregation of 30CrMnSi structural alloy steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.2
117	The relationship between ingot-shaped segregation and streamlines	The longitudinal and transverse configurations of ingot-shaped segregation in a low carbon steel billet. The longitudinal shows that the streamline follows the rolling direction, and the transverse gives the usual form of ingot-shaped segregation. Thus it can be seen that ingot-shaped segregation is formed by immense number of dots and these dots are the transverse section of the streamlines. Etching agent: 120ml hydrochloric acid 100ml distilled water and 90g. cuprous chloride. Before etching, the testing piece must be heated at 200-250°C for 5-30 minutes, then cooled off. Then it is

polished. During etching, the surface of the testing piece is continuously rubbed with a piece of solution soaked gauze or cotton cloth until the structure becomes clear. The copper sediment on the surface can be removed by using ammoniacal liquor or a light polishing.

Multiple: 1:1

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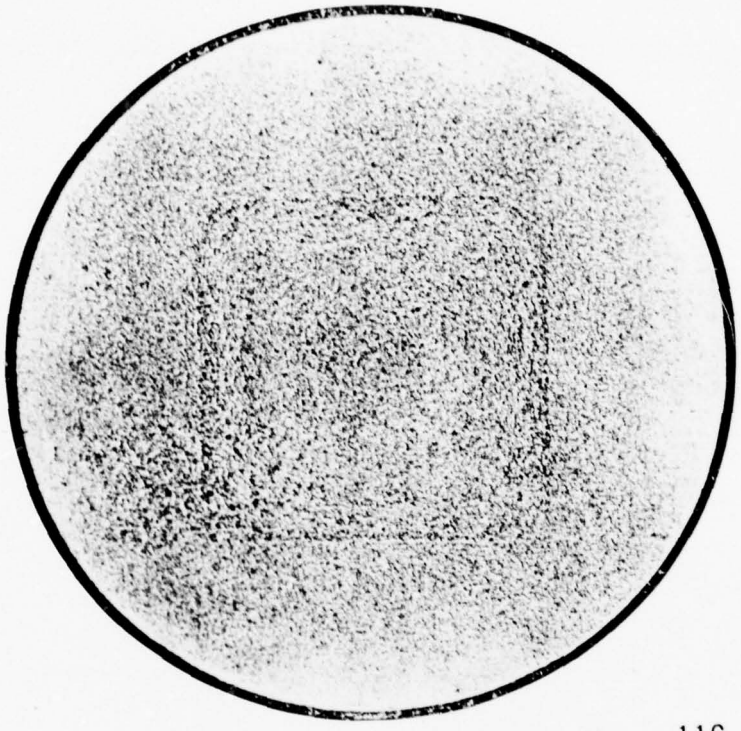

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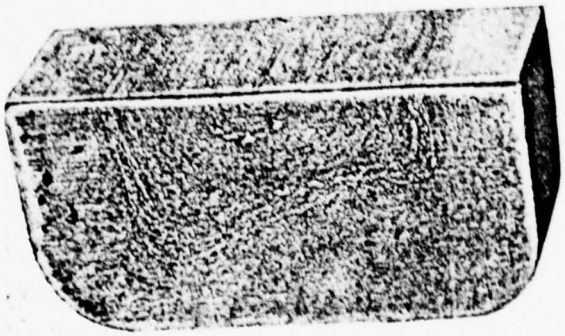
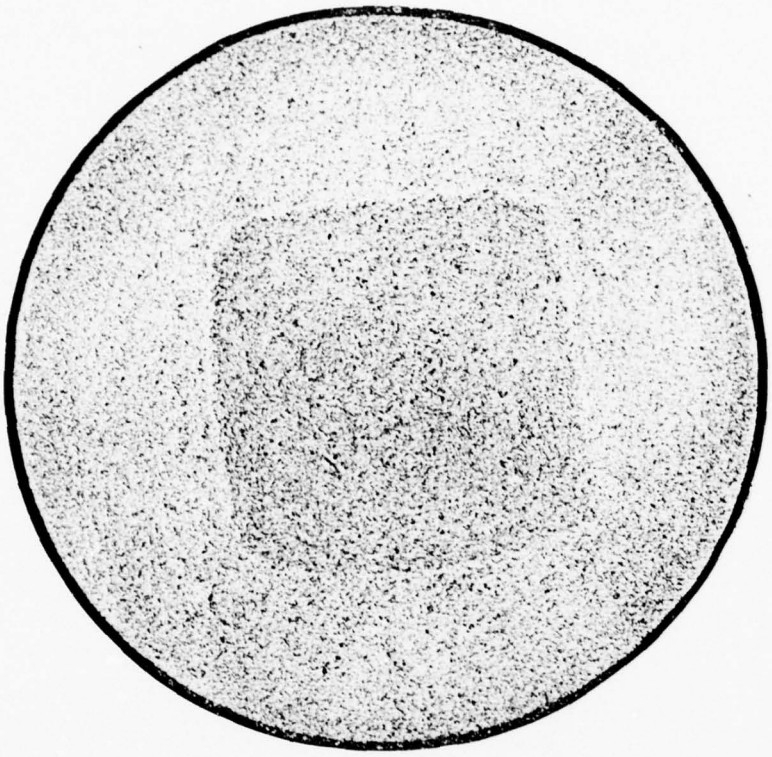


117

Picture No.	Title	Description
118	Ingot-shaped segregation	Ingot-shaped segregation of 45 steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
119	Square segregation of rust-proof steel	The deeply corroded and dark spots on the hot acid etching transvers testing piece. There is a clear boundary between the spots and the body of the testing piece. Sometimes there are interlocked white and black layers in the square spots. The sensitivity of producing square segregation is different from the rust-proof steel of different numbers. ICr18Ni9Ti steel is the most sensitive one. The cause of form square segregation is not yet known now. But the practice in several steel plants indicates that it can be eradicated by using high temperature diffusion treatment 1100-1150°C water cooling or 1150-1250°C gradual cooling). Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.2



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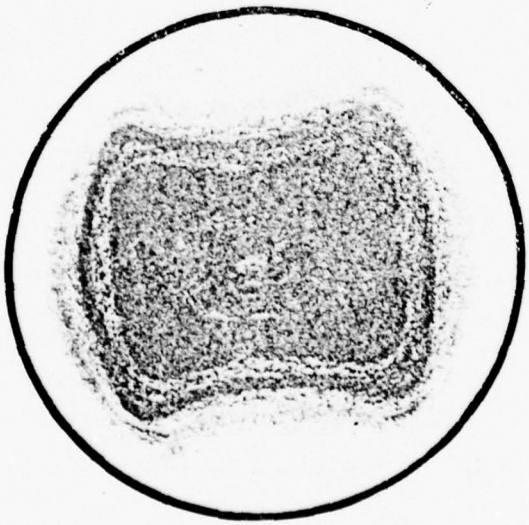
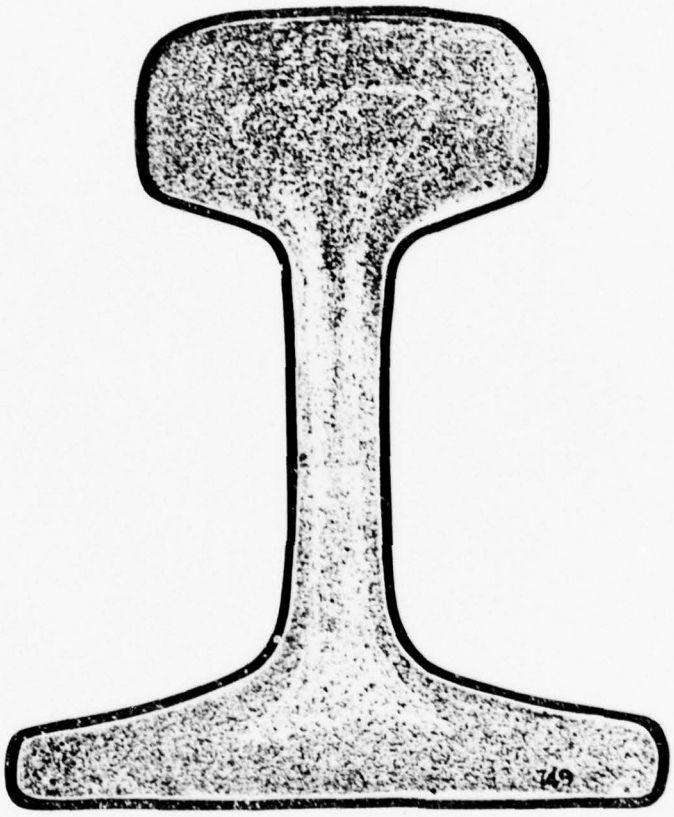


119

Picture No.	Title	Description
120	Ingot-shaped segregation	Ingot segregation on heavy rail steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.3



120

Picture No.	Title	Description
121	Ingot-shaped segregation and spot segregation	Ingot-shaped segregation and spot segregation of 38CrMoAl steel. This transvers testing piece is taken from a part corresponding to the middle-lower part of the steel ingot which has been rolled into a round piece of 200mm. Generally speaking, most of the spot segregation appear on the upper-middle part of a steel ingot and it gradually reduces from upper part downward. And most of the ingot-shaped segregation are at the middle part of a steel ingot and it gradually becomes severe from upper part downward. So at the middle lower part of a steel ingot, there is only ingot-shaped segregation and no spot segregation, and neither of them appears on the tail of ingot. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:2
122	Spot segregation	Spot segregation of 38CrMoAl structural alloy steel. Spot segregation on the hot acid etching transverse testing piece, according

to the different air content of the steel, appears generally in the following forms: spots of irregular forms; depression, oval, watermelon-seed or round spot, which are all darker than the body of steel; and air bubbles which were not welded off. Due to different crystalization conditions, the distribtution of the spots may be in the shape of broken square frame, cruciform or concentrical circle. On the hot acid etching longitudinal testing piece, spot segregation is of a shape of black strip stretching along the direction of extrusion.

Based on its position on the cross section, spot segregation can be classified into two different kinds: general spot segregation and edge spot segregation. The former on the testing piece shows an irregular distribution, while the latter generally distribute themselves along the edges of testing piece and keep a regular distance from the surface.

There has not yet been any definite conclusion about the cause of why spot segregation, especially of 38CrMoAl steel, comes into being. Whether the few forms described above should be given different names, the answer is under

study in several steel plants.

Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.

Multiple: 1:2

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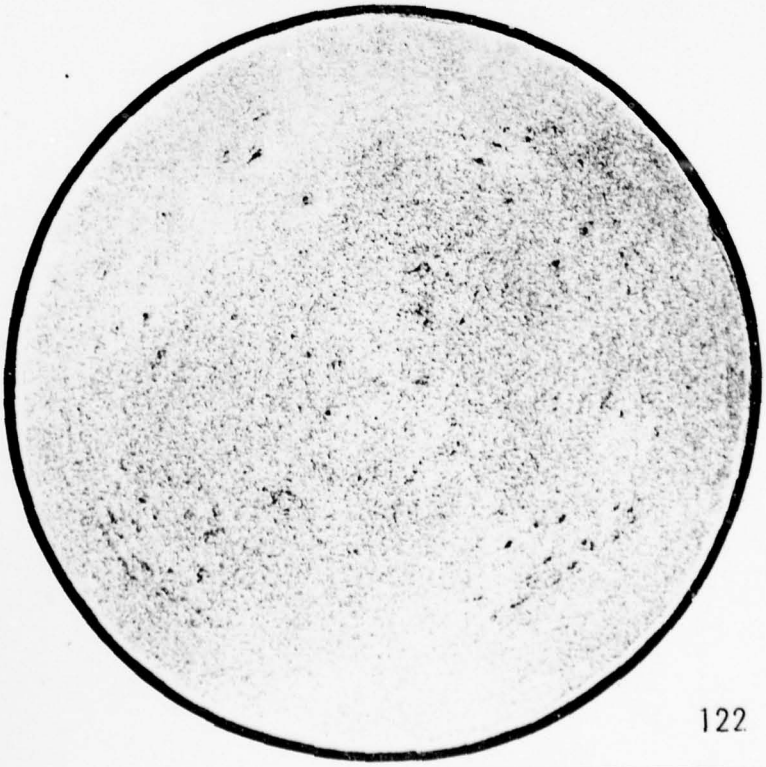
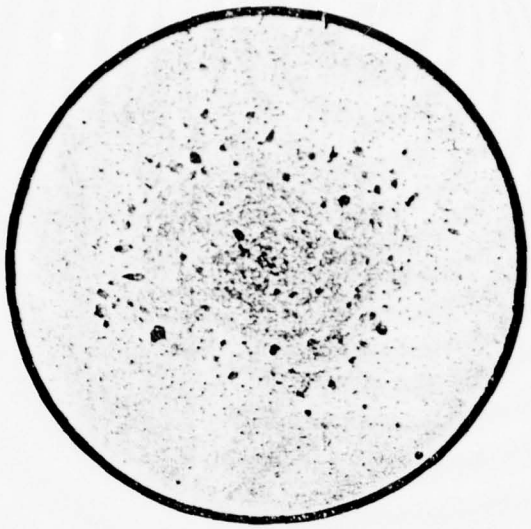
121



122

Picture No.	Title	Description
123	Spot segregation	Spot segregation in a 10 steel billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
124	Spot segregation	General spot segregation of 45 steel. Beside the segregation, there are fine herringbone cracks, which are made by the failure of welding well because of the existing of air bubbles. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1



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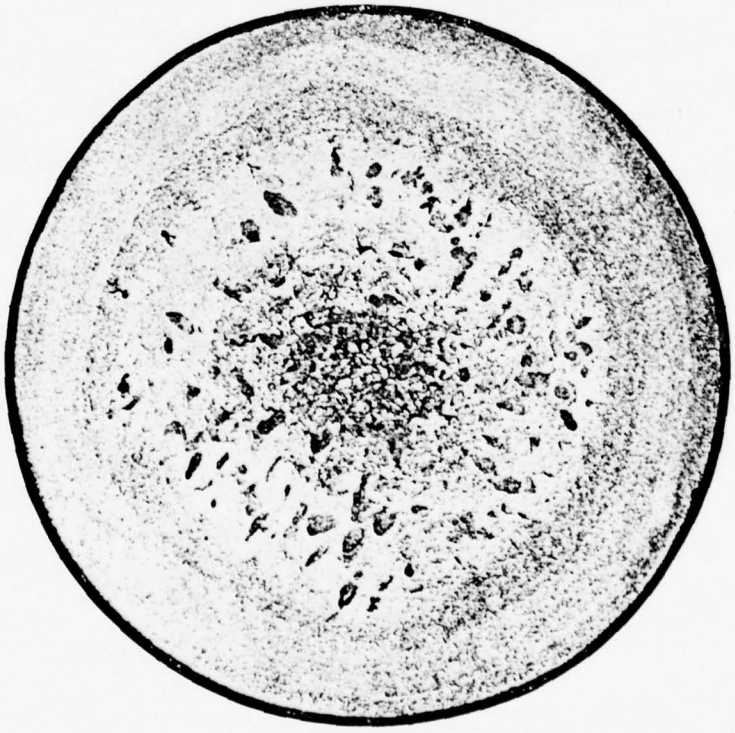
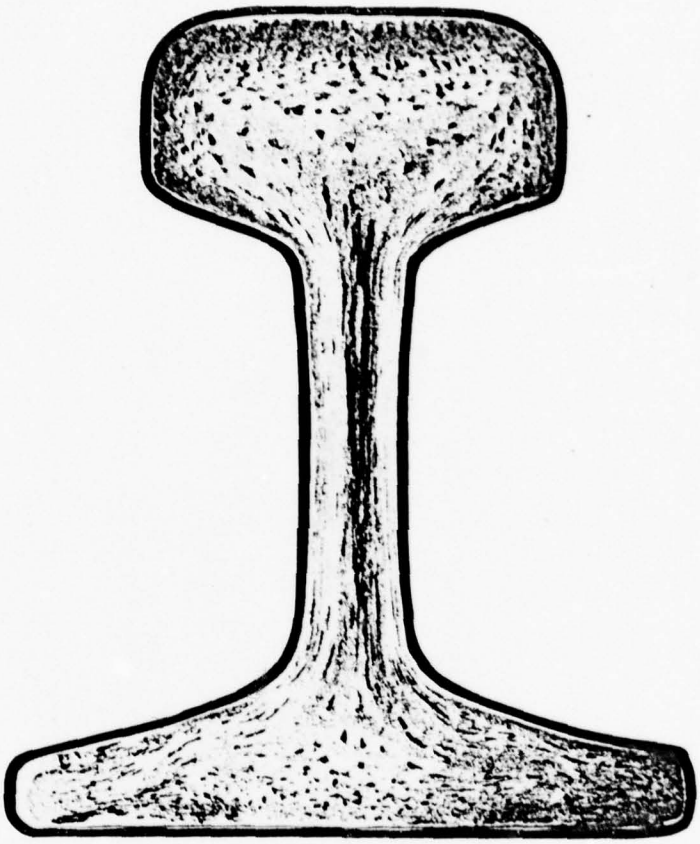


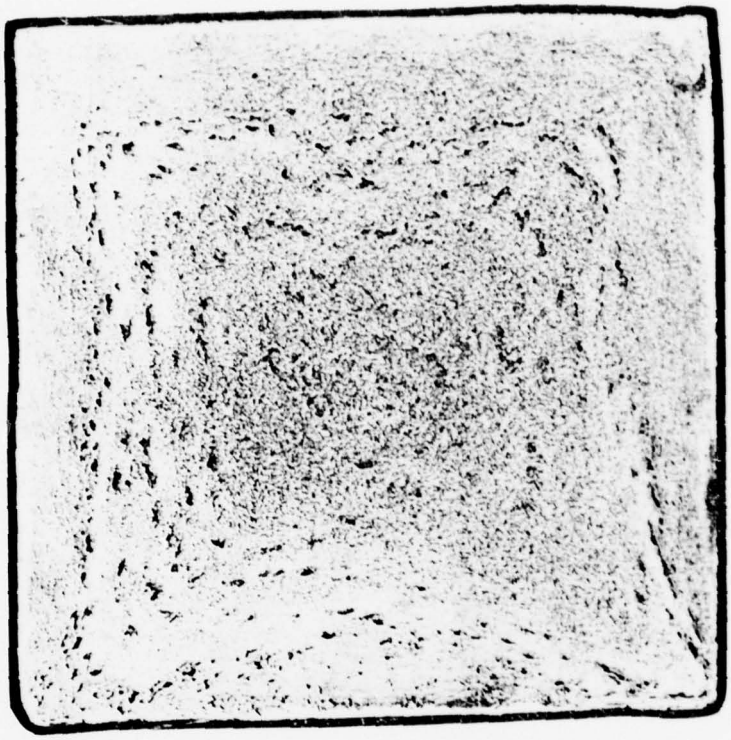
124

Picture No.	Title	Description
125	Spot segregation	Spot segregation appears on heavy rail steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.3



125

Picture No.	Title	Description
126	Spot segregation	Severe spot segregation in a steel billet of 38CrMoAl structural alloy steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
127	Shrinkage cavity remnant	Shrinkage cavity remnant in a steel billet of 20Cr structural alloy steel. Because the shrinkage cavities were cut off completely, what is seen in the picture is the severe segregation region at the bottom of the shrinkage cavities. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.2



126

127

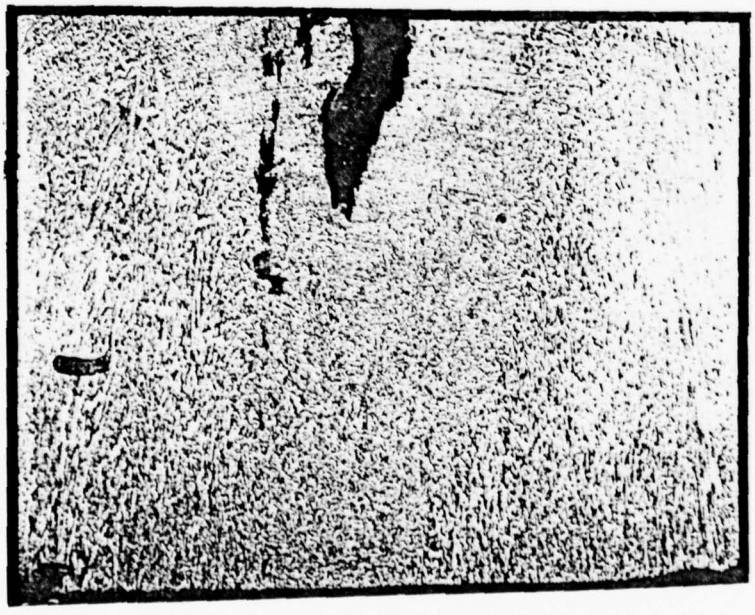
Picture No.	Title	Description
128	Shrinkage cavity remnant	Shrinkage cavity remnant in a steel billet of GCr15 bearing steel. There are overturned skin and other defects on the edge of the billet. The shrinkage cavity remnant at the central part of the hot acid etching transverse testing piece (perhaps because of the effect of hot working deformation, it moves close to the central part) appears to be wrinkle cracks, if the crop end of the billet is too few, they can even become macroscopic hollow. In the neighbouring areas of the shrinkage cavity remnant, there generally are aggregation of impurity inclusion, and unsolidness or segregation. This is the basis to differentiate shrinkage cavity remnant from internal cracks. Of the billet which is big-end up and with a hot top, the shrinkage cavities are confined in the riser part, but if the casting operation is not proper, they will penetrate below the riser line on the top of the billet. It is not permisable to have shrinkage cavities in a billet, and it can be continuously cut off from the billet.

Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.

