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Mod.9Cr−1Mo鋼、2¼Cr−1Mo鋼およびSUS321の超高温引張特性（Ⅰ）

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Mod.9Cr-1Mo鋼，2¼Cr-1Mo鋼およびSUS321の超高温引張特性（I）

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要　旨

ＦＢＲ蒸気発生器用材料として適用されるMod.9Cr-1Mo鋼，2¼Cr-1Mo鋼およびSUS321に関して，ナトリウム－水反応等を想定した高温バースト特性の解析評価の基礎データとして反映するため，最高1,200℃までの超高温領域における引張試験を実施した．主要な結果は次の通りである．

（１）2¼Cr-1Mo鋼，SUS321およびMod.9Cr-1Mo鋼伝熱管材の1200℃における引張強さは，各々約2.5，2，および2.5kg/mm^2 であった．

（２）引張強度におよぼす試験片の加熱昇温速度（5～50℃/min）および加熱保持時間（10～30min）の影響は，各鋼種とも本試験の範囲内では顕著に認められなかった．

（３）伝熱管内の蒸気圧力を150kg/cm^2 と想定した場合，Mod.9Cr-1Mo鋼，2¼Cr-1Mo鋼およびSUS321の破断の想定温度は，本試験の範囲内では各々約960℃，860℃および1040℃程度と考えられた．

本試験の結果は，今後の蒸気発生器伝熱管のナトリウム－水反応を考慮した高温ラプチャー評価のための基礎的データとして反映される．

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Ultra-high Temperature Tensile Properties on Mod.9Cr-1Mo,2¼Cr-1Mo and SUS321 Steel(Ⅰ)

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Abstract

This study clarified the tensie properties of Mod.9Cr-1Mo,2¼Cr-1Mo and SUS321 steels at ultra-high temperature up to 1,200℃ which will be used in analysys and evaluation of the tube burst in steam generators of fast breeder reactors.

(1) Tensile strength of Mod.9Cr-1Mo,2¼Cr-1Mo and SUS321 steels at 1,200℃ were 2.5, 2,and 2.5kg/mm^2 ,respectively.

(2) The difference for tensile strength and 0.2% yeild strength btween specimen heat rate and heat holding time could not be found in the present.

(3) The temperatures of the tube burst at the maximum internal pressure of 150kg/cm^2 corresponding to the practical use condition were expected to be approximately 960 ℃ for Mod.9Cr-1Mo, 860℃ for 2¼Cr-1Mo and 1040℃ for SUS321,respectively.

These tests result will be reflected to evaluation of tube burst by sodium water reaction.

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1. はじめに

原子力発電プラントでは，蒸気発生器での水リークはプラントの稼働率の低下に大きく影響する．ＦＢＲでは冷却材にナトリウムを使用することから，蒸気発生器伝熱管からの水リークが熱と圧力の発生を伴うナトリウムー水反応につながるため，軽水炉などとは異なる設計上の配慮が必要となる．ＦＢＲ蒸気発生器での水リークは，1987年の英国ＰＦＲの過熱器で発生しており大リーク･ナトリウム-水反応によって伝熱管が両端ギロチン破断の損傷を起こした例がある[1][2]．ＰＦＲでの伝熱管の主な損傷原因は，高温ラプチャー（ナトリウム-水反応時の発生熱により伝熱管の機械的強度が低下して，蒸気側の内圧により伝熱管が破損してしまう現象）であるとことが報告されている[3]．蒸気発生器の伝熱管の損傷伝播メカニズムとしては，一般にウエステージ型と高温ラプチャー型が考えられる[4]が，損傷時のこれらのメカニズムは種々の条件により左右されることとなる．

高温ラプチャーに関しては，大規模ナトリウム-水反応を考慮した解析が行われており[4]，伝熱管の温度が約1200℃以上と高温[4]となることが予想されている．このため，1000℃を超えるような伝熱管の短時間強度データが望まれている．しかし，国内外においても1000℃以上の強度データは非常に少ない．また，これらの温度領域では，引張特性に対するひずみ速度，加熱速度，均熱保持時間等が影響を与え[5]，試験データの信頼性を低下させることが懸念される．

このような背景を踏まえ，本報告ではＦＢＲ蒸気発生器材料であり，実証炉の候補材となっているMod.9Cr-1Mo鋼，「もんじゅ」に使用された2¼Cr-1Mo鋼およびSUS321について，機器システム室が実施するナトリウム-水反応解析に基づく高温ラプチャー評価の基礎データとして，最高1,200℃までの引張試験を実施し，超高温領域での短時間強度特性を評価した．

2. 試験方法

2.1 供試材

供試材は、ＦＢＲ蒸気発生器伝熱管材料として適用あるいは適用が予定されているMod.9Cr-1Mo鋼、2¼Cr-1Mo鋼およびSUS321の3鋼種である．試験には、伝熱管そのままでは試験片形状などの試験上の制約から試験片に一様な応力がかからず，試験評価が充分に行えないために、これらの材料の伝熱管そのものと同一仕様で製作された伝熱管相当板材（25～30mm^t）を用いた．これらの供試材の化学成分、熱処理条件およびミルシートの強度特性値をTable 1～3に示す．

2.2 試料採取要領および試験片形状寸法

Fig.1に、各供試材からの試験片の採取要領を示す．試験片の採取は、試験片の平行部が主圧延方向(L)と平行となるように採取した．Fig.2に試験片の形状寸法を示す．平行部直径が10mmの中実丸棒試験片であり、標点間距離（G.L）は50mmとした．

2.3 引張試験方法

引張試験は、JIS-Z-2241「金属材料引張試験方法」、JIS-G-0567「鉄鋼材料および耐熱合金の高温引張試験方法」ならびに「ＦＢＲ金属材料試験実施要領書」[6]に準拠し，ナトリウム－水反応条件を考慮した試験条件とした．ひずみ速度は、10%/min（標点間ひずみ制御）とし、試験温度は800から1200℃までとした．試験中の試験片の温度制御精度は±３℃以内で実施した．また試験では，試験温度が超高温であることから，引張試験特性が試験前の熱影響を受けることが懸念されるため，試験片の加熱昇温速度および試験温度到達後の均熱保持時間をパラメータとして、これらの影響を試験温度1100℃で調査した．試験片の加熱昇温時間は5℃／minおよび50℃/min，均熱保持時間では，試験機の試験前調整時間を考慮し、最小10分および最大30分とした．試験条件一覧をTable3に示す．なお，加熱昇温時間についてはナトリウム－水反応時で，伝熱管が瞬時に超高温となることが予想されるが，現有試験装置の性能上の制約から試験片に加わる試験開始前の熱的要因によるダメージは，時間パラメータから外挿することとした．また，引張速度についてはナトリウム－水反応時で高温となった時の瞬間的な高速引張領域での強度評価が必要であるが，ＪＩＳ法も勘案し，ＪＩＳ法の最大引張速度値（10%／min）で試験を実施した．試験には，超高温域での引張試験用として二ケイ化モリブデンの発熱体を使用した超高温加熱炉（最高1,600℃）と超高温耐熱材料で製作された試験片つかみ部，ひずみ測定用ロット，および試験片引張用プルロット等を使用した．荷重測定用ロードセル部近傍には，加熱炉の輻射および伝熱による熱影響を防止するための熱遮蔽板および冷却ジャケットを設置した．試

験に使用した引張試験機の詳細仕様をTable4に、試験機外観図を Fig.3に示す.

3. 試験結果および検討

3．引張特性

Mod.9Cr-1Mo鋼，2¼Cr-1Mo鋼およびSUS321の超高温引張試験結果をTable6～9ならびにFig.4～18に示す．また，試験後の外観写真をPhoto.1～12に示す．

3．1 引張強度特性

(1)Mod.9Cr-1Mo鋼

Mod.9Cr-1Mo鋼の800℃での引張強さは，約10kg/mm²の強度を有しているが，試験温度の上昇にともない徐々に低下し，1200℃では2.2kg/mm²程度となった．強度低下の傾向は，800～1200℃まではほぼ直線的に低下する傾向を示した．

0.2%耐力は，800℃で約7kg/mm² 程度，1200℃では1.6kg/mm²前後の値となった．0.2%耐力の温度依存性は，引張強さの傾向と類似している．また．温度上昇にともなって0.2%耐力と引張強さが比較的近い値となった．これは，真応力ー真ひずみ曲線で塑性変形抵抗（加工硬化）が温度上昇にともなって低下していることを示すものである．ただし，降伏比（0.2%耐力と引張強さの比）で評価すると温度依存性はあまり見られていない．

(2)2¼Cr-1Mo鋼

2¼Cr-1Mo鋼の800℃での引張強さは，7kg/mm² 程度で，1200℃では，2kg/mm² 前後の値であった．温度上昇にともなって徐々に引張強さおよび0.2%耐力は低下する．800℃から850℃の間でオーステナイト変態によると思われる降伏比と一様伸びの顕著な変化が見られる．Mod.9Cr-1Mo鋼でも起きているはずであるが，これよりも顕著である．