Multiple: 1:1.1

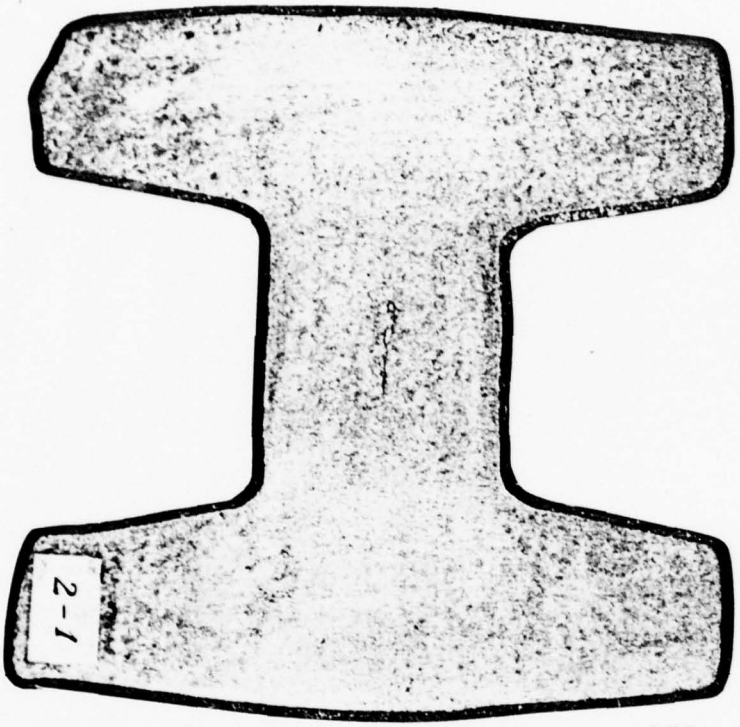
129	Shrinkage cavity remnant	Shrinkage cavity in a longitudinal testing piece of 42Mn2 steel billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1

128

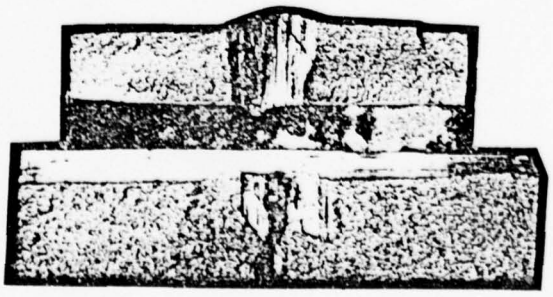


129

Picture No.	Title	Description
130	Shrinkage cavity remnant	Shrinkage cavity remnant in 30CrMnSiNi isomeric steel billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.
131	Shrinkage cavity remnant	Shrinkage cavity remnant seen at the fracture axial part of T8 (picture below) and T9 (picture above). Defect is that the remnant becomes a number of amorphous strips or constitutes an area of unsolidness, and there is always a happening of oxidizing.

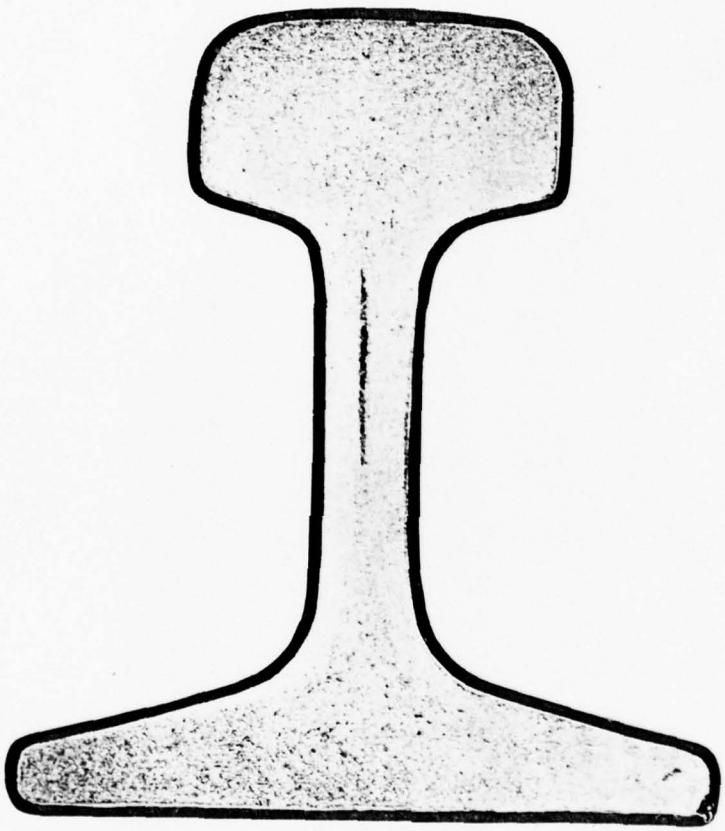


130



131

Picture No.	Title	Description
132	Shrinkage cavity remnant	Shrinkage cavity remnant on the heavy rail steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.3



132

Picture No.	Title	Description
133	Underneath -skin bubble	Underneath-skin bubble in 45 steel billet. According to their different positions, the bubbles can be classified into "underneath -skin bubble" and "internal bubble". The distribution of underneath-skin bubble is very close to the surface, and generally the depth underneath the skin is very regular. If they are too close to the surface, when the billet is heated, the inner walls of the bubble will be oxidized, therefore it will be very difficult to weld the steel together when hot working takes place. The bubbles can be burned open and exposed on the surface of the billet and become longitudinal cracks. The unexposed underneath-skin bubbles on the hot acid etching transverse testing piece become pores or dark spots, which are either round or oval in shape. There are a few conditions which can cause the becoming of underneath-skin bubbles, such as the casting condition is not good (for example, the quality of the oil used on the

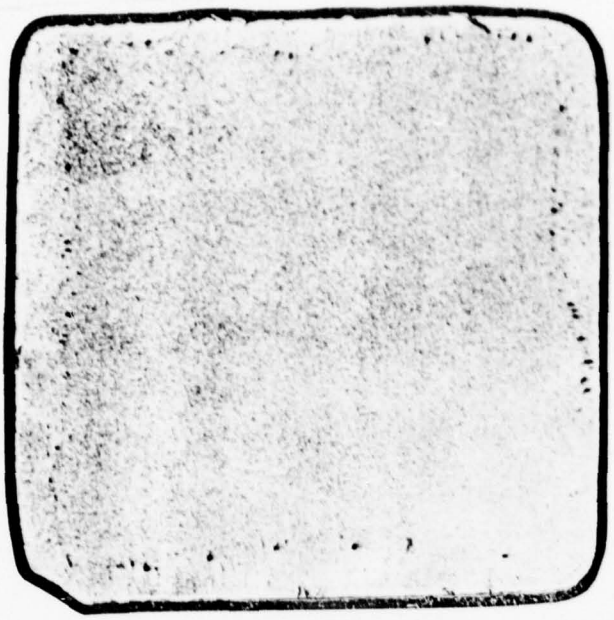
ingot mould is not good enough), the deoxidation of the steel is not thorough enough and the original materials are not dry enough.

Steel that has surplus working capacity will allow bubbles to exist in the surplus capacity underneath the surface. In evaluating the effect of underneath-skin bubble to the quality of steel, the number of bubbles and their depth from the surface should be given serious consideration.

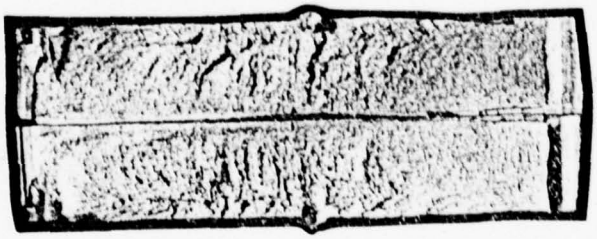
Etching agent:1:1 hydrochloric acid water solution at 60-70°C.

Multiple: 1:1

134	Underneath -skin bubble	Underneath-skin bubble at the longitudinal fracture of 45 steel billet. Their deffect is that they become fine strips, which have different color from the body of steel. When the fracture is of the shape of fibre, it should be observed under a 10-time magnifier because the bubble is not easy to be discovered due to the existence of fibre.

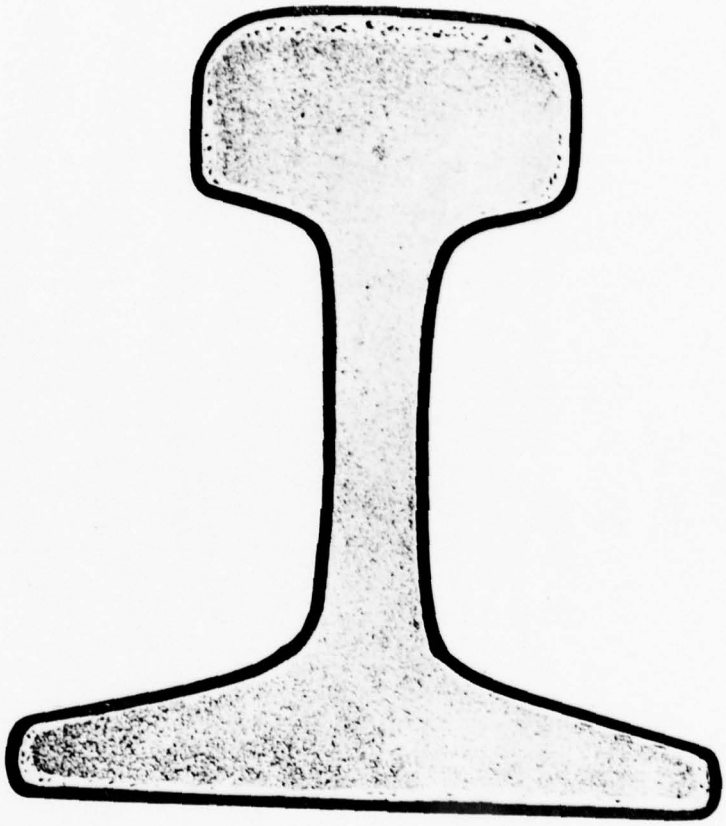


133



134

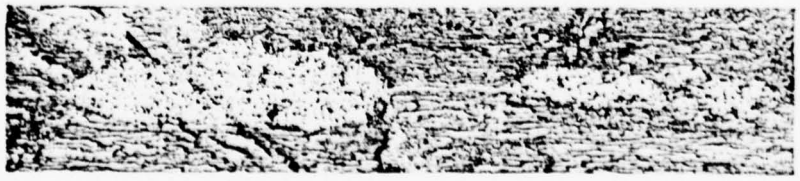
Picture No.	Title	Description
135	The underneath-skin bubble	The underneath-skin bubble on the heavy rail steel. Etching agent: Hydrochloric acid water solution at 60-70°C. Multiple: 1:1.3



135

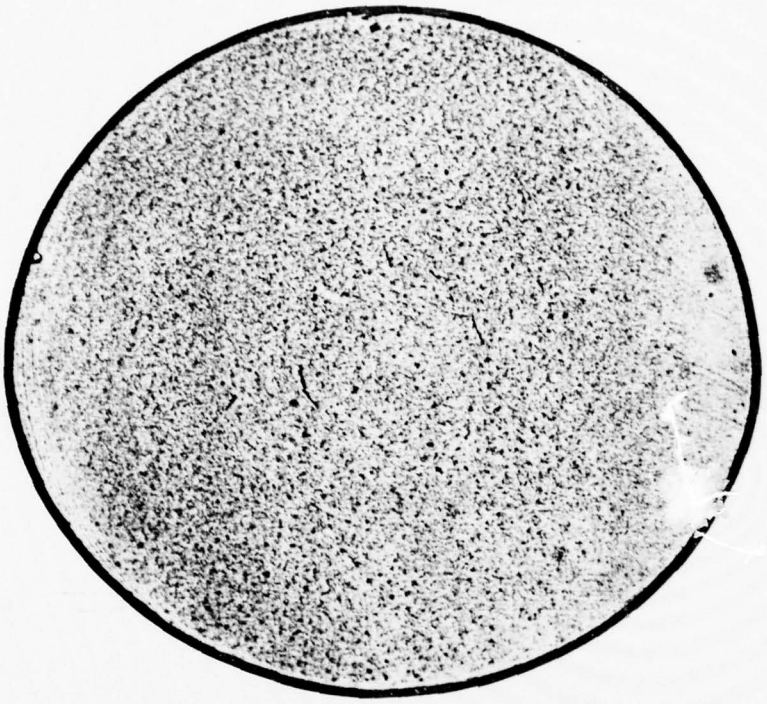
Picture No.	Title	Description
136	Underneath -skin bubble	The underneath-skin bubble in 20 steel billet. Part of the bubbles were burned open and exposed on the surface of the billet, so they became a crack. Besides these underneath-skin bubbles, there is defect of unsolidness in the billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
137	White spots	At the longitudinal fracture of 50 steel billet, the white spots became coarse crystal which is of the shape of silvery bright oval dots, and the inner walls of the spots have the characteristics of coarse grains. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:2

136

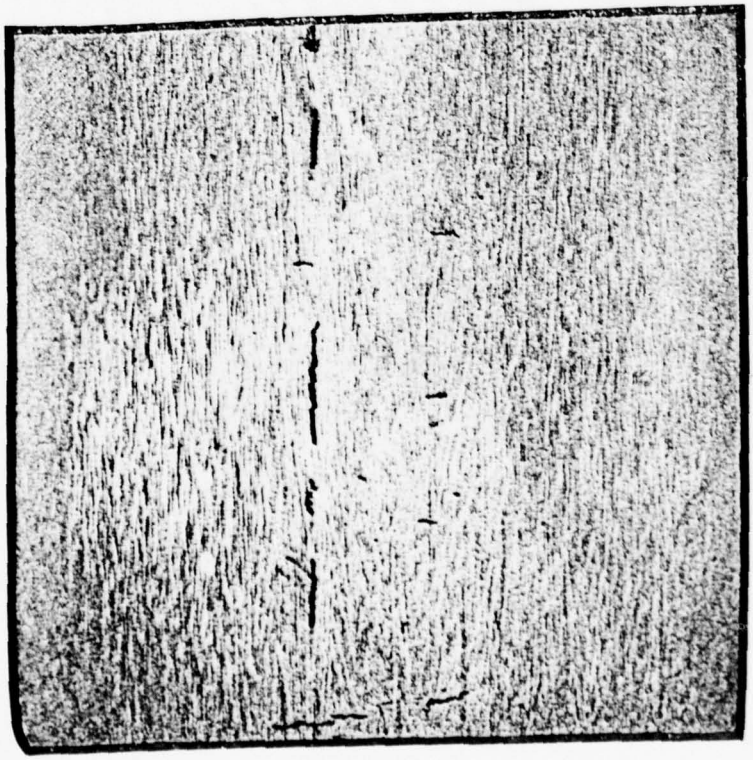


137

Picture No.	Title	Description
138 139	White spots	White spots on the transverse testing piece of 50 steel billet (picture 138), and the white spots became fine and short cracks. On the longitudinal testing piece, the white spots became horizontal and vertical cracks which look like saw teeth (picture 139). From microscopic observation, the cracks are piercing crystals. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:2



138



139

Picture No.	Title	Description
140	White spots	White spots on the transverse section of a round billet of 20 steel. On a hot acid etching transverse testing piece, white spots become a fine and short crack, which has a regular distance to its borders (generally larger than 20 mm). Some of the cracks are of a shape of saw teeth. On the longitudinal testing piece, the crack made of white spots usually runs parallel with the fibre stretche or makes an angle. the saw-teeth-like characteristic of the crack is very easy to be seen. On the longitudinal fracture under the condition of quenching, because of the different kind of steel and the difference of position and direction of the broken face, the white spots become a bright slice with convex surface like a duck-bill, and they also become round or oval silvery specks. The inner walls of the white spot are of the shape of coarse crystal grain. The white spot comes from the undissolved hydrogen, which concentrate in the loose pores and produce a pressure. This pressure

together with the heat stress and structure stress caused by steel phase changes, forces the inside of a steel billet to produce cracks.

The martensitic and semi-martensitic steel is easy to produce white spots. Next comes pearlitic steel. Because the solubility of hydrogen in austenite is great, austenitic steel is not east to produce white spots.

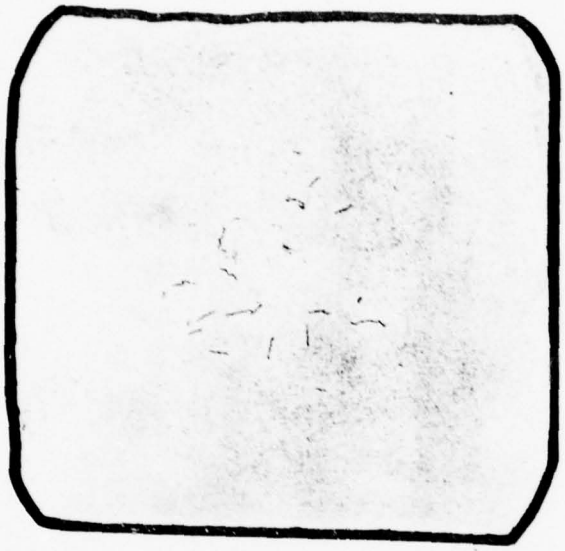
Because of the foregoing reasons, in smelting, the hydrogen content in steel should be reduced, and another measure to prevent white spots is to let the steel gradually cool to below 200°C after forge rolling.

White spot is an unpermisable defect. But the usefulness of the steel can be decided according to the welding condition after re-forging.

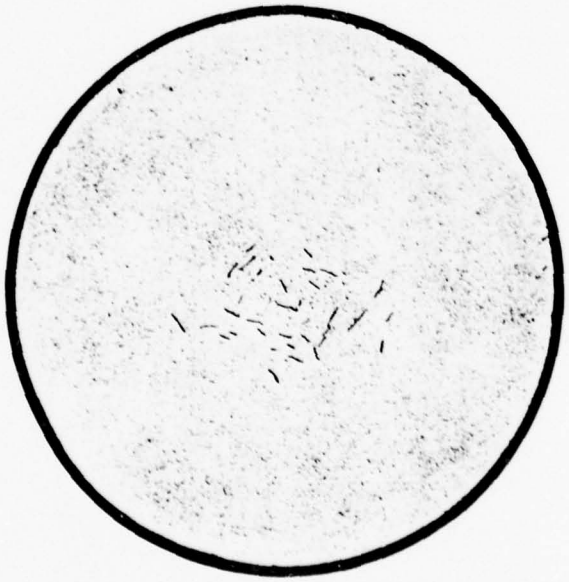
Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.

Multiple: 1:1.2

141	White spots	White spot in GCr15 bearing steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1

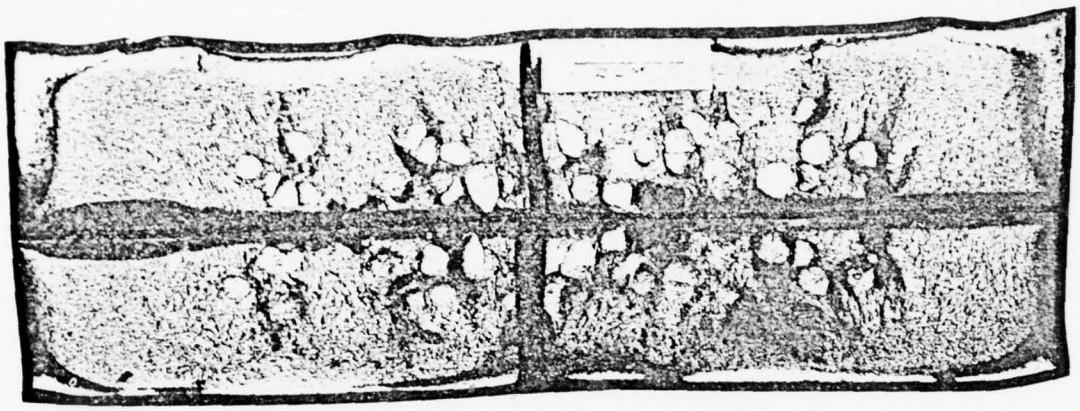


140

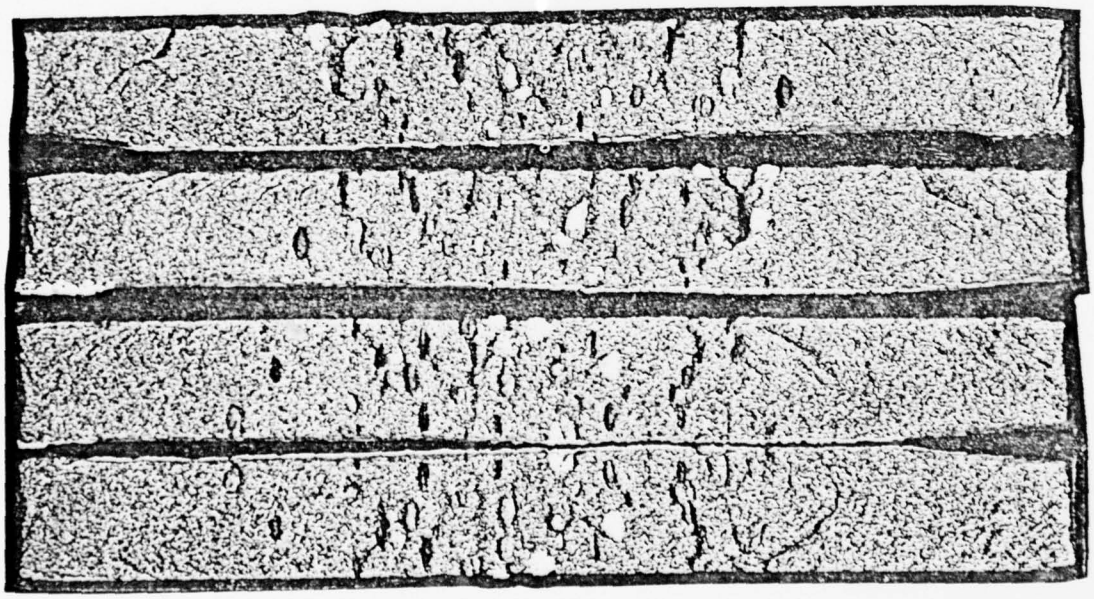


141

Picture No.	Title	Description
142	White spots	White spots on the longitudinal fracture of a square billet of 18CrMnTi structural alloy steel. The spots form some silvery bright round or oval specks.
143	White spots	White spots on the longitudinal fracture of a square billet of 5CrMnMo tool steel. The silvery bright spots are the white spots, which are parallel with the surface of the body on which the fracture exists. The dark ones projecting like a duck-bill are the white spots which are perpendicular to the body.