(3)SUS321

SUS321の引張強さは，800℃で約19kg/mm² ，1200℃では2.5kg/mm² 程度の値であった．試験温度の上昇に伴って引張強さは急激に低下し，低下の傾向は，Mod.9Cr-1Mo鋼，2¼Cr-1Mo鋼と同様であった．また，SUS321では，Mod.9Cr-1Mo鋼および2¼Cr-1Mo鋼より，温度依存性が大きく表れた．

0.2%耐力は引張強さと同様の傾向を示し，温度依存性が大きく認められた．この傾向は，真応力ー真ひずみ曲線でも，Mod.9Cr-1Mo鋼および2¼Cr-1Mo鋼と異なり，大きく温度依存性が認められた．

3．2 引張破断延性

(1)Mod.9Cr-1Mo鋼

800℃での破断伸びは，約55%であり，900℃以上では70～100%と高い破断伸びを示した．外観写真から判るように，900℃での破断の形態は，他の試験温度とは異なり破断伸びが平行部全体で比較的均一に延びており，900℃で特異的な挙動となった．破断絞りでは，各温度とも約100%の最大値を示しており，試験温度の影響を評価することはできなかった．破

断部の先端は大きく絞れ，破断時の断面積は非常に小さいものとなっていた．

一様伸びは試験温度の上昇に伴って徐々に増加し，1200℃では約15%の値を示した．

(2)2¼Cr-1Mo鋼

破断伸びは，試験温度の上昇にともなって800℃以上で赤熱脆性と考えられる破断　びの低下する温度依存性が認められ，1200℃で約65%程度となった．破断絞りでは，800℃から1000℃までは温度上昇にともなって破断絞りが減少する．これは2¼Cr-1Mo鋼が高温脆性[5]によって延性が低下したものと考えられ，1100℃以上ではほぼ100%となった．

試験片表面は，酸化による表面の剝離現象が観察された．このような，剝離現象はMod.9Cr-1Mo鋼よりより顕著に認められた．

一様伸びは，800℃で約2～3%前後の値を示し，900℃以上では13～22%と高い値を示した．高温脆化により延性が低下したためと推察された．

(3)SUS321

破断伸びおよび破断絞りとも温度依存性が認められ，試験温度の上昇に伴って破断伸びおよび破断絞りが上昇する傾向を示した．破断伸びは，800℃から徐々に温度上昇にともない約1100℃まで上昇した．また，破断絞りは，800℃から900℃までは温度上昇にともなって上昇するが，900℃以上ではほぼ100%の最大値を示した．SUS321では，Mod.9Cr-1Mo鋼および2¼Cr-1Mo鋼で観察された試験片表面の剝離現象はほとんど認められない．

試験温度における一様伸びの傾向的な温度依存性は，本試験範囲では認められず，900℃および1000℃を除くと約8から15%程度の値となった．ここで900℃および1000℃のデータが極端に小さい値を示したことについて，真応力ー真ひずみ曲線において900℃および1000℃のデータでは1～2%の低ひずみ側で最大強度を示していることから比例限以上の応力が極端に低下していることも考えられる．本試験では試験データ点が少ないため，これを明かにすることはできなかった．また，低温側のSUS321では，Fig.18に示すように，Mod.9Cr-1Mo鋼および2¼Cr-1Mo鋼とは異なり，比例限以上のひずみにおいて応力の低下傾向が小さいことが観察された．しかし，ひずみが50%以上では応力がMod.9Cr-1Mo鋼および2¼Cr-1Mo鋼と異なり著しい応力低下が観察された．

応力ーひずみ線図において超高温側で応力変動が観察されたのは，試験片が超高温状態でクリープ現象によって本試験条件である10%min以上のひずみ速度より速いクリープひずみ速度が発生し，応力緩和が起きて荷重値が変動したものと推定される．

3．3　引張特性に及ぼす諸因子の検討

蒸気発生器の伝熱管破損における実機での高温ラプチャーを考慮した強度特性評価について検討する．試験は，伝熱管温度がナトリウム-水反応によって1～2秒とほぼ瞬時に1100～1200℃になった場合の損傷モードをできるだけ再現しなければならない．しかし，現実