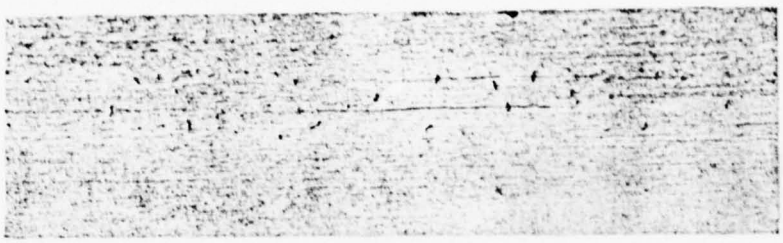


142



143

Picture No.	Title	Description
144	White spots	White spots on the longitudinal section of a rail end, and the heavy rail does not have gradual cooling after rolling (picture above). There is no white spot on the longitudinal section of the rail end after gradual cooling (picture below). Etching agent: L:l hydrochloric acid water solution at at 60-70°C. Multiple: Approximately 1:1.3
145	White spots	Small white spots (as arrow pointing) on a billet of train wheel steel (corresponding to 65 steel). Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1



Above

Below

144

145

Picture No.	Title	Description
146	Axis center "crack"	The axis center "crack" in a billet of 18CrNiW structural alloy steel, when it is magnified, looks like a "dotted line" which is made of a series of dots. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 2:1
147	Crack between axial crystals	Crack between axial crystals in a billet of anchor chain steel (0.12-0.18%C, 0.35-0.55%Mn, ≤ 0.050%Si, S, P ≤ 0.030). In addition to the defect of crack, there is non-metal inclusion in the billet. Crack between axial crystals on a hot acid etching transverse testing piece refers to three or more than three fine curved cracks, which run along the crystal boundary. The cracks radiate from the center of axis, and they can connect together and become a spider net when they become severe. In most cases, this kind of defect appears in billet, of which the size is relatively large and

the dentrite structure is severe.

The defects of "dotted line" axis (see picture 149) and groove-like axis (see picture 150) should not be regarded as crack between axial crystals. These defects are made due to the non-metal inclusion being eaten away or the structure is not homogenous. Before the harm made by these two defects is thoroughly studies and standardized, in this Collection, we temporarily use the term of 'Axis center "crack"' with such quotation marks.

Etching agent: 15-20% hydrochloric acid water solution, electrollytic etching. Electric current, 0.01A/mm^2; voltage, 7V; solution temperature, 25°C; and time, 4-5 min.

Multiple: 1:1.5

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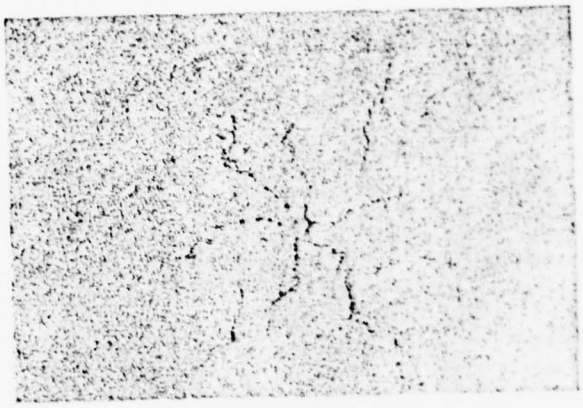
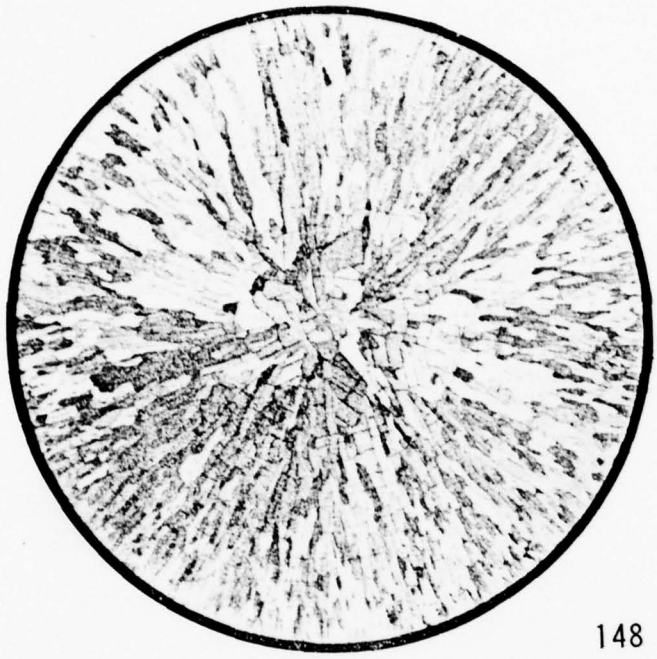


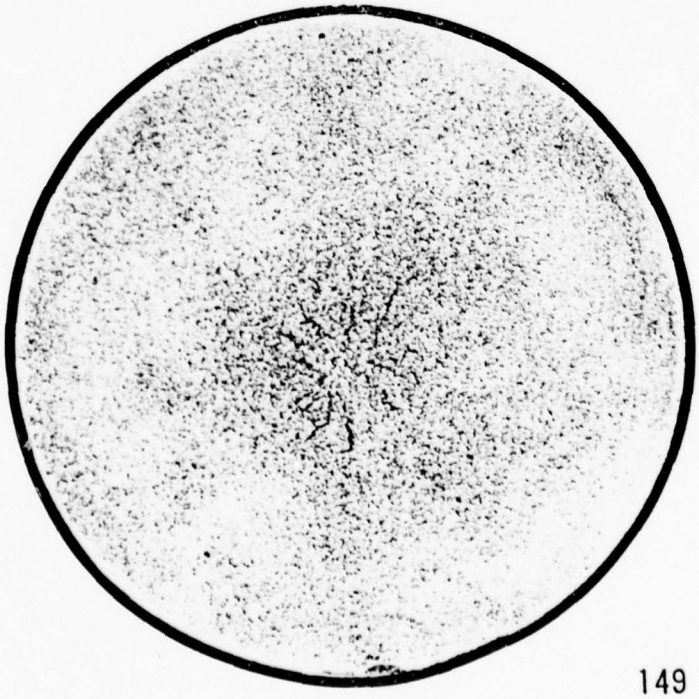
146

147

Picture No.	Title	Description
148	Concentric circle and crack between crystal boundary	In a testing ingot of Cr17Al4Si heat resistant steel, due to cooling stress, there happen concentric cracks, and some of them are cracks between crystal boundaries. Etching agent: hydrochloric acid and potassium dichromate water solution at 60-70°C. Multiple: 1:1
149	Axis center crack	Axis center crack in a billet of Cr5Mo die set steel. According to the result of electro-microprobe metallographic analysis, they are not real cracks but corroded grooves. Among the primary dentrite crystals, there is some sulphide, which is corroded when hot acid corrosion takes place and produces such grooves. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.5

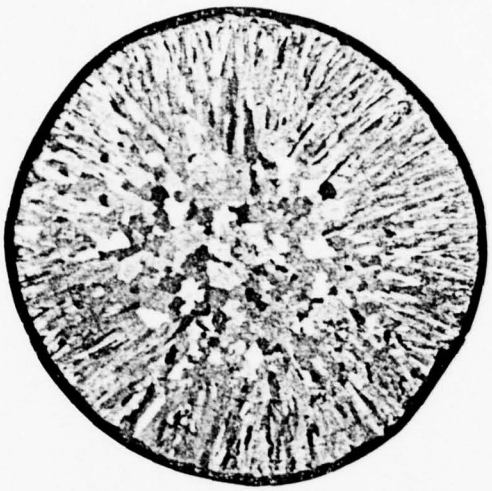


148

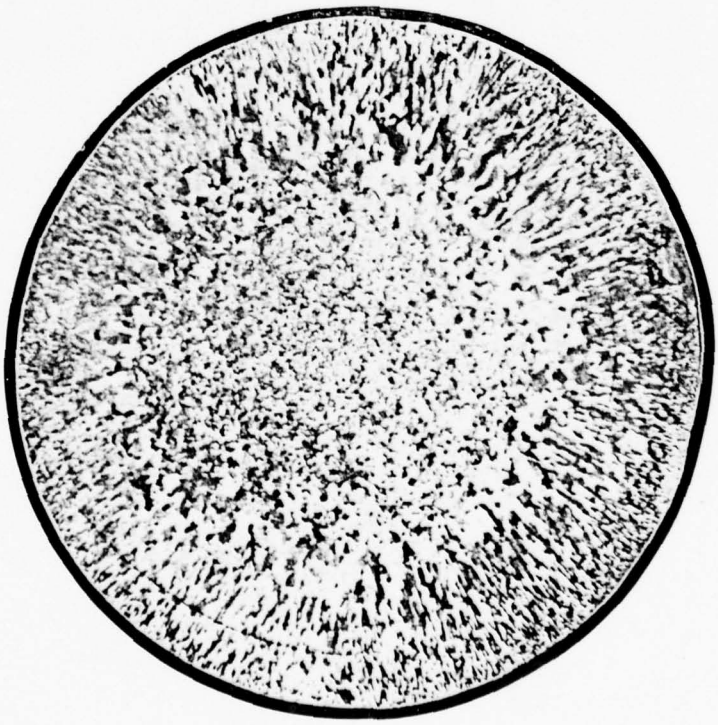


149

Picture No.	Title	Description
150	Concentric circle crack	Concentric piercing crystal crack on a testing ingot of Cr18Ni5Mo6 rust-proof steel. Etching agent: Cupric sulpate plus 1:1 hydrochloric acid sulfuric-acid solution, cold acid etching. Multiple: 1.3:1
151	Concentric circle crack	Concentric circle crack on the tail of an ingot of Cr27 rust-proof steel. Etching agent: Cupric sulfate plus 1:1 hydrochloric acid sulfuric-acid solution, cold acid etching. Multiple: 1:2



150

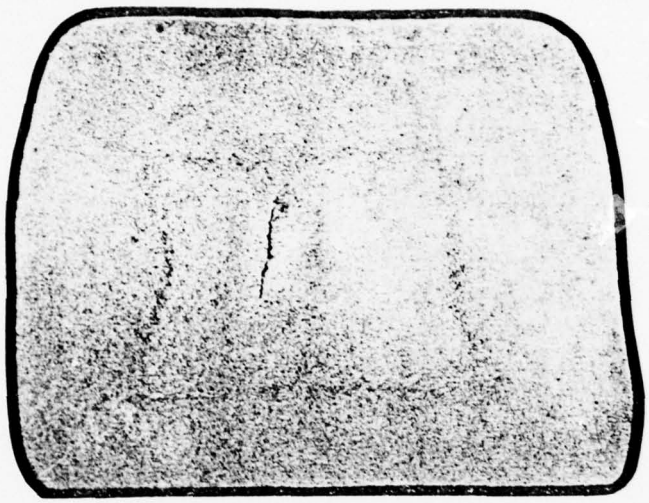


151

Picture No.	Title	Description
152	Inside crack	Crack in a billet of 30CrMnMoTi structural alloy steel. When the speed of increasing heat to the ingot is too fast, inside it produces crack acompaning a sound (the crack is usually called a snap). This kind of inside crack is sometimes easily confused with shrinkage cavity remnant or a forge crack. The way to differentiate them is that in the vicinity of the shrinkage cavity remnant there is always an aggregation of inclusions and there is none around an inside crack. When there is only one forge crack, it always runs along the diagonal direction on the billet. When they are two or more, they will in cruciform radiate from the axis center. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:4
153	"Tongue"	"Tongue" is a metaphoric term used by rolling mill operater to indicate whether there

is defect in the billet. The experienced operators often use "tongue" as a means to do macroscopic examination. In this picture, the form of the "tongue" looks like an arc-shaped concave in the midmost part of the billet, and there are strips in the concave.

In the process of hot shearing of the billet, there are three continuous stages of change and each stage constitutes a different part of the billet. (1) the depressed part, this is the part where the shear presses the metal and the metal begins to shrink and curve; (2) the sheared part, this constitutes the most part of the end; and (3) the broken part. The "tongue" often appears between part (2) and part (3).

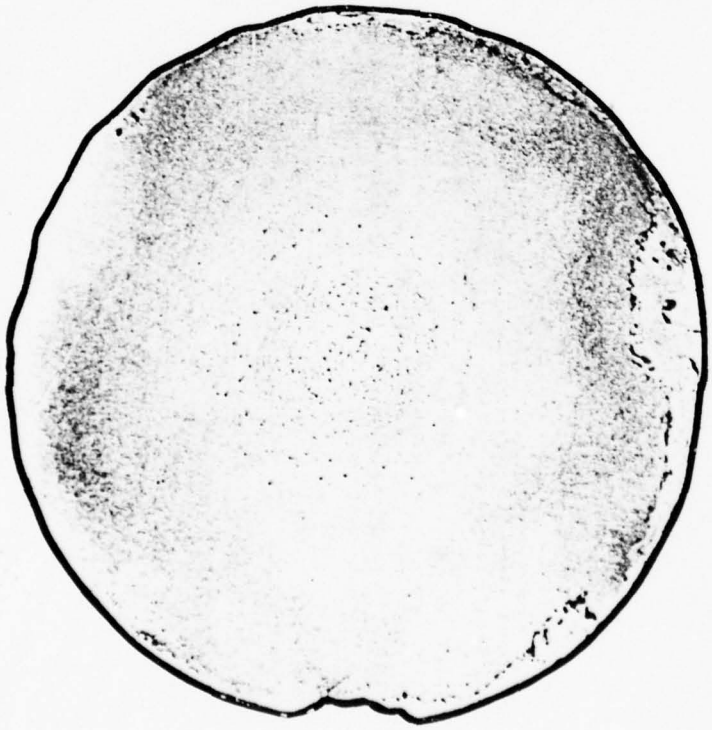


152

153

Picture No.	Title	Description
154	Overturned skin	Overturned skin (also called titanium shell) on a round billet of 18CrMnTi structural alloy steel. The form of curling skin of this kind of steel is different from that of other kind of steel. It often appears in a shape of fine strip, but the reason of its coming into being is all the same. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
155	Overturned skin	Underneath surface overturned skin of 34CrMo structural alloy steel. Underneath surface overturned skin refers to that of which the position is very close to the surface of the steel material. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:3.5

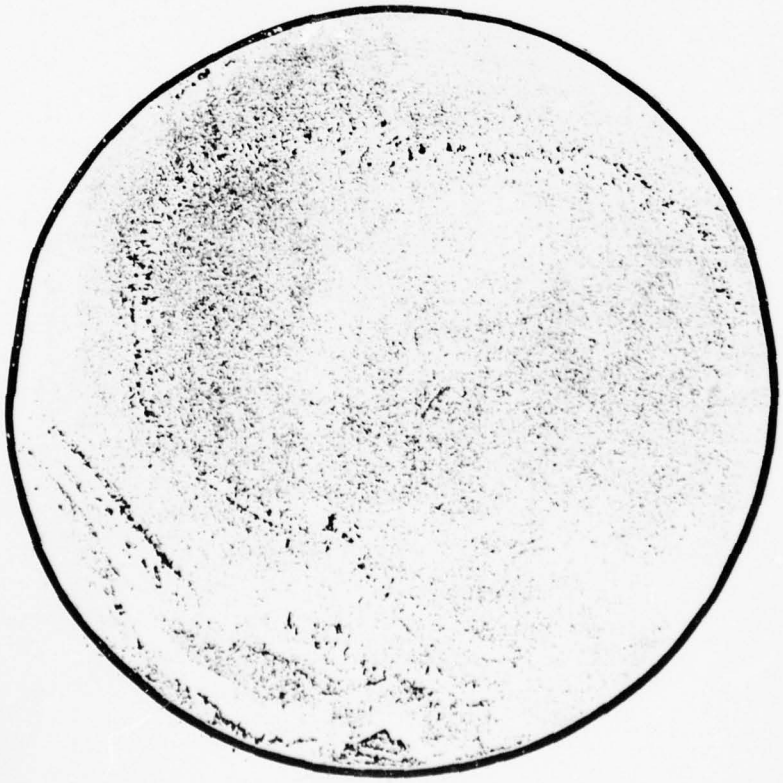
154



155

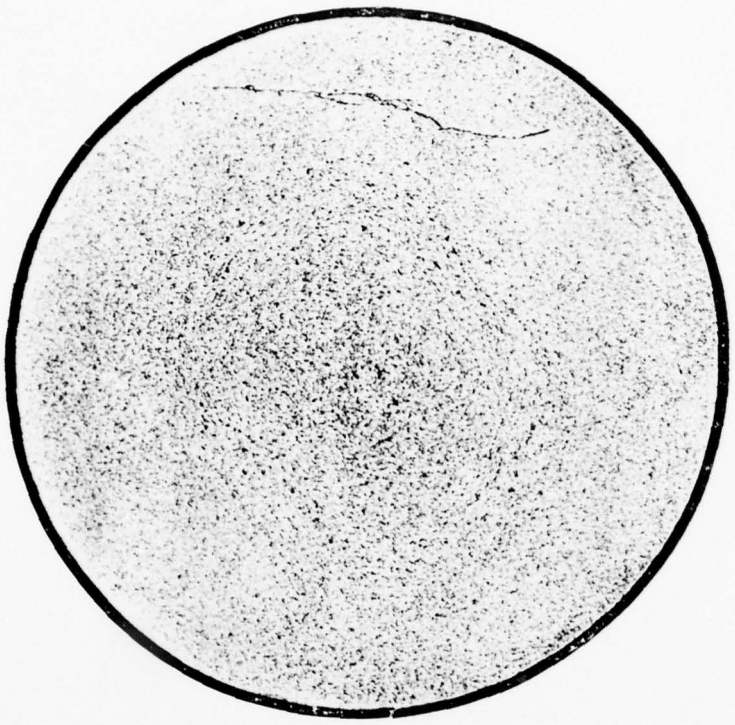
Picture No.	Title	Description
156	Overtuened skin	The overturned skin in 45 steel. At the left upper corner, the overturned skin appears to be a white bright band, and around it there are pores, which were left after the impurity inclusion was eaten away by acid etching. At the right lower corner, the overturned skin is of the shape of black curved band. In the black band and its vicinity, there are some impurity inclusions. During ingot casting, there is an oxide film floating on the surface of steel liquid. In pouring, the film goes down into the liquid, and then it became an overturned skin in or on the cast ingot. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.
157	Overturned skin	The laminar overturned skin in a large steel bloom. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.

156

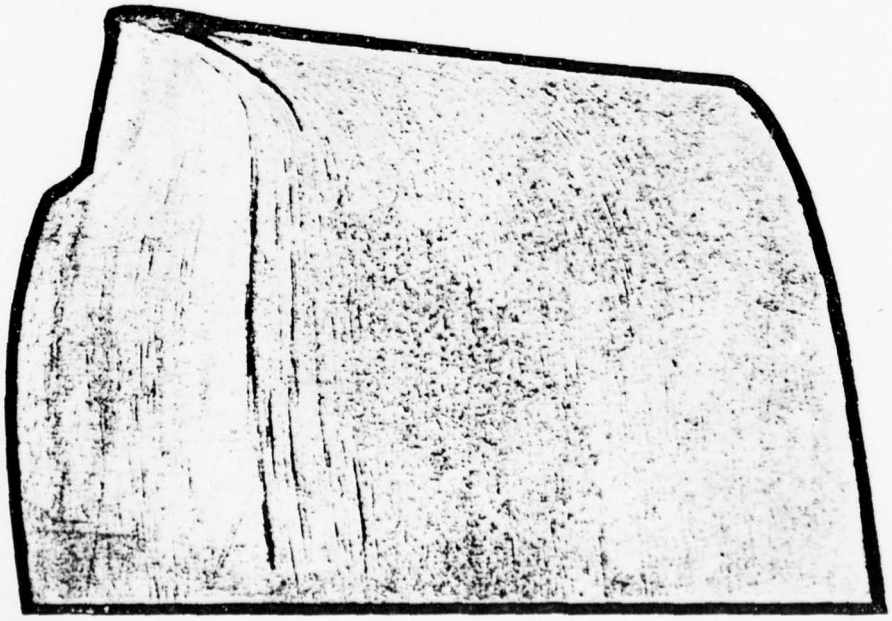


157

Picture No	Title	Description
158	Overturned skin	Overturned skin in a billet of 30CrMnSi structural alloy steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.2
159	Overturned skin	The form of overturned skin on the longitudinal testing piece of an axial billet of 45 steel. The skin is like a black strip. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.7

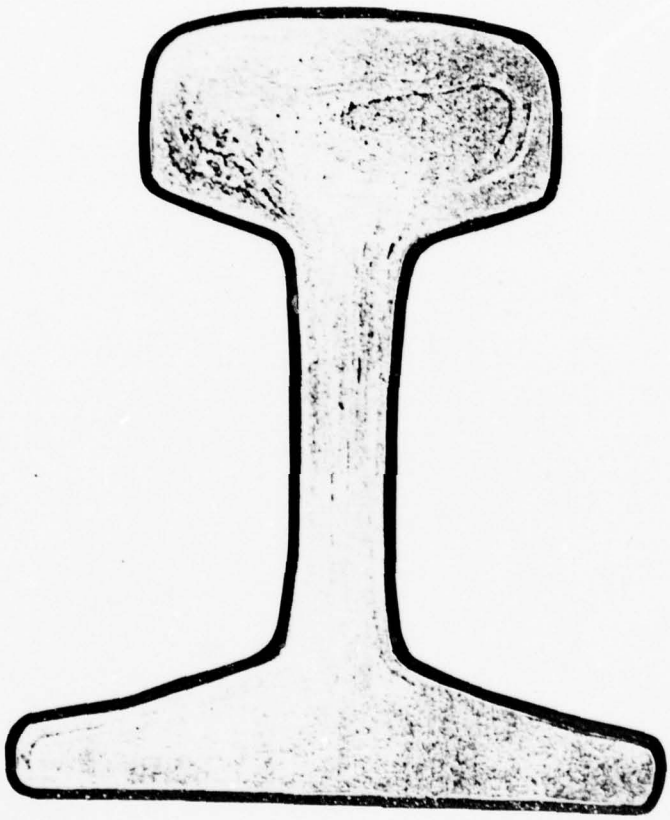


158



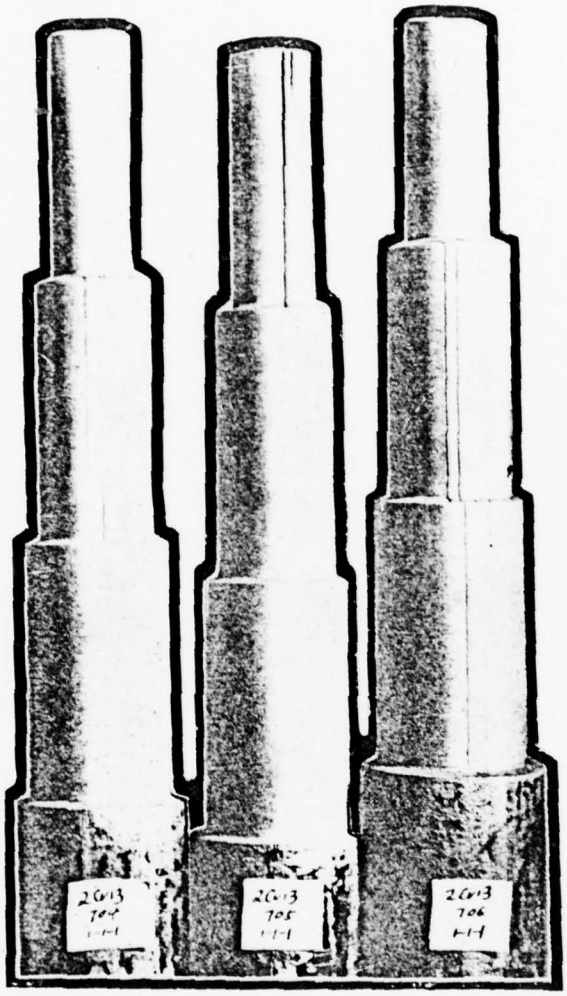
159

Picture No.	Title	Description
160	Overturned skin	Overturned skin seen in heavy rail steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.3

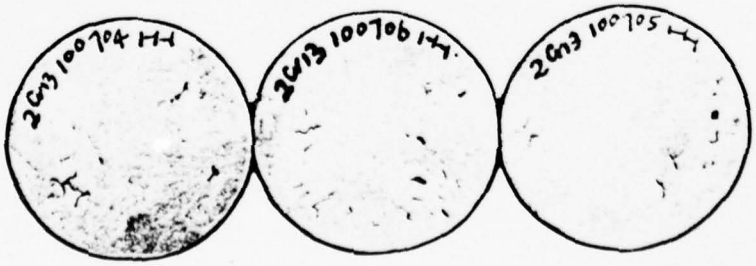


160

Picture No.	Title	Description
161 162	Inside bubble	The form of inside bubble in the transverse section of a billet of 3Cr13 rust-proof testing steel (picture 162), and the inside bubble in the pagpda-shaped testing piece (picture 161). Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1

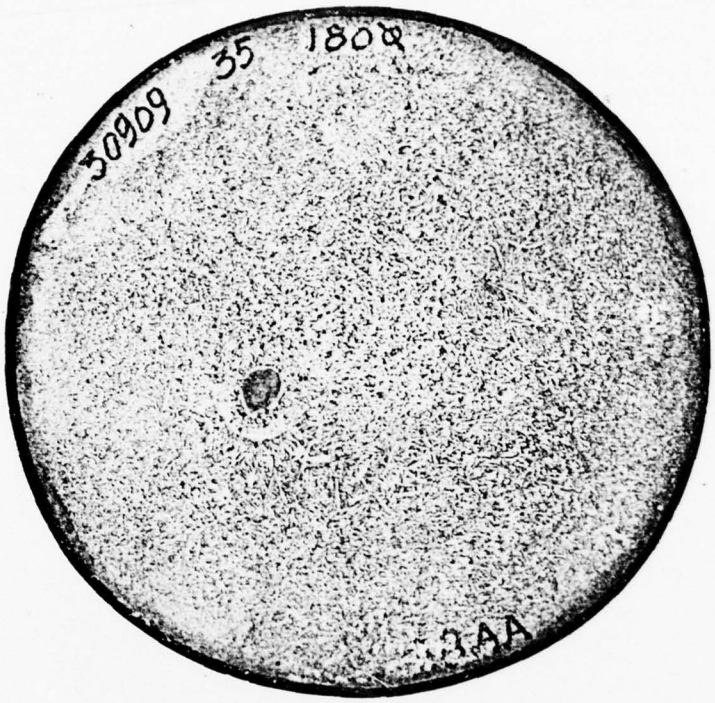

2G13
704
HH
2G13
705
HH
2G13
706
HH

161

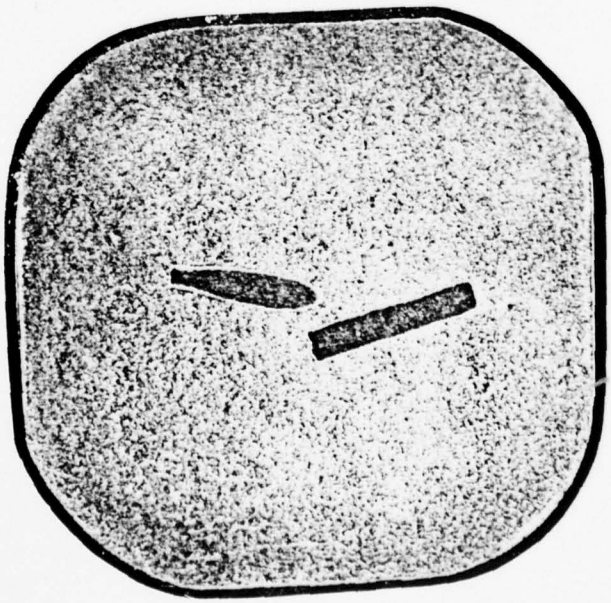

2G13 100704 HH
2G13 100706 HH
2G13 100705 HH

162

Picture No.	Title	Description
163	Foreign metal inclusion	Foreign metal inclusion in a billet of 35 Steel. The color of the foreign metal is distinctively different from that of the billet. If the etching agent is proper, the internal structure of the foreign metal can be exposed. According to analysis, the foreign metal in this picture is like a flying ring. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:2
164	Foreign metal inclusion	Foreign metal inclusion in a D60 steel billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.4

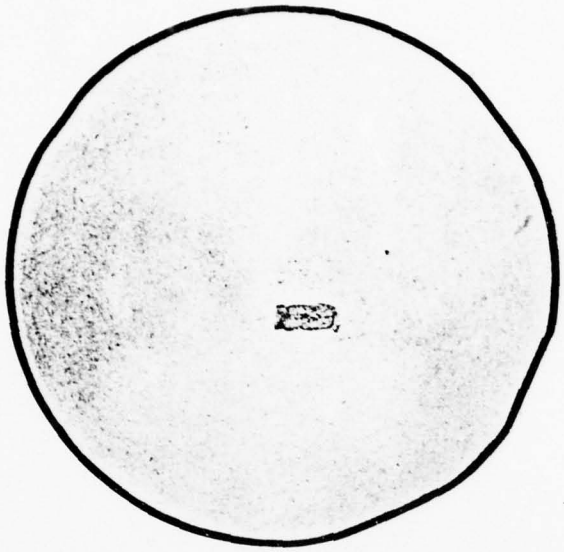


163



164

Picture No.	Title	Description
165	Foreign metal inclusion	Foreign metal inclusion in a billet of CrNi3Mo structural alloy steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.4
166	Titanium inclusion	Titanium inclusion in a billet of 1Cr18Ni Ti rust-prrof steel. Titanium is included or scattered at the edge of the billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1



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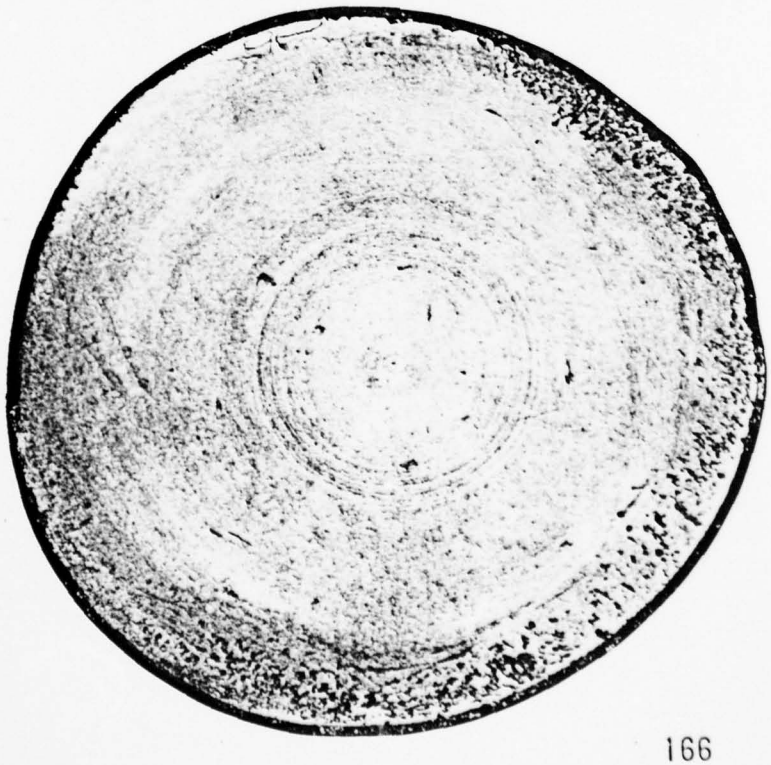
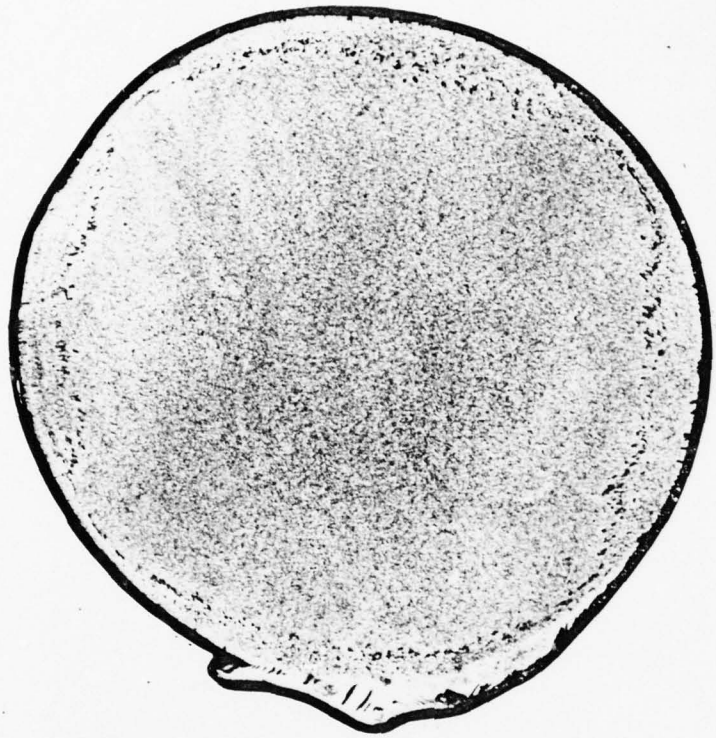


166

Picture No.	Title	Description
167	Titanium inclusion	Titanium inclusion in a billet of 1Cr18Ni9Ti rust-proof steel. Titanium is included or scattered underneath the skin of the billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
168	Titanium inclusion	Titanium inclusion in a billet of 18CrMnTi structural alloy steel. The inclusion aggregated on one side. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1



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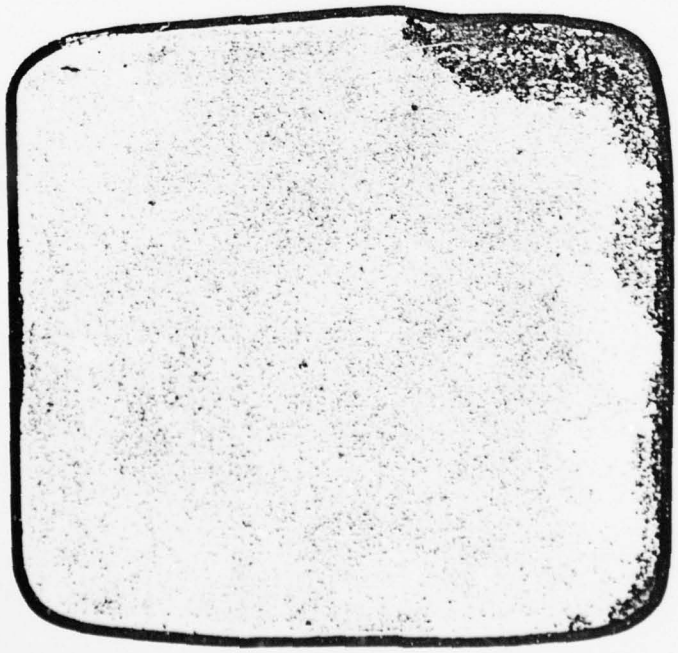

168

AD-A061 960 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO F/G 11/6
A COLLECTION OF STEEL METALLOGRAPHIES WITH ILLUSTRATION AND DES--ETC(U)
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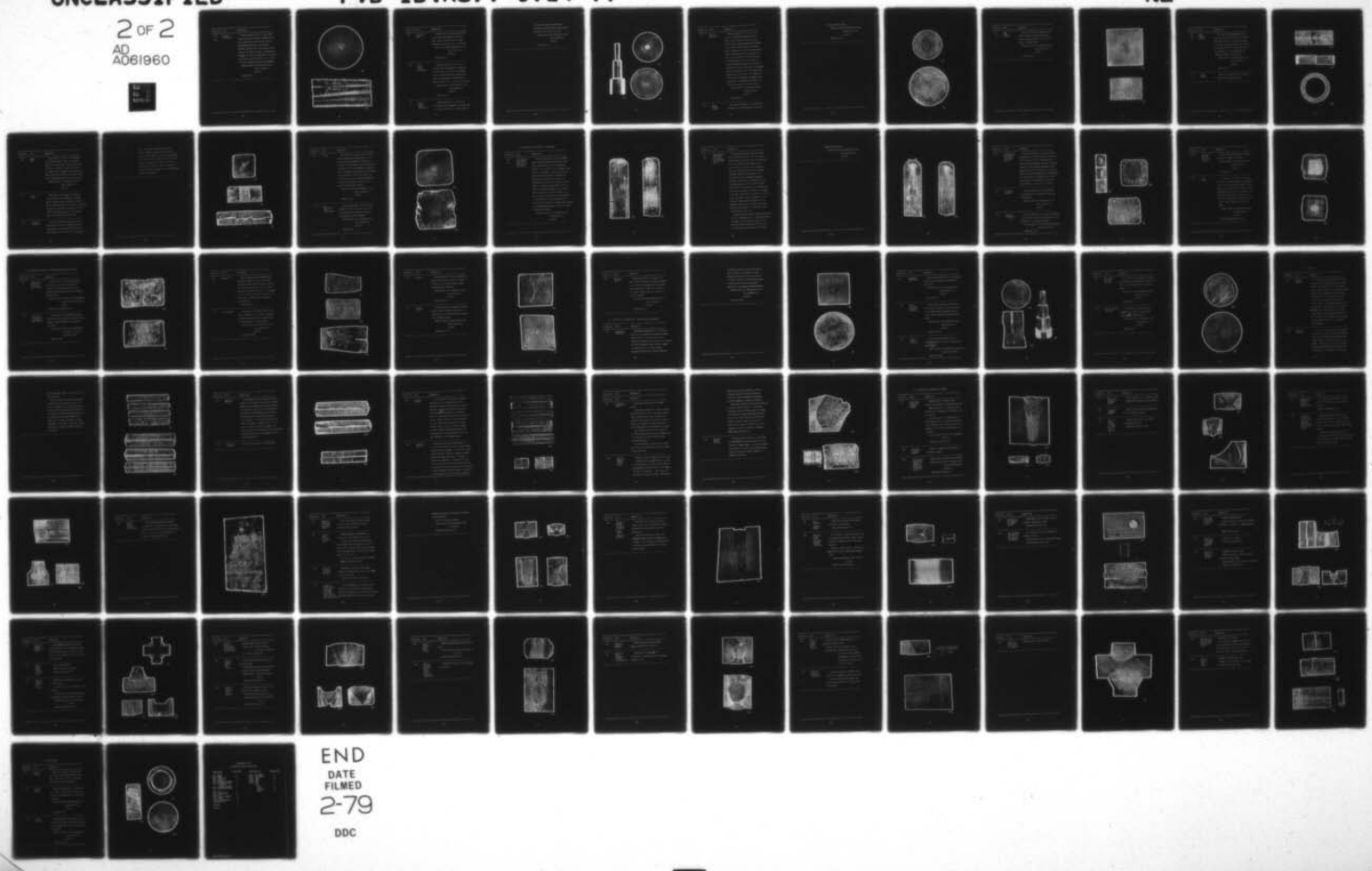

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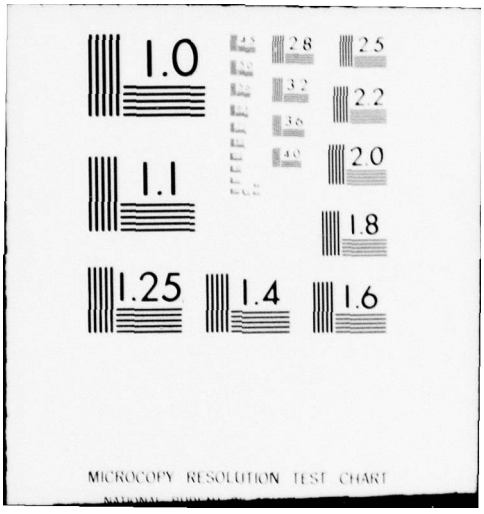
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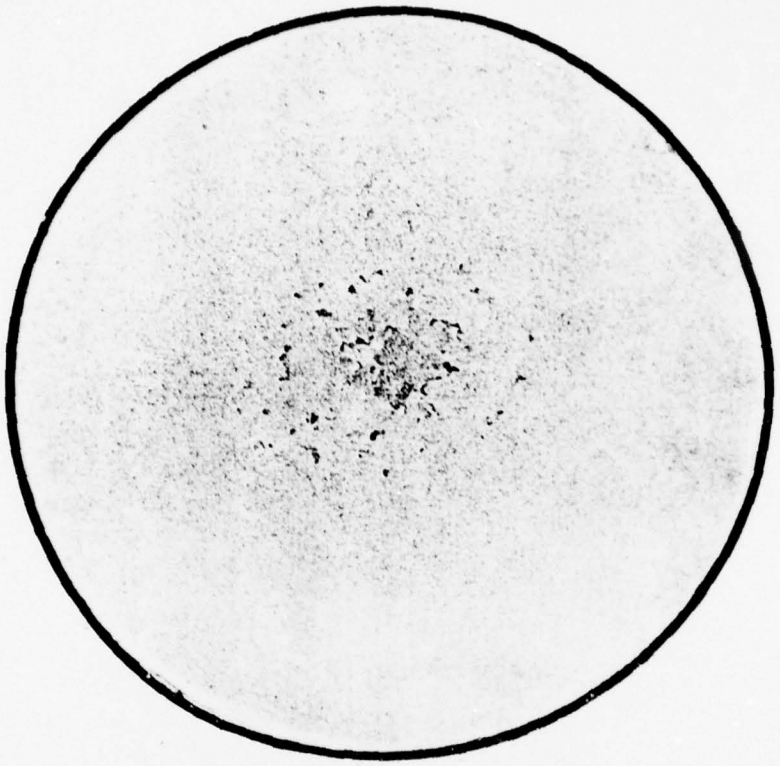
4.0
MICROCOPY RESOLUTION TEST CHART

Picture No.	Title	Description
169 170	Silicon segregation	Silicon segregation on the transverse testing piece of a billet of 3Cr2W8V alloy tool steel (picture 169) and the form of silicon segregation on a longitudinal fracture (picture 170). The segregation was caused by the fact that when the casting was shielded by using graphite slag, the silicon contained in the slag entered to the top of the ingot, thereby segregation was created. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1



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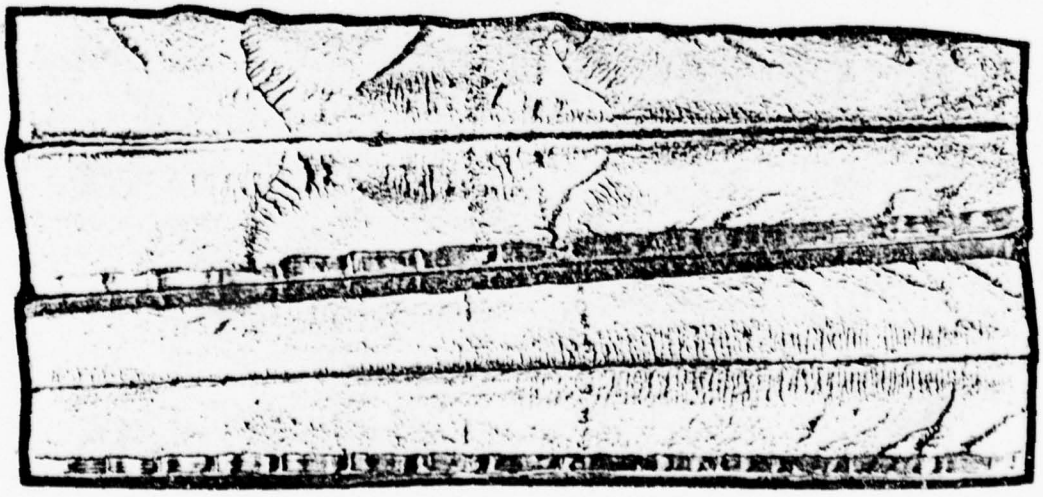

170

Picture No.	Title	Description
171	Incipient crack	Incipient crack on the pagoda-shaped testing piece of 40CrNiMoV structural alloy steel. Incipient crack is made by non-metal inclusion or air in the steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
172	Axis center carbon segregation	Carbon segregation in a billet of 10 steel, and the segregation appears in the area close to the top of the ingot. It was caused by the fact that when the casting was shielded by graphite slag, carbon entered into the top of the ingot. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C Multiple: 1:1
173	Axis center carbon segregation	Carbon segregation in a billet of 20 steel, and the segregation appears close to the top of the ingot. It was caused by

the fact that when the casting was shielded by graphite slag, carbon entered into and to the top of the ingot.

Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.

Multiple: 1:1

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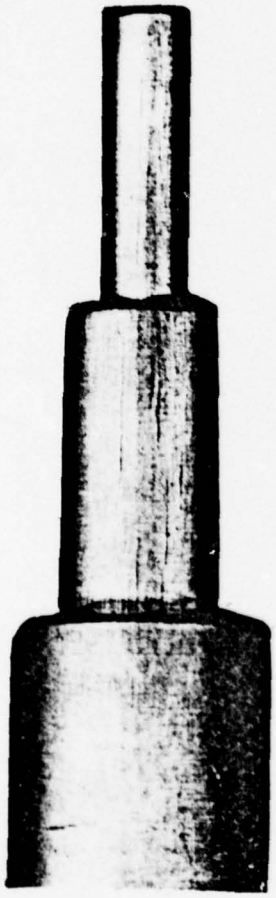

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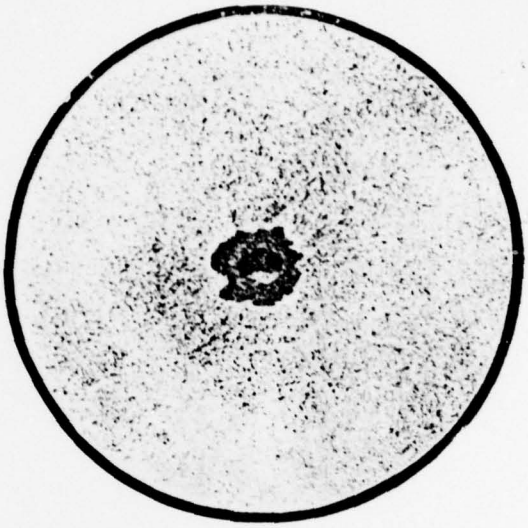

172

173

Picture No.	Title	Description
174	Negative segregation	Negative segregation on the tail of an ingot of 30SiMnMoV structural alloy steel. On a hot acid etching transverse testing piece, negative segregation appears in the shape of either oval or irregular white or black band. The difference between negative segregation and overturned skin is that in the vicinity of the band there is no inclusion, and at the same time, the C and S contents are lower than that in the composition of ingot. The reason of producing this kind of defect is not yet known, nevertheless, it can be avoided by increase the steel liquid temperature, pouring faster, especially at the beginning of pouring or changing the shape of the die bottom. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
175	Edge caorse crystal	DT1 pure steel ingot. if the control of heating is not appropriate, there will

be edge coarse crystal.

Etching agent: 1:1 hydrochloric acid
water solution at
60-70°C.

Multiple: 1:1

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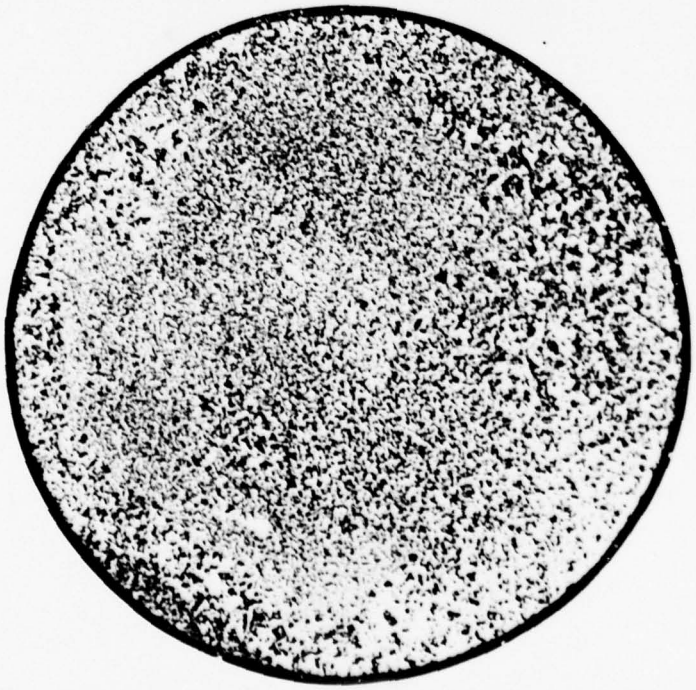
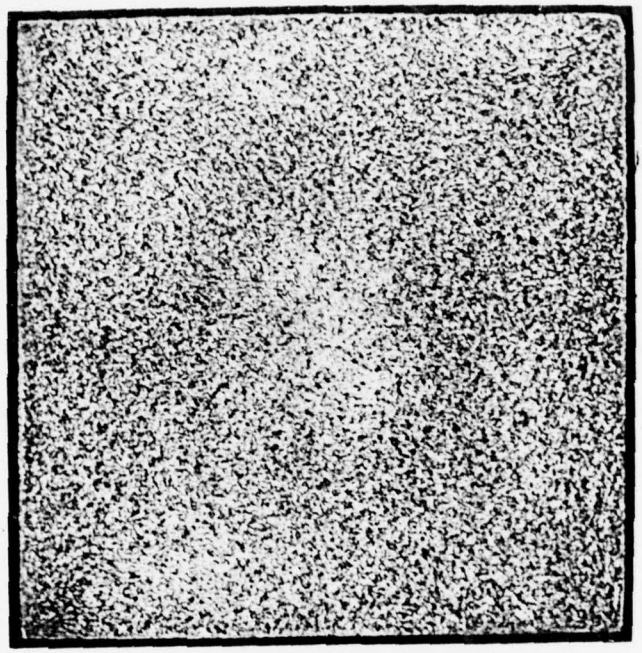
174



175

Picture No.	Title	Description
176 177	Edge coarse crystal	Hot acid etching transverse testing piece (picture 176) and longitudinal testing piece (picture 177) of a forge billet of 25Cr3Mo steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1



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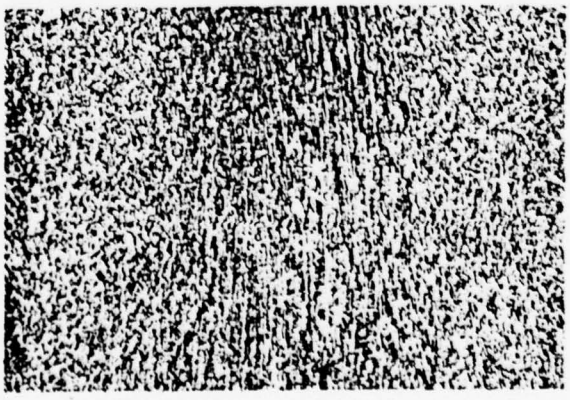
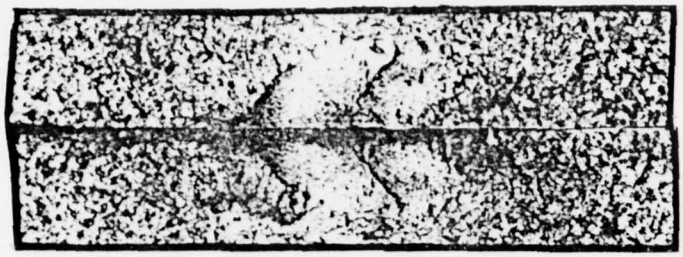


177

Picture No.	Title	Description
178 179	Edge coarse crystal	The form of edge coarse crystal at the fracture on a forge billet of 25Cr3Mo steel (picture 178). The coarse crystal is of strong metal brightness. Maintaining temperature of 920°C for some time, then after heating, the coarse crystal will basically disappear (picture 179). Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
180	Coarse crystal	Coarse crystal seen at the fracture on a tube of Cr25 rust-proof steel.



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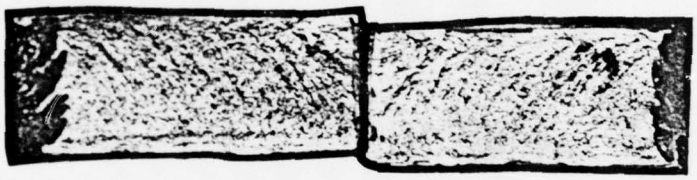

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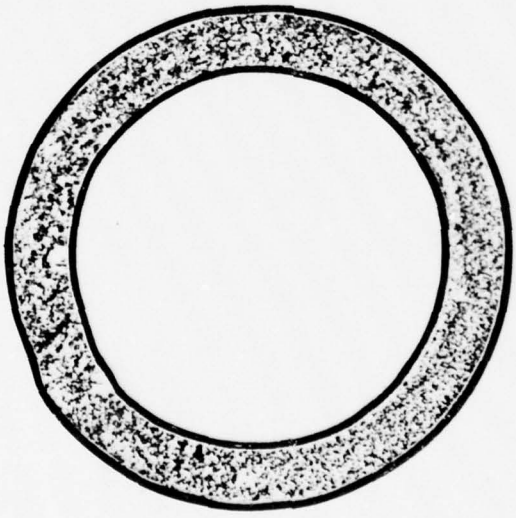

180

Picture No.	Title	Description
181	Forge crack	Forge crack in a billet of Cr18Ni25Si2 heat resistant steel. Most of the crack appear at the axial part. When there is only one strand of crack, it always runs along a diagonal direction, when they are two, they make a cruciform and when they are more than two, they radiate out from the axis center. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.
182	Forge crack	The form of forge crack at a fracture when a forge billet of W18Cr4V high speed steel is broken along the crack. The crack is grey in color and there is no oxidizing happening. Because when the billet is broken, the crack is not completely open, so on the fracture, there are a few crystal-like strips.
183	Non- metal inclusion	The form of non-metal inclusion at the fracture of a billet of 12CrNis structural alloy steel. On the longitudinal fracture, the inclusion is of the shape of fine strip.

On a hot acid etching transvers testing piece, to judge non-metal inclusion must be on the basis of what can be seen by naked eyes. If there are only hollows or pores of various shapes, you can say that part of the steel is unsolid. To the steel which is required to have high quality, you must give a supplementary micrscopic examination.

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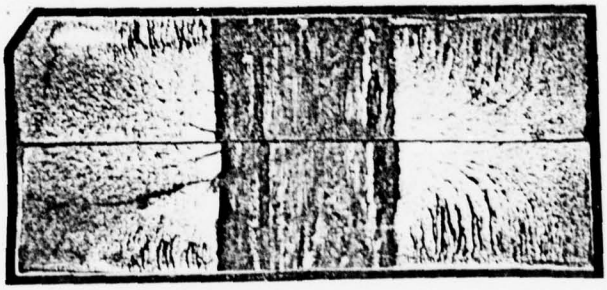
181



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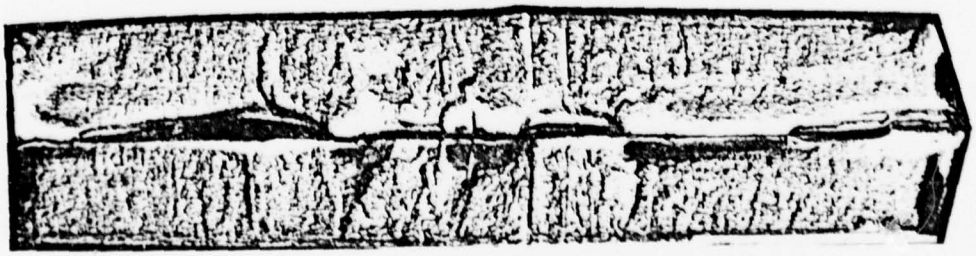
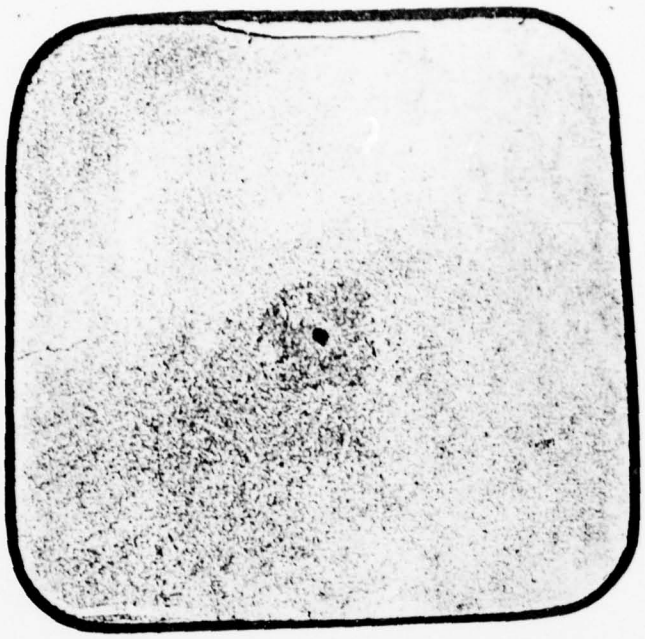


183

Picture No.	Title	Description
184	Folding	The folding of 45 steel. On a hot acid etching transverse testing piece, it is a crack which runs bevelingly against the surface of the billet, and in the vicinity of the crack, there is decarbonizing happening. This is because that the scars or projections on the surface of the billet bend on the billet when hot working takes place or that the ears of steel fold together as the continuous hot working goes on. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
185	Hot brittleness (Red brittleness)	Forge crack caused by low Mn, S ratio (Mn:S=2.5) in DT1 pure steel. This kind of brittleness is generally called hot brittleness or red brittleness. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:2



184

185

2. The Structure and Defects of Open Steel

Picture No.	Title	Description
201 202	The structure and sulphor print of an open ingot of open steel	The structure (picture 201) and sulphor print (picture 202)of an open ingot of B3F steel. The structure of the longitudinal section of the ingot is of the following few layers: The outmost layer is a solid and hard shell,which contains no bubble. The thickness or thinness of this layer is determined by the condition of smelting and casting. Inside the hard shell, there is a layer of honeycomb bubbles. On this layer scatter many long strip-like bubbles, and the long axis of the bubble is perpendicular to the mould wall and stretches from the bottom of the ingot to its central part. Inside the honeycomb bubble layer, there is a layer of secondary bubbles. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.

201

202

Picture No.	Title	Description
203 204	The structure and sulphor print of a bottle-shaped ingot of open steel	The structure (picture 203) and sulphor print (picture 204) of a 7 .26 ton bottle-shaped ingot of B3F steel. From the structure of the longitudinal cross-section of the ingot, it can be seen that the thickness of the ingot shell is 20-30 mm and thickness increases gradually from down up. The distribution of the honeycomb bubbles is different from that of the open steel ingot, the bubbles scatter over the whole length including the round arc part at the head, and their body is shorter than those on the open steel ingot. The latter is generally 70-100 mm while the former is about 25-45mm, and they gradually become short from down up. The secondary bubbles are not clear. The liquid extract concentrates in an area which constitutes 6-16% of the top. There is clear inverted V-shaped segregation in the bottle-shaped ingot. The sulphor print indicates that the sulphor content of the inverted V-shaped segregation is high, but it is lower than the part where the liquid

extract concentrates.

Etching agent: 1:1 hydrochloric acid
water solution at
60-70°C.

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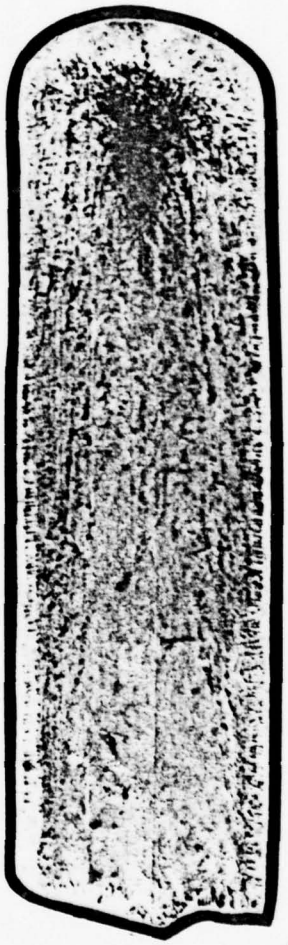
203



204

Picture No.	Title	Description
205	The structure and sulphor print of an open steel ingot	The structure seen on the longitudinal cross-section of an open ingot of open steel, which contains 0.09% C. From down up at a distance of 25%, 50% and 75% from the bottom, there are three not-acid--corroded testing pieces (left half) and sulphor prints (right half). The former illustrates the distribution of various kinds of bubbles and the latter illustrates the distribution of sulphide from surface to the center of the ingot.
206	Honeycomb bubbles	Honeycomb bubbles on the transverse cross-section of the middle and lower part of open steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.
207	Silicon segregation	When B3F steel ingot has chemical sealing of its top by using silicon iron, some silicon enters into the honeycomb bubbles. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:2.5

205

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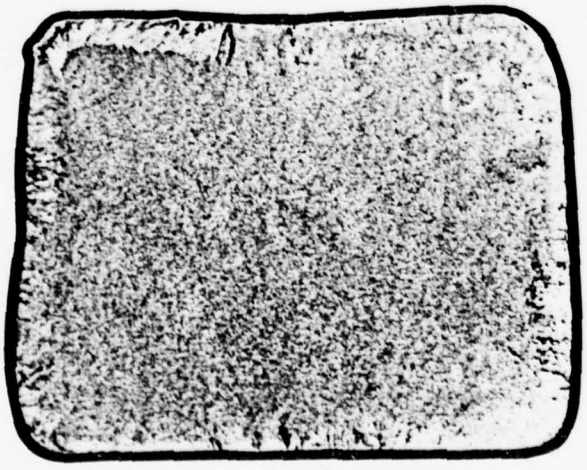
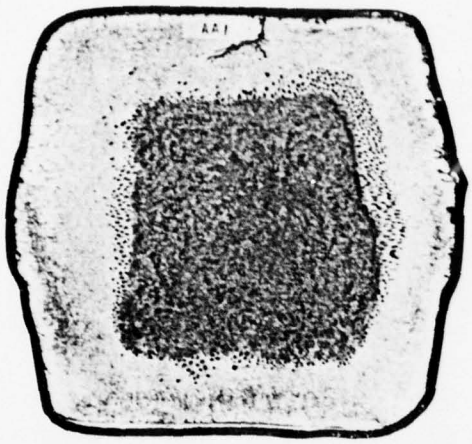


207

Picture No.	Title	Description
208	Secondary bubbles not rolled together	Secondary bubbles that are not rolled together in a billet of B3F steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:4
209	Tail pores	Tail pores on a billet of B3F steel. This defect is made because at the beginning there is not large enough pressure or the heating of the steel is not enough, so the deformation cannot reach the middle of the transverse section of the ingot and as a result, the extension of outer side of the ingot is much larger than that of its center. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: approximately 1:4



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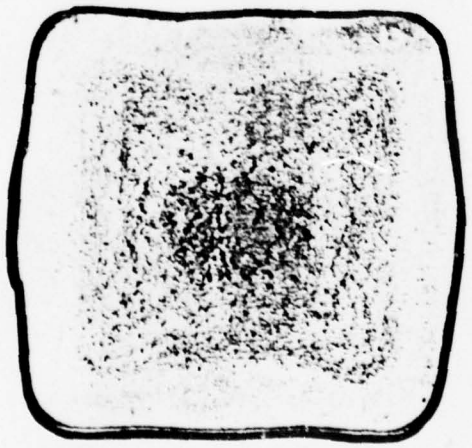
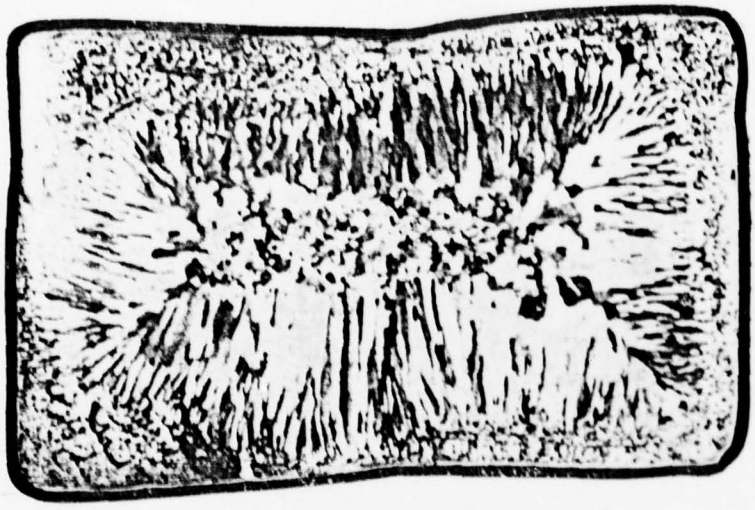


209

3. The Structure and Defects of Continuous-casting Steel Billet

Picture No.	Title	Description
301	Cast billet structure of continuous-casting steel	A cast billet of silicon steel shows three crystal regions after cold acid etching: fine isometric crystal region, columnar crystal region and coarse isometric crystal region. Etching agent: 200g ferric trichloride plus 300ml nitric acid and 100ml water. Multiple: approximately 1:1.5
302	Cast billet structure of continuous-casting steel	A cast billet of 1Cr18Ni9Ti rust-proof steel after cold acid etching shows that the columnar crystal stetches from surface to its center. Etching agent: 200g ferric trichloride plus 300ml nitric acid and 100ml water. Multiple: 1:1.5



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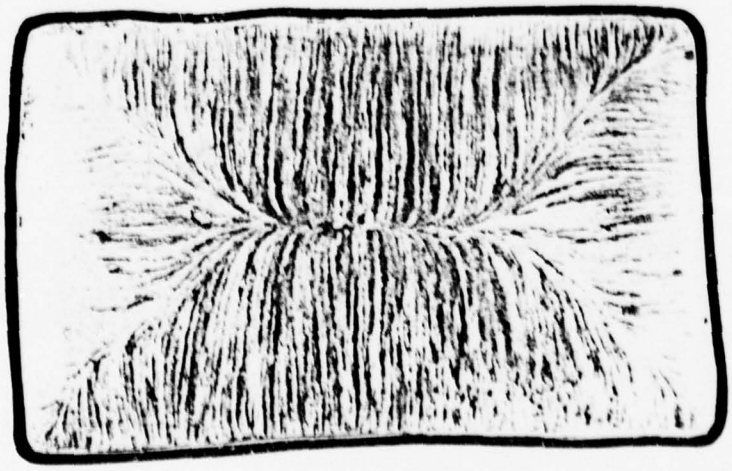
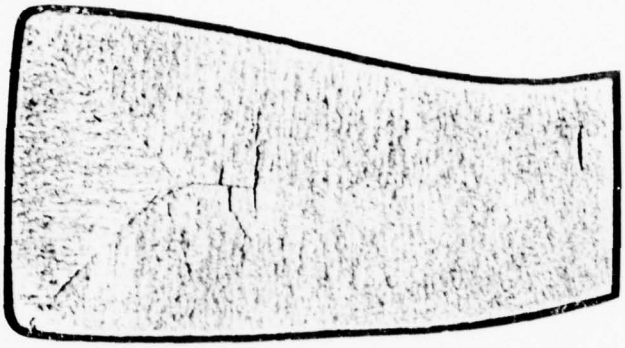


302

Picture No.	Title	Description
303 304	Depression	When the quantity of secondary water-jetting on a cast billet of 0.08%C semi-degasified steel is 6350 litres per minute, there will be a depression on the billet (picture 303), when the quantity is reduced to 5250 litres per minute, the size of the billet will be exactly what is required (picture 304). Multiple: 1:4.5
305	Protuberance	Protuberance on the cast billet of No.3 steel, produced by 700x 180 mm arc-shaped continuous casting machine. In addition to the protuberance, there are cracks. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:~~1.2~~ 3.5



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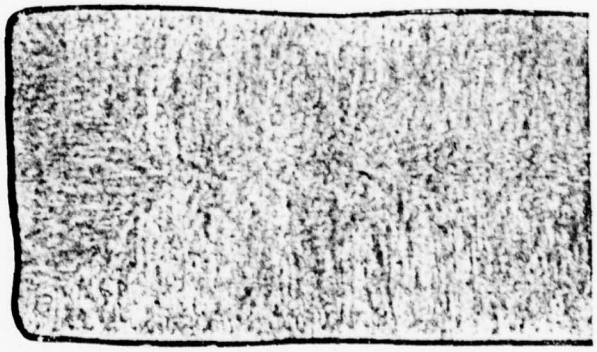
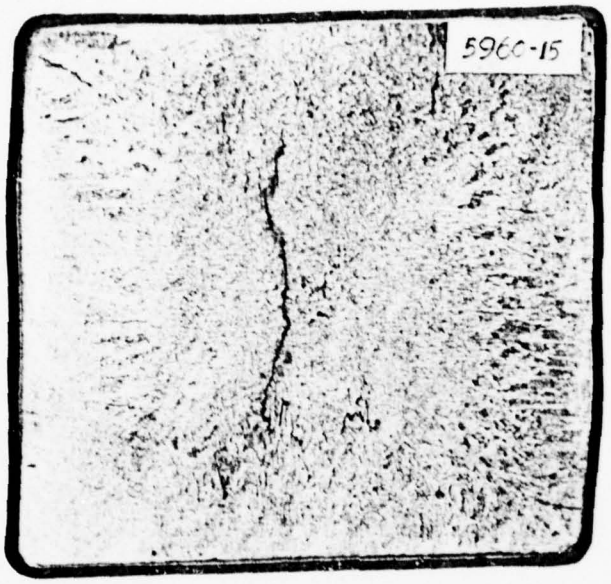


304

305

Picture No.	Title	Description
306	Cleavage	Center cleavage and corner cleavage on a cast billet of No. 3 steel. The billet is produced by a 90 x 90mm standing bowed continuous-casting machine. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.2
307	Rhombic change	A 90 x 90mm standing bowed continuous-casting machine produced cast billet of 20MnV steel, and its cross-section becomes slant--rhombic change. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.2



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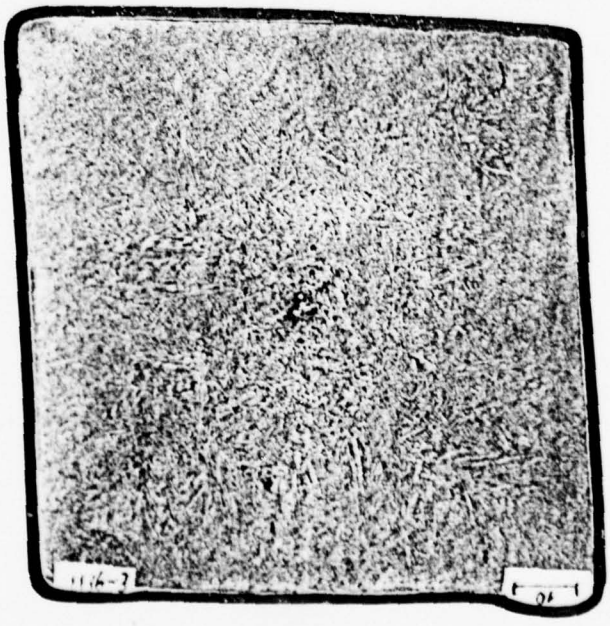

307

Picture No.	Title	Description
308	Shrinkage cavity	Shrinkage cavity at the center of a cast billet of 60Si2 spring steel, produced by a 90 x 90 mm standing bowed continuous-casting machine. In addition, there is a fine crack running along the direction of columnar crystal. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.2

4. The Structure and Defects of Electro-slag Remelted Steel

Picture No.	Title	Description
401	Corrugated segregation	Corrugated segregation on the transvers section of an electro-slag remelted 12Cr2Ni4 steel billet. At the beginning stage of electro-slag remelting, the vibration of voltage and electric-current causes change of speed in crystalization , and thus creates corrugated segregation. Generally speaking,

the ferrite content in white ring band is more than that in the black ring band. Because each ring band is very narrow, so it hardly possible to differentiate their composition by merely using chemical composition or ordinary spectrum analysis.

Etching agent: 1:1 hydrochloric acid water solution at 60-70°C.

Multiple: 1:2.5

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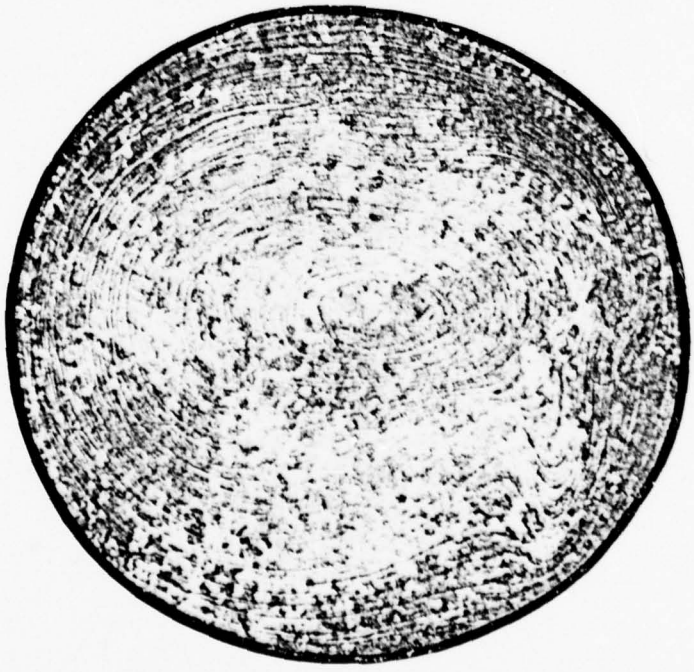
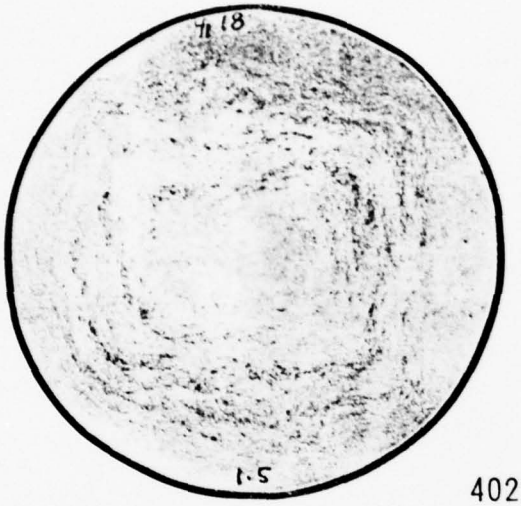


401

Picture No.	Title	Description
402	Corrugated segregation	Corrugated segregation on the transverse section of an electro-slag remelted Cr18 steel billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1
403	Foreign metal and non-metal inclusion	Foreign metal inclusion (dark color) and non-metal inclusion (white color) seen on the longitudinal cross-section of an electro-slag remelted GCr15 bearing steel billet. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.6
404	Foreign metal inclusion	Foreign metal inclusion seen on a pagoda-shaped testing piece of electro-slag remelted 30CrMnSi steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.75



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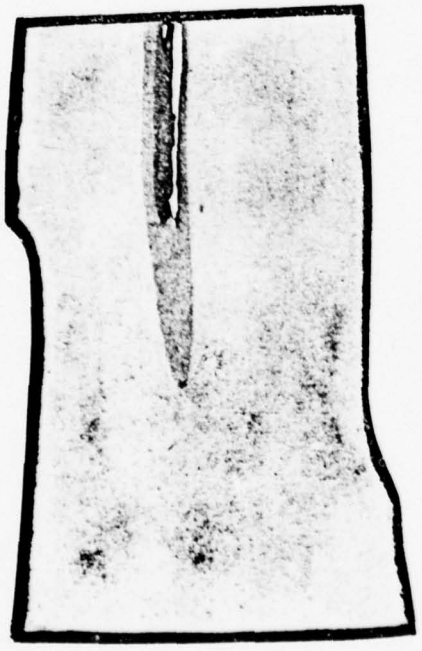

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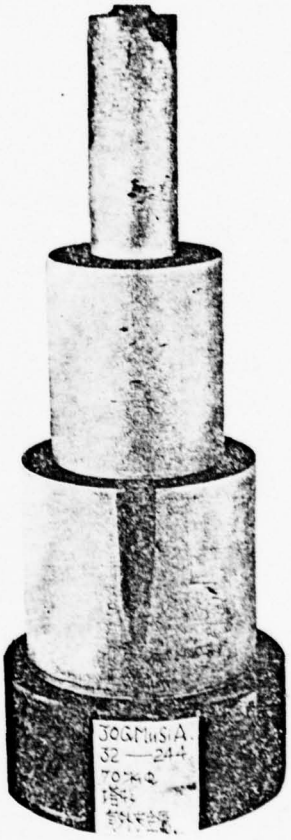
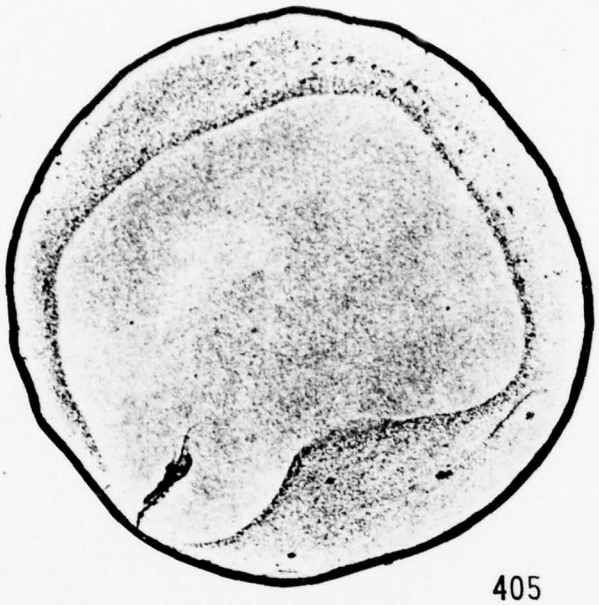


404

Picture No.	Title	Description
405	Ingot guide board not cut clean	Ingot guide board sticked to a billet of electro-slag remelted GCr15 bearing steel was not cut clean (the dark part on the edge). Etching agent: 1:1 hydrochlori acid water solution at 60-70°C Multiple: 1:1
406	Calcium fluoride inclusion	Fine crack-like calcium fluoride inclusion in a billet of electro-slag remelted GCr15 bearing steel. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1



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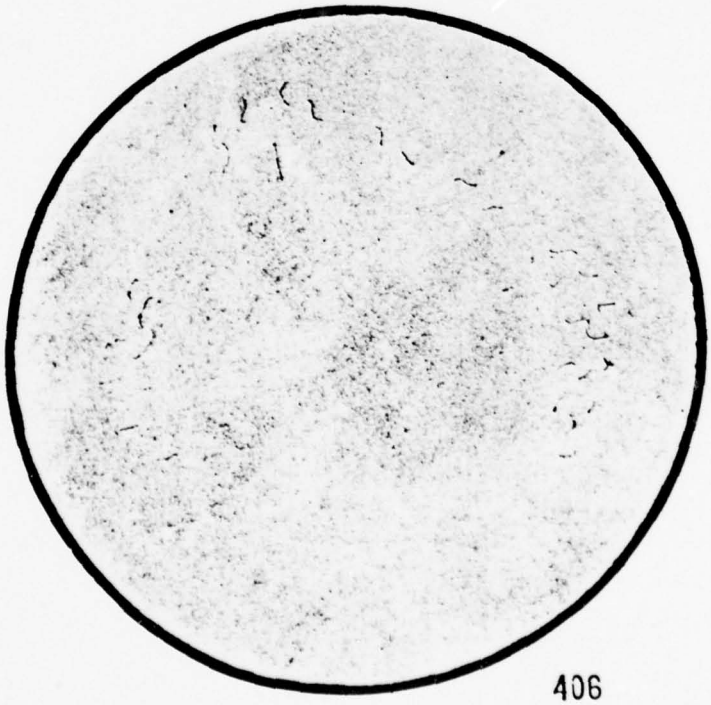


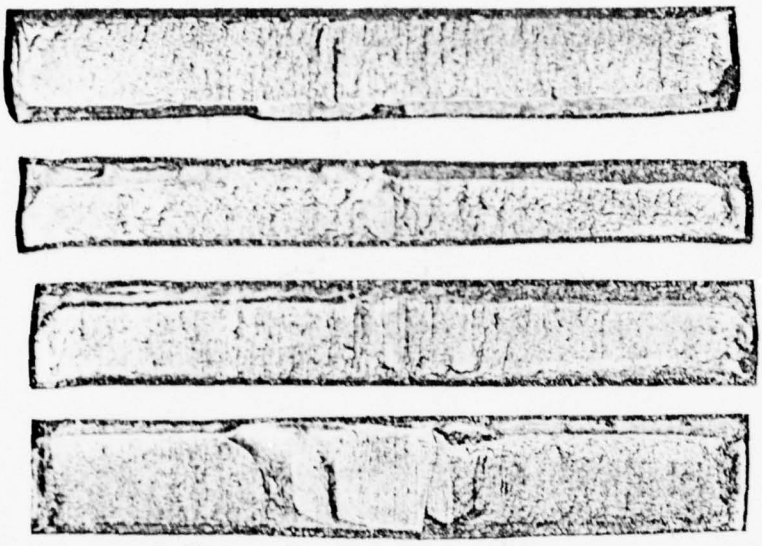
406

5. Fracture

Picture No.	Title	Description
501	Terrace fracture	In the picture from up down are terrace fractures with different degrees of 30CrNiMo steel. On the broken longitudinal fracture testing piece, under condition of modification, there are flat terraces of different size. The structure of the terrace is similar to that of the steel body but its color is lighter. Most of the terraces scatter in the areas of axis and segregation on the ingot. The less severe terrace fracture has only slight effect to the transverse plasticity of the steel, but the severe ones can reduce the transverse plasticity to a degree of being useless.
502	Tearing fracture	In the picture from up down are tearing fractures with different degrees of 18CrNiW steel. On the broken longitudinal fracture testing piece, they are solid, shining grey strips. The joining point of the strips shows concavo-convex marks of tearing. The distribution of the strips is not regular.

When they become severe, they can cover the whole fracture.

They are primarily regarded as products of remaining high aluminum content of the steel. The less severe tearing fracture has little effect to the mechanical property of the steel, but when they become severe, they can reduce the transverse plasticity and tenacity of the steel. According to their experiment in one plant, the effect of high-temperature annealing (1200°C, 5 hours) is not obvious.



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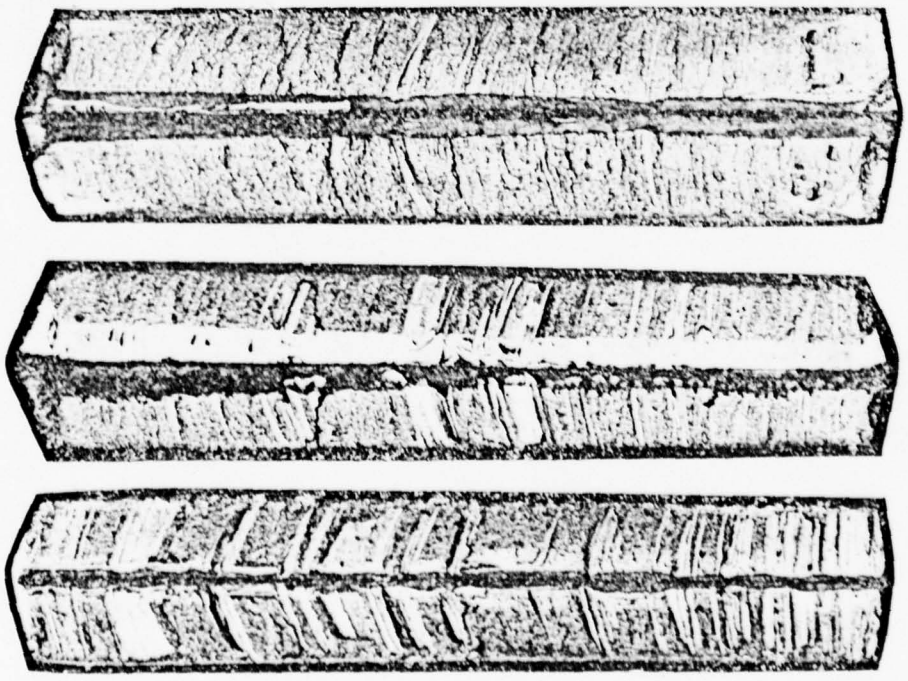
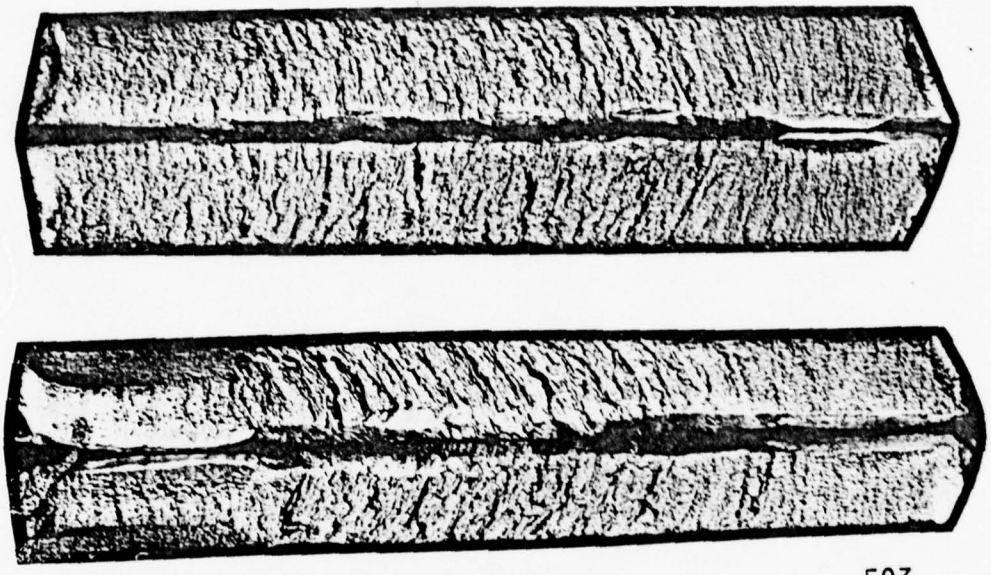


502

Picture No.	Title	Desxription
503	Wood-ring fracture	Less severe wood-ring fracture (picture above) and severe wood-ring fracture (picture below) seen in 18CrNiW steel under condition of modification. The fracture shows concavo-convex wood rings without metal brightness, but sometimes there are bright lines with various length. It has been considered that when the non-metal inclusion is high in the steel, the wood rings will be severe, and that the width of the wood-ring region is closely related to the width of the region of ingot-shaped segregation.
504	Wood-ring fracture	Wood-ring fracture seen in 18CrNiW steel.



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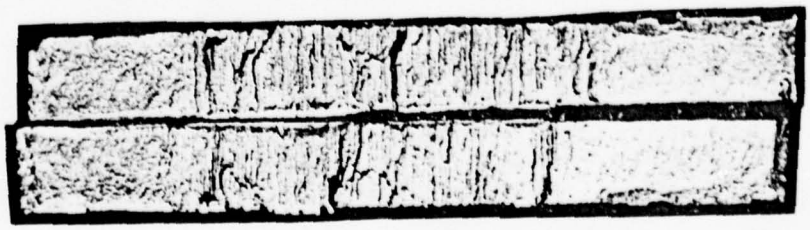
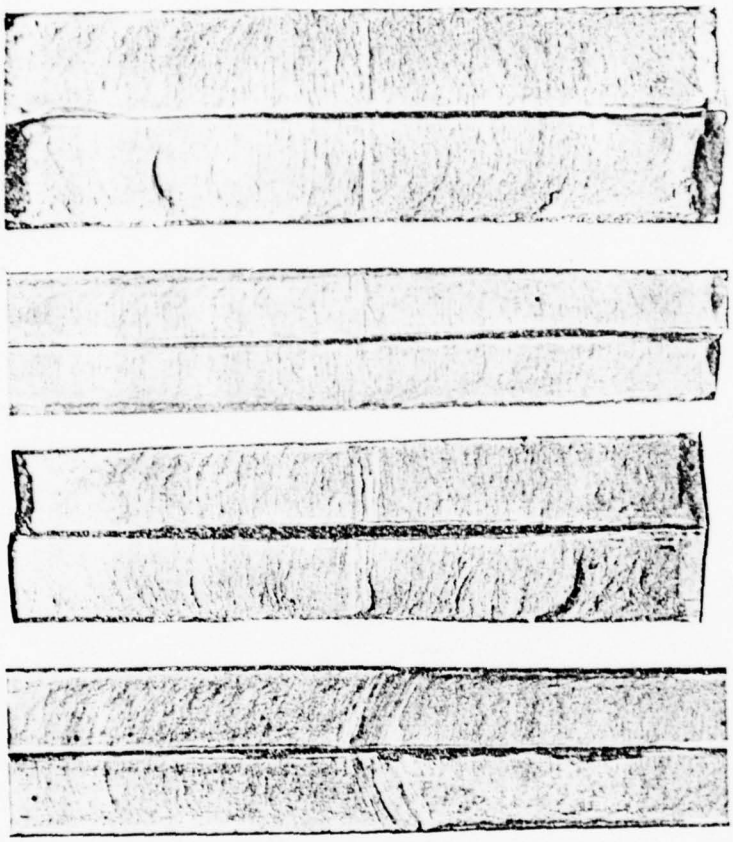


504

Picture No.	Title	Description
505	Laminar fracture	In the picture from up down are laminar fractures with different degrees. On the longitudinal fracture testing piece, they are strips of various width. They are generally distributed at axis region of the testing piece, and sometimes they appear in some other region. Laminar fracture is mainly made by the fact that during hot working, the axis center cracks of the ingot were not welded together. Laminar fracture can destroy the continuousness of steel structure and it is not permissable to have such defect.
506	Rock-like fracture	Rock-like fracture of 18CrNiW steel. It is a kind of brittle fracture of coarse crystal without metal brightness. It looks like a piece of clay made of fragments of broken concreted cement and rocks. This kind of fracture is created by overheating. Overheating of same kind of steel varies from the characteristics of smelting. Rock-like fracture can be eliminated by heat-treatment (such as annealing, regulated heating, modification and repeated treatment).



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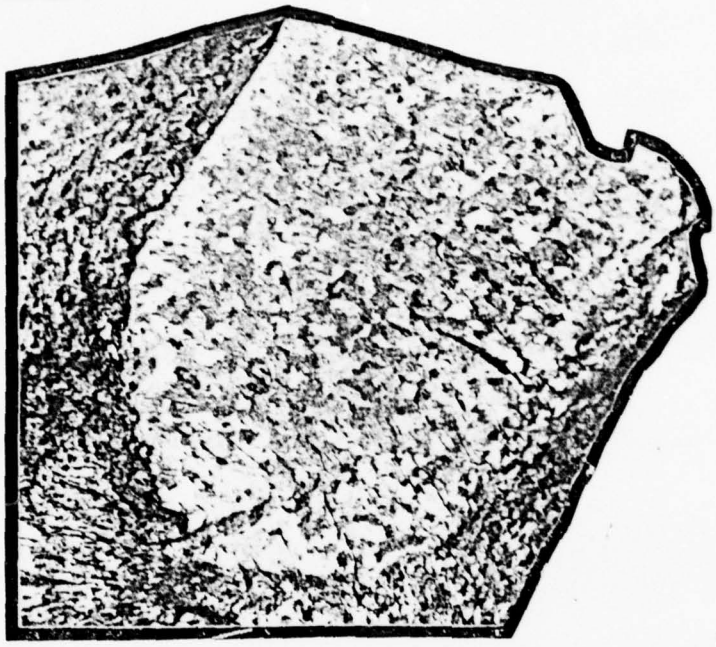
506

Picture No.	Title	Description

Picture No.	Title	Description

507	Naphthalenic fracture	Naphthalenic fracture of high speed steel. Naphthalenic fracture is a kind of coarse crystal fracture of brittle piercing crystal break. From the slant angle formed by the coming-in light during the change of testing piece, some naphtha-like grain whith weak metal brightness on the fracture can be seen. Naphthalenic fracture is the result of not having annealing when the high speed steel is overheating at about 1250°C or having repeated quenching. The naphthalenic fracture of high speed steel can not be eliminated by the techniques of heat treatment.
508	Graphite fracture (black brittle-ness)	Graphite fracture of T8 carbon tool steel. Graphite fracture is a defect, which occurs at the time when the silicon spring steel or eutectoid and over-eutectoid tool steel is in the state of annealing. The surface of the fracture is black in color. The factors

		that cause graphitizing are many, such as chemical composition, preheat-treatment condition, degree of plastic deformation, and the atmorsphere of annealing furnace. Experiement indicates that graphite fracture can happen under any one of the following conditions, such as gradual cooling of carbon tool steel after super-temperature annealing, and the steel which contains graphitization promoting elements (such as silicon and aluminum) over what is required, maintains temperature and cools gradually slightly below lower critical point.
509	Rod-like crystal fracture	Rod-like crystal appears in the fracture of 22Mn2MoCuBR steel piece. According to the finding of primary study this kind of defect is made due to the fact that aluminium oxide comes out along the crystal boundary of primitive austenite.



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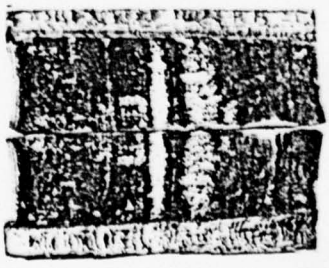

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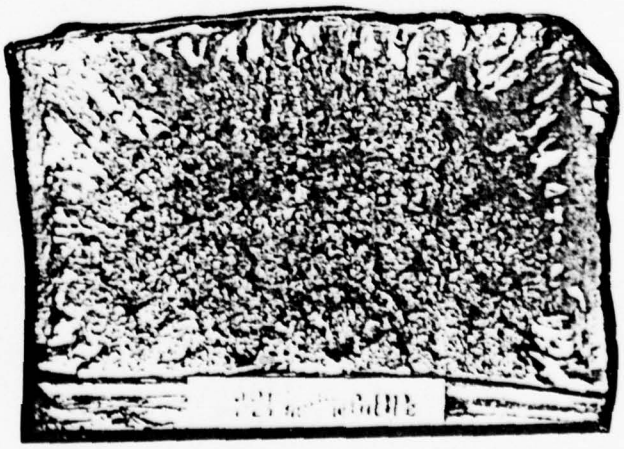
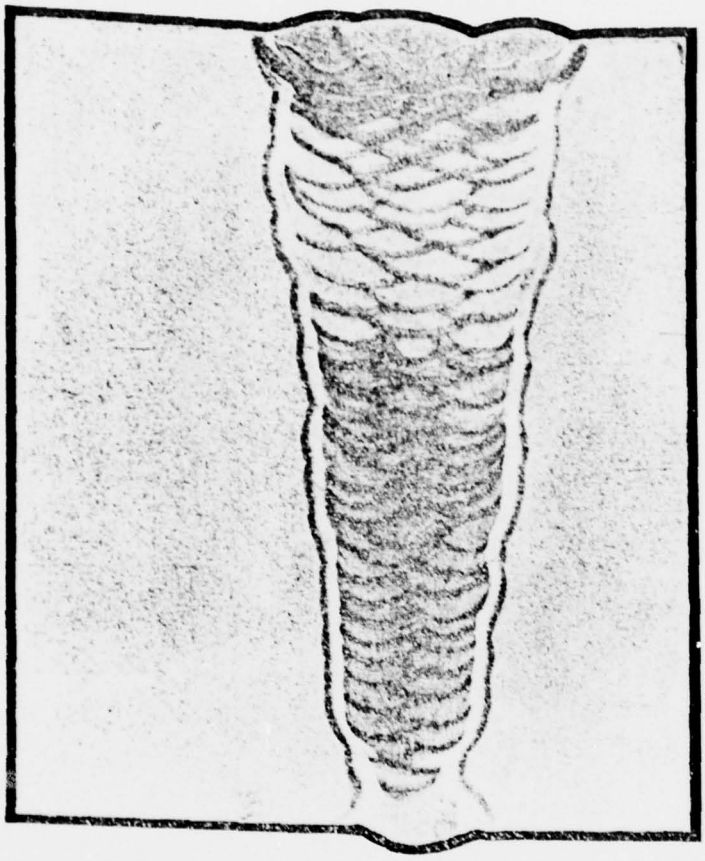


509

6. The Structure and Defects of Welding

Picture No.	Title	Description
601	Thick board hidden arc automatic welding	18MnMoNb steel, thickness 115mm, welding wire H08MnMoA, and welding agent 250. After welding, put to heating to 640°C and retain the temperature for 5 hours, then air cooling. The lower half of the welded seam is black because that is through after-welding heat treatment, and the upper half is white because that is without after-welding heat treatment. Etching agent: 2% nitric acid alchohol solution. Magnifying multiple: 1:1
602	The joint of isoion welding	Cr-Mn-N is rust-proof steel and its thickness is 18mm.
603	The joint at double-face section of hidden arc automatice single-face weldiing	15MnTi steel and welding wire H08MoSi. Etching agent: Ferric chloride, hydrochloric acid alchohol solution. Magnifying multiple: 1:1



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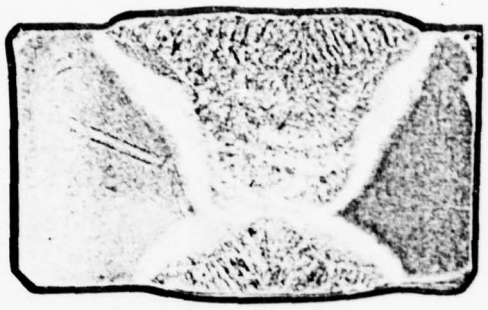
603

Picture No.	Title	Description
604	The joint of double-face automatic welding	15CrMo steel and its thickness is 32mm. Through 650°C tempering after welding.
605	Three-wire automatic welding	Ship-building steel plate, welding 350 and its thickness is 24mm.
606	Seams of angle-welding in hidden arc automatic welding	16MnNb steel, welding wire H08MnA and welding agent 102. Magnifying multiple: 2.5:1



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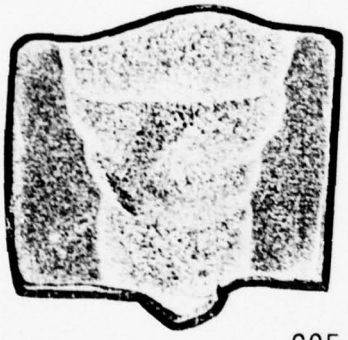

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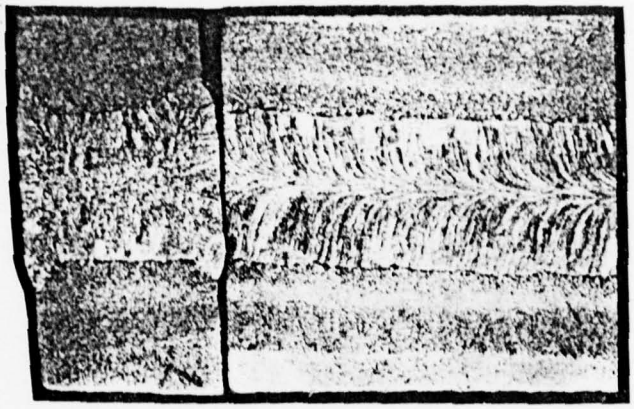
606

Picture No.	Title	Description
607	Perpendicular automatic welding shielded by carbon dioxide	Low alloy and high strength steel, low alloy steel welding wire and welding agent 350. Magnifying multiple: 1:1
608	Transverse section and longitudinal section of Tee-joint in melting nozzle electro-slag welding	Picture on left-hand side is No.3 degasified steel plate and its thickness is 80mm. On it is the transverse section of Tee-joint of melting mozzle electro-slage welding. Picture on rught-hand side is the longitudinal section of melting nozzle electro-slag welding on No.3 degasified steel plate and its thickness is 80mm.



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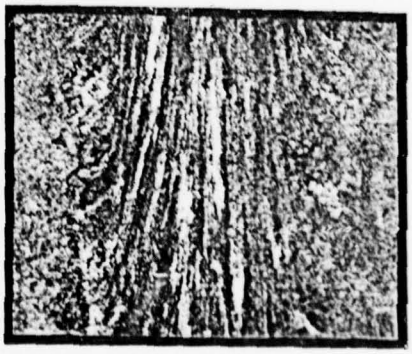
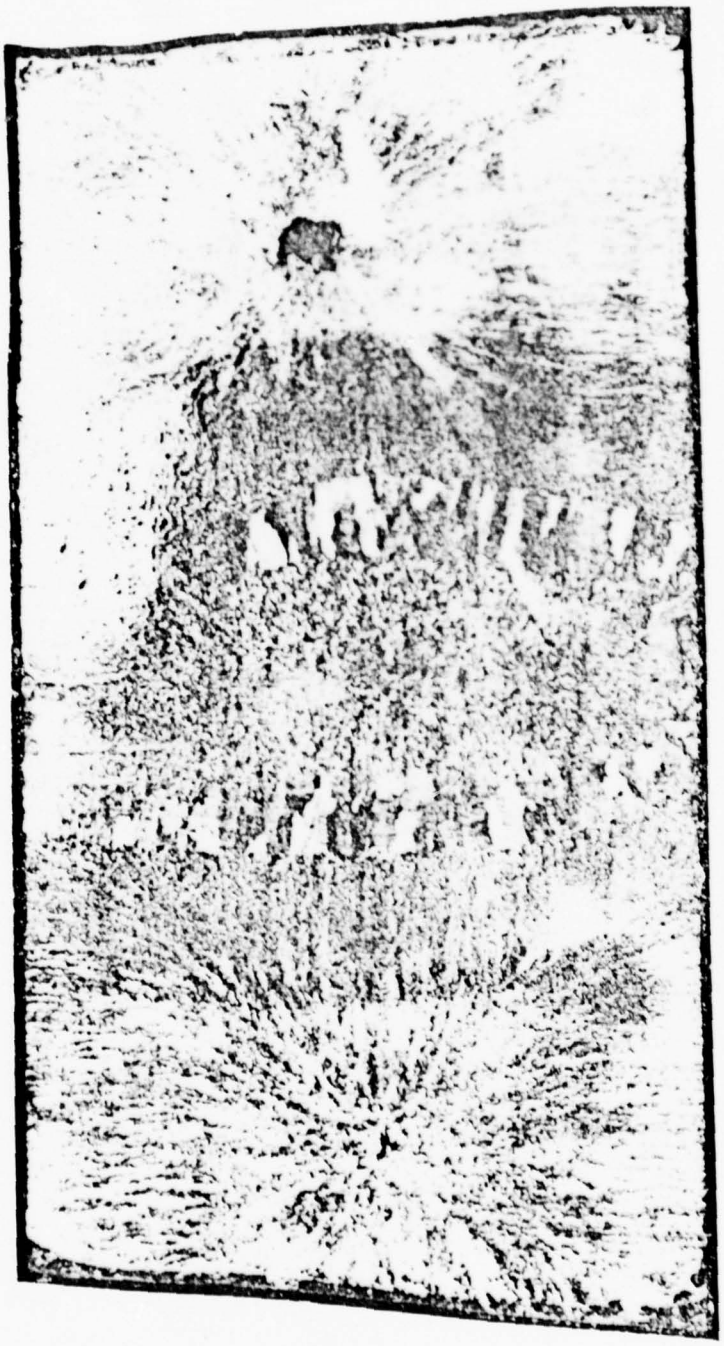


Right

608

Picture No.	Title	Description
609	Casting steel electro-slag welding	The normal welded seams of electro-slag welding on the parts of a water press machine. Down and above are shrinkage cavities of the ingot, and in the middle are the seams of electro-slag welding.



609

Picture No.	Title	Description
610	Pores not welded off by manual elecro-arc welding	Pores concentration of No. 20 steel and the not well welded part between layers and at the bottom.
611	Not-well welded joint of composite steel	Composite plate of 1Cr18Ni9Ti and A3 steel and its thickness is 14.5 mm. The stainless welding layers welded using manual electro-arc welding and the basic welding cleaves welded by using hidden-arc automative welding. Welding is H08MnA and welding agent is 431. Etching agent: Nitric acid water solution. Magnifying multiple: 1.2:1
612	Multiple-ply plate automatic welding	Multiple-ply plate of 16 Mn steel, sealing end 20MnMo steel, welding wire H08Mn, and elding agent-9. There are two small inclusions.
613	Isomeric steel welding joint slag inclusion at sealing end of multi-ply plate high pressure container	Internal cylinder of 1Cr18Ni9Ti steel, multi-ply plate of No. 20 furnace steel, sealing end 20MnMo steel, welding wire internal cylinder H1Cr18Ni9Ti and the joining point

Cr25Ni20, multi-ply and sealing end welding fissure H08Mn2Si.

There is one slag inclusion.

Etching agent: 50% hydrochloric acid hot etching.

Magnifying multiple: 1:2

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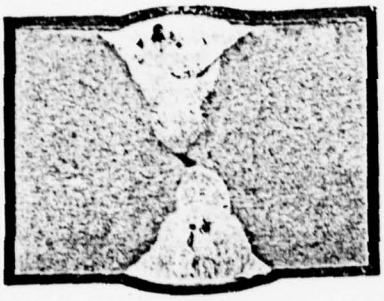

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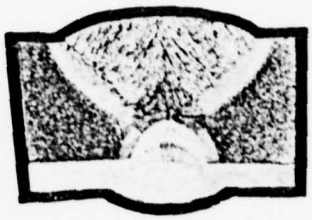

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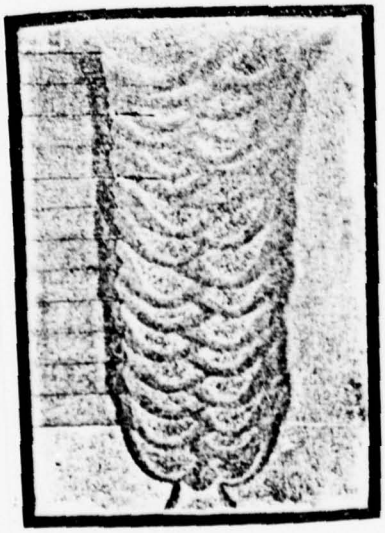

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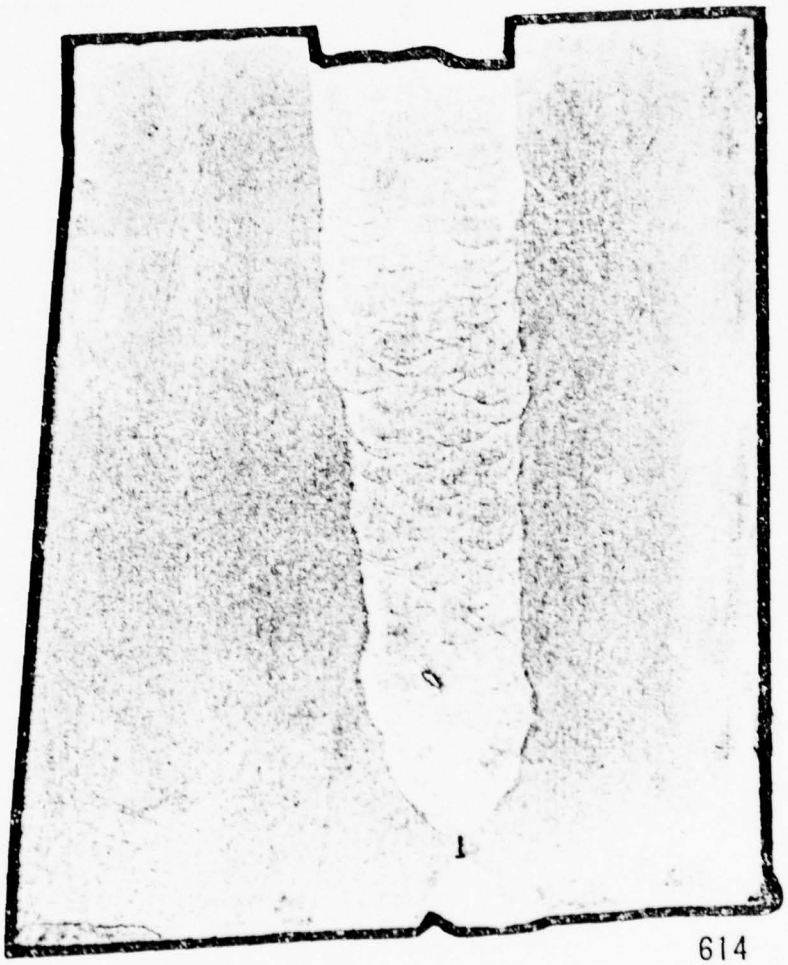
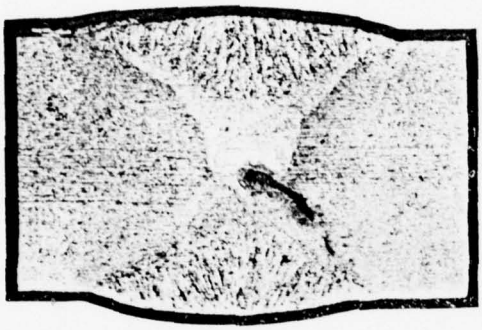
613

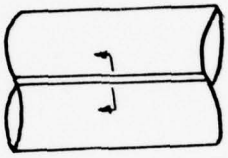
Picture No.	Title	Description
614	Not-well welded and slag-inclusion of thick plate hidden-arc automatic welding	Mn-Ni-Cr-Mo is a low alloy and high strength steel and its thickness is 150mm. Mn-Ni-Cr-Mo is steel welding wire and welding 250. Heating after welding to 660°C and temperature retention heat treatment for 15 hours. Slag inclusion, not-welded-well, cut edge and not-welded-full can be seen between layers.



614

Picture No.	Title	Description
615	Slag inclusion of automatic welding	Large slag inclusion at bottom and slant end of No.20 steel. Magnifying multiple: 1:1
616	Scattered spines remain on a high frequency welding steel pipe	No. 20 steel. Voltage 13000-13500 volt, grid current 10-12 ampere, screen current 2.5 ampere, frequency 3004 cycle, speed 40m/min. Spines on inwall were not cleared and they did not stick together after pressed flat. Etching agent: Nitric acid alchohol solution Magnifying multiple: 20:1





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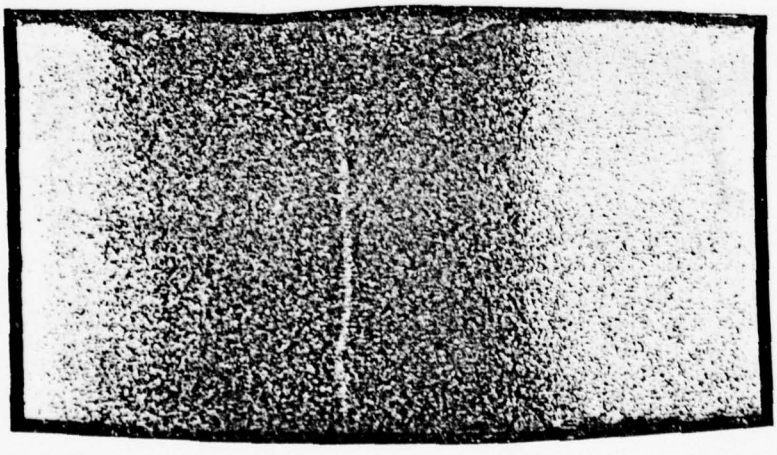
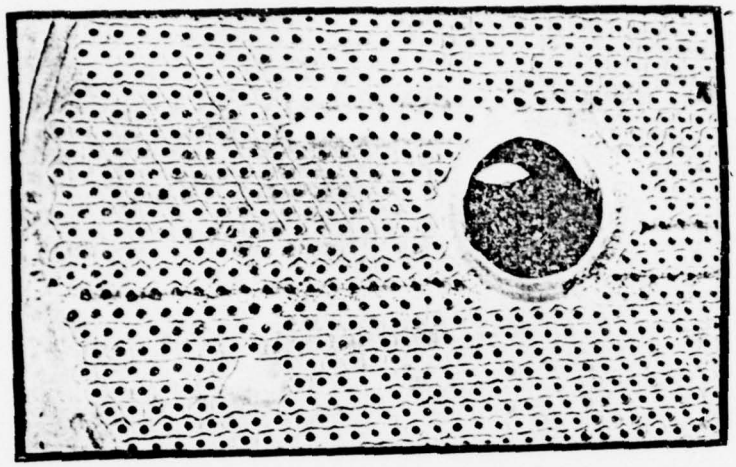


616

Picture No.	Title	Description
617	Concentrated air bubbles of manual welding	Micro-carbon pure iron (DTD), rotten-resistant welding bar 50-D52. Magnifying multiple: 1:3
618	Slag inclusion and unmelted part at joint of electro-slag welding	No. 3 steel, welding wire H08MnA, and welding agent 431. Etching agent: Nitric acid water solution. Magnifying multiple: 0.85:1



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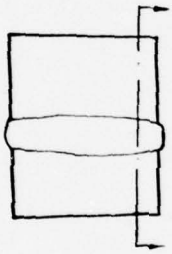
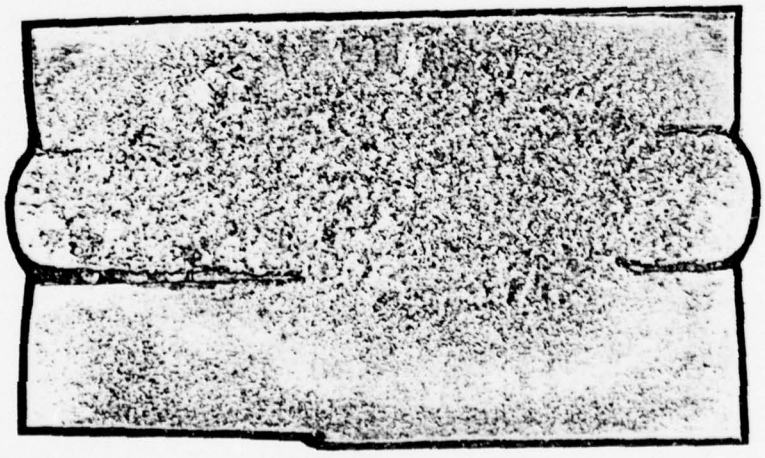
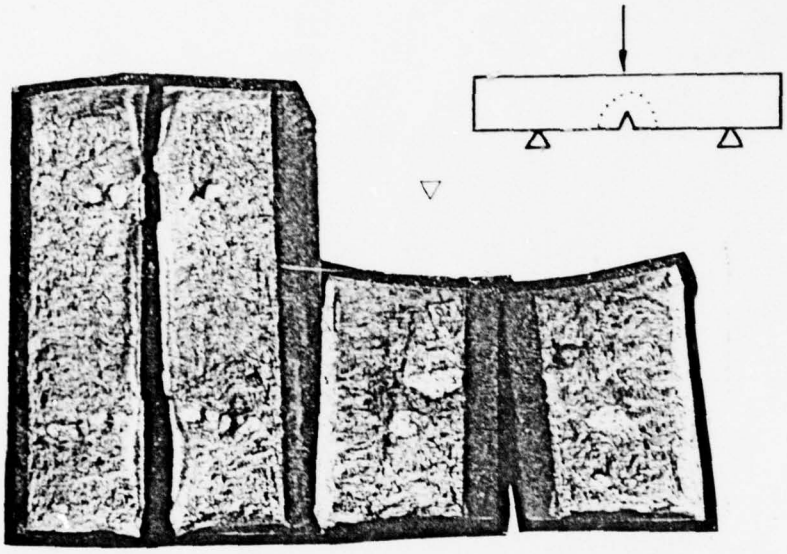




618

Picture No.	Title	Description
619	White spot at fracture of automatic welding	15MnMo,1Cr18Ni9Ti steel. Fracture testing of three-wire automatic welding, it is white spot at welded fracture. Magnify multiple: 1:1
620	Cleaves of double-face hidden-arc automatice welding	Creaves at the bottom. Magnifying multiple: 1:1
621	Cleaves of manual electro-arc welding	14MnCrMoV low alloy steel. Cleavage resistant testing, crystal cleaves of welding metal. Etching agent: Nitric acid water solution. Magnifying multiple: 1:1



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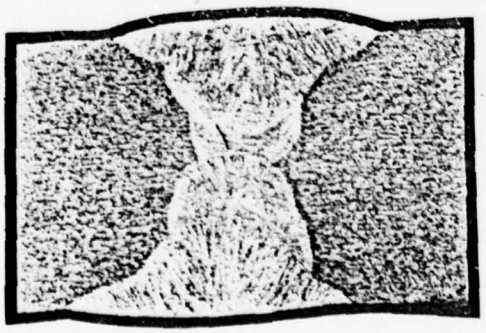

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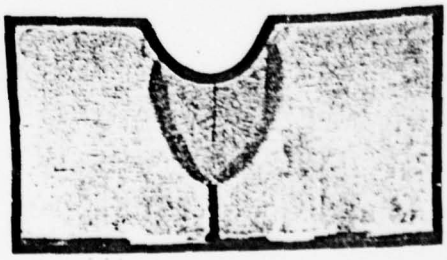
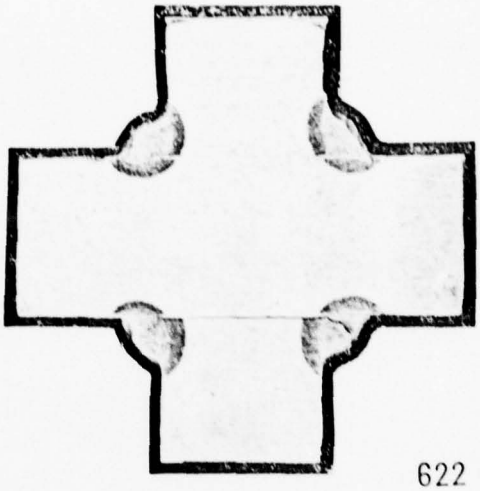


621

Picture No.	Title	Description
622	Cleaves of manual electro-arc welding	High strength welding bar of hsip-building steel and its thickness is 35mm. During chrack resistant testing, at the fourth corner welding (below right corner) produces crack.
623	Effect of manual corner welding to local crack	Ship-building steel. Crack at the foot of welding. Magnifying multiple: 1:1
624	Crack of manual electro-arc welding	High strength welding bar of ship-building steel. In grinding testing, cracks were fused together. Picture on left hand side is partial enlargement of that on right hand side. Etching agent: Nitric acid alchohol solution. Magnifying multiple: 10:1



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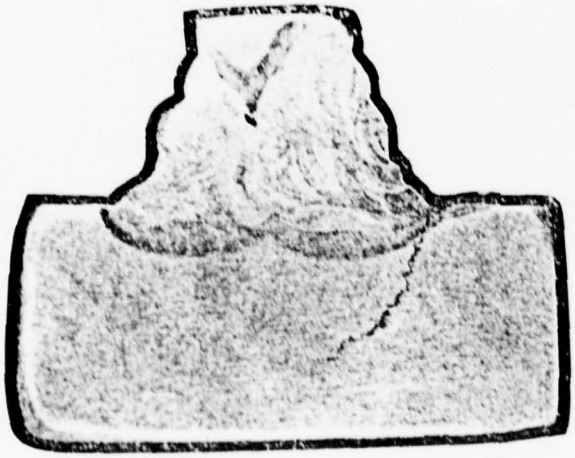

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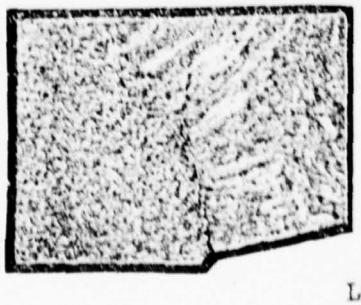

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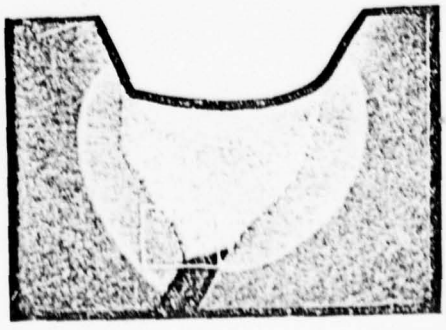
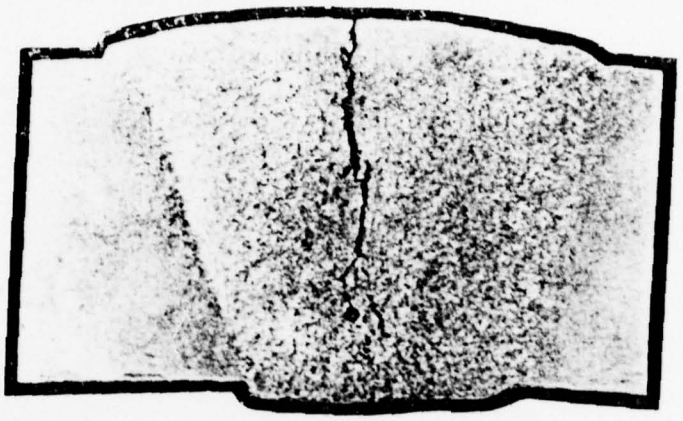


Right

624

Picture No.	Title	Description
625	Crack of electro-slag welding on a plate of furnace steel	Crystal crack in welding seam. Etching agent: Nitric acid water solution, cold etching. Magnifying multiple: 1:1
626	Crack of manual electro-arc welding	High strength welding bar of ship-building steel. In toughness testing, crack happens in the lower part of the welding seam. Etching agent: Nitric acid alchohol solution. Magnifying multiple: 5:1
627	Crack of manual electro-arc welding	Cr-Al steel, welding metal is 18-8 steel and the thickness is 10mm. Crack lines were fussed together. Etching agent: Nitric acid alchohol solution. Magnifying multiple: 5:1



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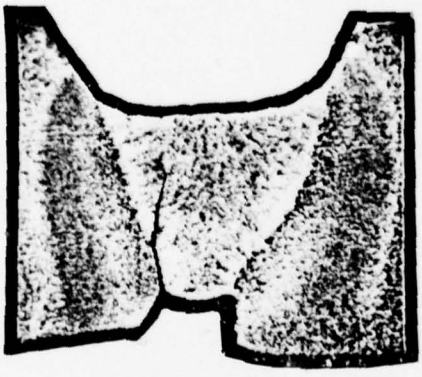

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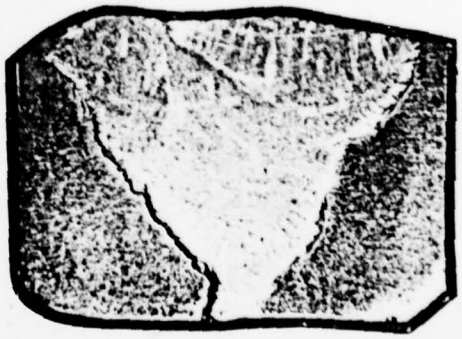
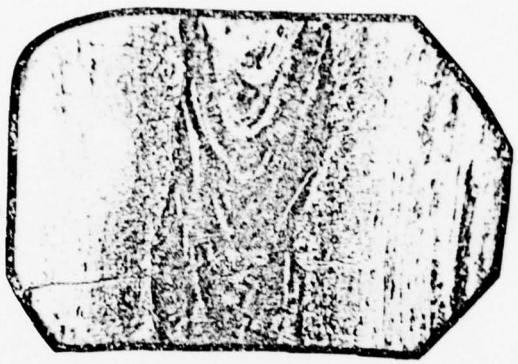


627

Picture No.	Title	Description
628	Crack of manual electro-arc welding	Crack on welding seam of Cr18Ni12Mo2 steel. Etching agent: Nitric acid alchohol solution. Magnufying multiple: 5:1
629	Crack of jar-like arc auto-matic welding on ply-board and sealing end	Longitudinal crack and slag inclusion at the joint.



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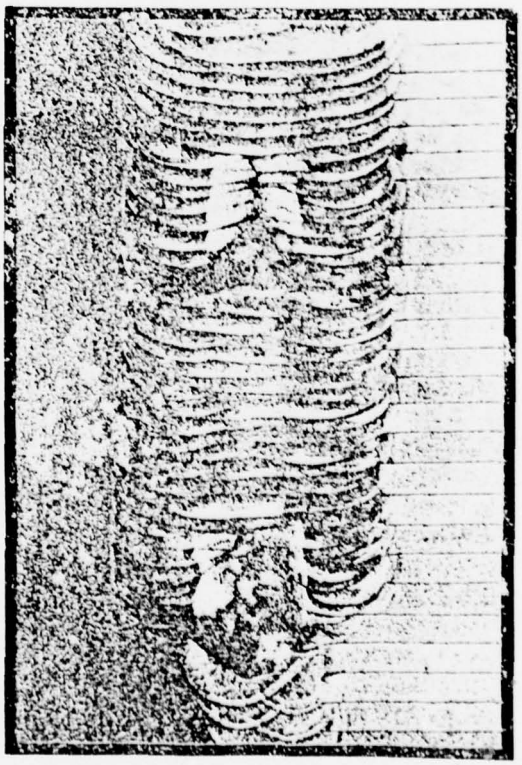
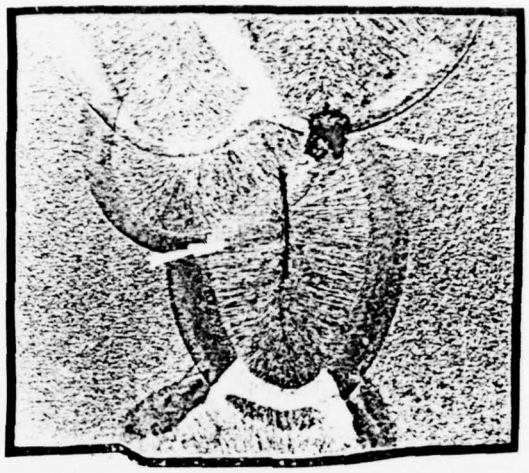


629

Picture No.	Title	Description
630	Crack of automatic welding	Crystal crack and slag inclusion between layers of No. 20 steel.
631	Crack and slag-inclusion of automatic welding	Because of the inadequacy of temperature in perheating and not reducing stress in time.

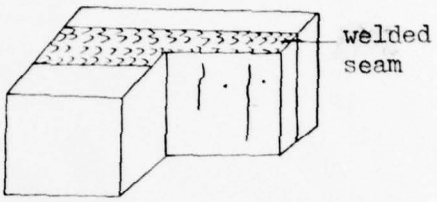


630

631

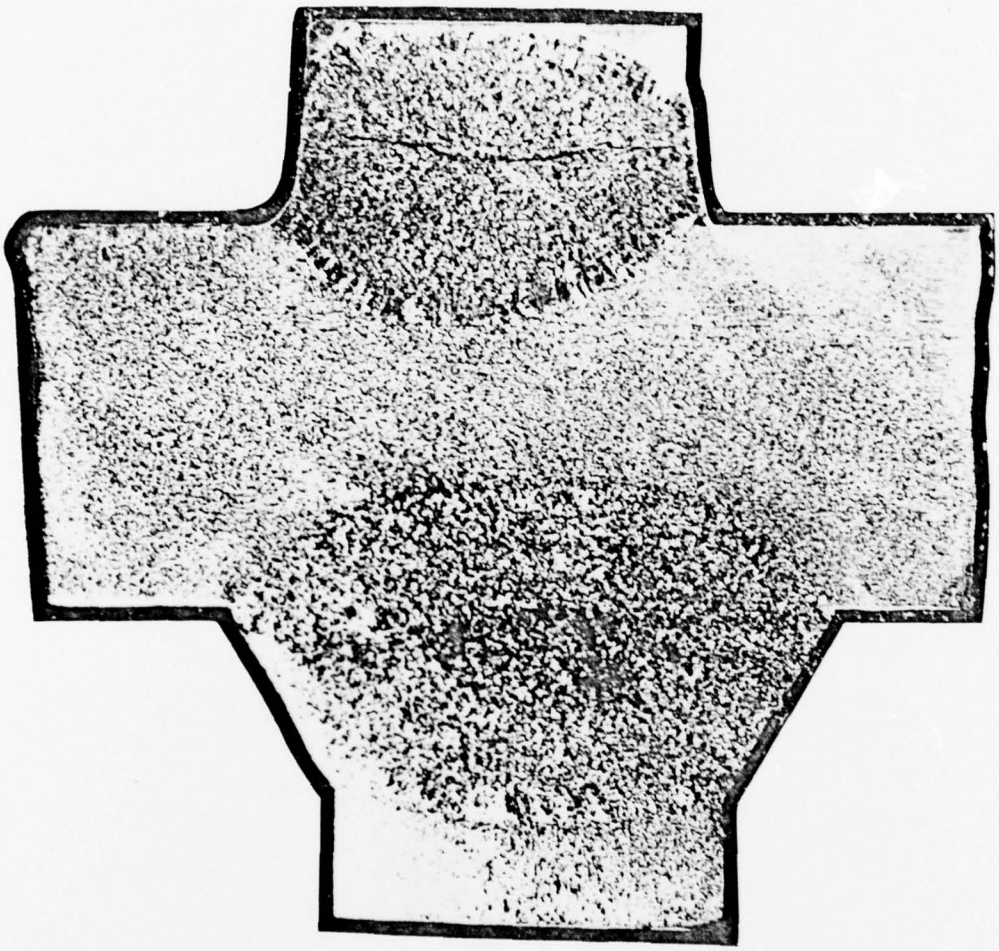
Picture No.	Title	Description
632	Crack of manual electro -arc welding	Welding of No.20 furnace steel and Cr16Ni36 stainless steel. Crack at foot part of welding seam. Etching agent: Hydrochloric acid 50ml, nitric acid 5ml, potassium bichromate 2.5g, water 50ml, mix tigether and heating to 50°C, hot etching.
633	Crack of automatic welding on thick plate	115mm thick plate of 18MnMoNb steel, welding wire H08Mn2MoA, welding agent 250. Heating to 640°C after welding and temperature retention for 5 hours, then air cooling.

632



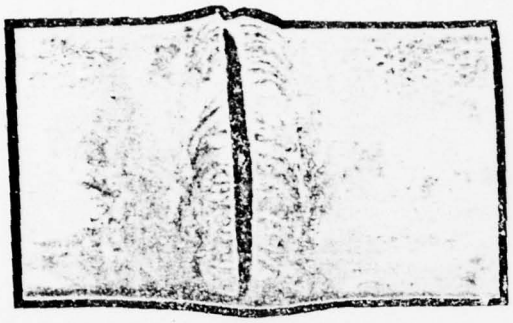
633

Picture No.	Title	Description
634	Crack at cross joint of electro-slag welding	Crystal crack in welding metal.

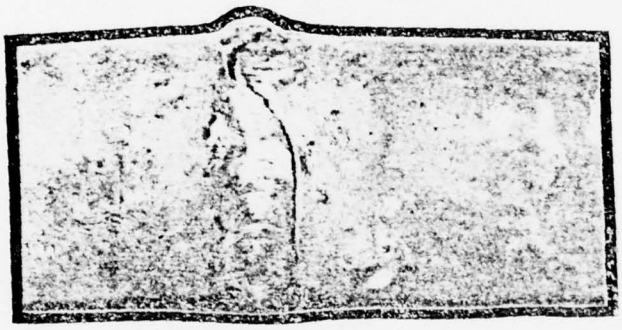


634

Picture No.	Title	Description
635	Straightening crack of steel pipe by manual electro-arc welding	Crack of brittle break. The reason of its happening: Giving a slight straightening to the welding seam of manufactured pipe (both the picture above and picture below are examples).
636	Crack of manual electro -arc welding	09CuWSn low temperature steel. Macrocrack of ring seams on the outside of an explosion testing piece.



Above



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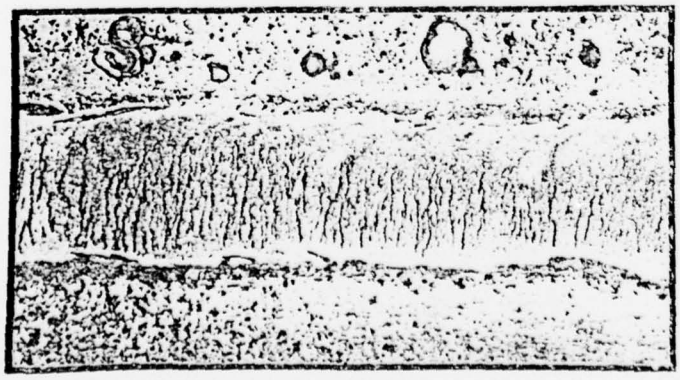
635

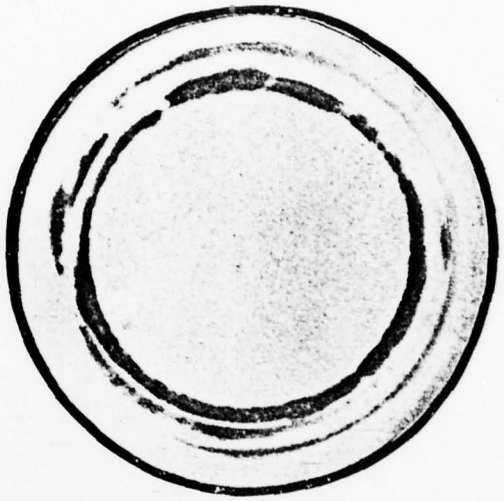


636

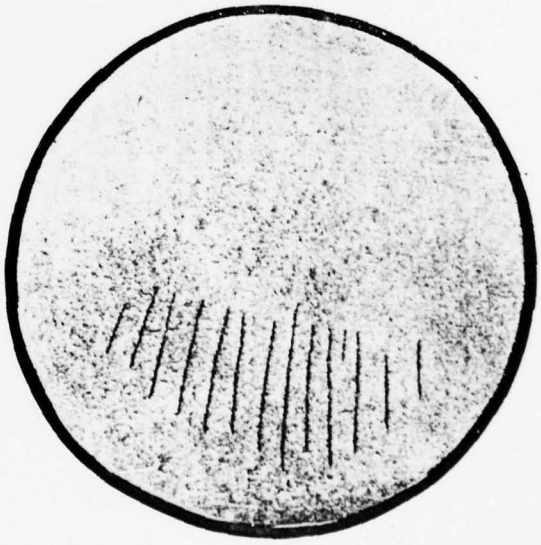
7. Miscellaneous

Picture No.	Title	Description
701	Cutting defects	Cracks and structural changes made at the time when á round billet of 60Si2 spring steel is cut with a sand-wheel-blade and partially overheated.
702	Cutting defects	Black circles made at the time when a round billet of GCr15 bearing steel is cut with a sand-wheel-blade and partially overheated. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.3
703	Cutting defects	Cracks made at the time when a round billet of GCr15 bearing steel is cut with a sand-wheel-blade and the cooling is not appropriate. Etching agent: 1:1 hydrochloric acid water solution at 60-70°C. Multiple: 1:1.4

701



702



703

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