的には，試験機の性能および技術上の問題からこれらと同等の条件を模擬することはできない．このため試験特性に影響を及ぼすと考えられる試験片昇温速度，試験温度到達後の均熱保持時間をパラメータとした引張試験を行い，これらの影響を検討した．試験温度までの昇温時間を5および50℃/min，試験温度到達後の保持時間は10および30分である． 試験片の均熱保持時間の影響は，引張強さが試験片の均熱保持時間10分の場合3.5kg/mm^2 程度であり，保持時間が30分の場合でも約3.6～4.1kg/mm^2 となり，試験片の均熱保持時間によらず本試験範囲では同様の強度と考えられた．これは，0.2%耐力においても同様であった．試験前の試験片の均熱保持時間の影響に関しては，高温時における保持時間が長くなるにつれて均熱的影響により軟化し，引張強度が低下することが考えられたが，本試験では，均熱保持時間の影響はほとんど認められなかった．また，引張強さおよび0.2%耐力におよぼす試験片の加熱昇温速度の影響も，本試験の範囲内ではほとんど認められなかった．加熱昇温速度および均熱時間による引張強さ0.2%耐力への影響は，2$\frac{1}{4}$Cr-1Mo鋼，SUS321についても上記と同様に認められなかった．

破断伸びは，均熱保持時間が長くなるほど，昇温時間が速くなるほど大きくなる傾向を示した．しかし，その程度は，小さく，かつデータの大きいことから有意な差とは言難い．

破断伸びにおよぼす試験片の均熱保持時間の比較では，試験片保持時間が長い方が破断伸びが僅かに大きい値を示した．これは， Table2に示すように2$\frac{1}{4}$Cr-1Mo鋼の熱処理温度よりかなり高い温度領域での試験のため，試験片の均熱保持時間中に延性に対して影響をおよぼし，延性が増加したものと推察された．すなわち，試験片を当該試験温度に長時間曝すことによって，破断延性に大きく影響するものと考えられた．また，破断絞りでは，Mod.9Cr-1Mo鋼と同様に破断時の原断面積は非常に小さくなっていることから，試験片の均熱保持時間および試験片の加熱昇温速度の影響を評価することはできなかった．

SUS321では，破断伸び，破断絞りおよぼす試験片の均熱保持時間および試験片の加熱昇温時間の影響はほとんど認められなかった．

試験片の均熱保持時間および試験片の加熱昇温速度をパラメータとし，これらの一次回帰から伝熱管損傷時の高温バースト条件も模擬することを試みたが，試験データのばらつきレベルであり，はっきりした傾向は認められない．

4. 考察

実機伝熱管の高温破断強度について考察する．

実機高温バースト条件では，内圧が負荷された状態で瞬時に高温領域に達すると考えた場合，伝熱管そのものには温度条件によって短時間で高い応力（引張強さ以上の応力）が負荷されている場合と考えることができる．Fig.31には，一例としてSUS321の実機運転条件における内圧負荷状態での破損領域を示す．図中には土田ら[5]が行った類似した比較的高温のデータも合わせて示した．ここで，伝熱管内部において常時負荷されている圧力より，相当応力σ_{eq} は薄肉円筒を前提として次式で換算される．

軸応力σ_y は

$$\sigma_y=\frac{PD}{200t} \quad (kg/mm^2) \tag{1}$$

フープ応力σ_z は

$$\sigma_z=\frac{\sigma_y}{2} \quad (kg/mm^2) \tag{2}$$

相当応力σ_{eq} は

$$\sigma_{eq}=\frac{1}{\sqrt{2}}\left\{(\sigma_x-\sigma_y)^2+(\sigma_y-\sigma_z)^2+(\sigma_z-\sigma_x)^2+6(\tau_{xy}^2+\tau_{yz}^2+\tau_{zy}^2)\right\}^{\frac{1}{2}} \tag{3}$$

で求められる．

ここで

P　：伝熱管内圧　（kg/cm^2）

t　：伝熱管肉厚　（mm）

D　：伝熱管外形　（mm）

である．

伝熱管内圧をＦＢＲ蒸気発生器伝熱管と想定し[7]，圧力の変動を考慮し150kg/cm^2 とすると，相当応力は約5.9kg/mm^2 となる．過熱器の高温ラプチャーは図から判るように約1000℃以上になった場合，内圧からの応力により破断することと考えられる．これらの評価を同様にMod.9Cr-1Mo鋼および2$\frac{1}{4}$Cr-1Mo鋼を考えた場合，Fig.32およびFig.33に示す破断領域を推定することが可能となる．すなわち本試験範囲では，SUS321で約1040℃，Mod.9Cr-1Mo鋼で約960℃，2$\frac{1}{4}$Cr-1Mo鋼では約860℃で高温ラプチャーを起こすこととが判る．しかしながら，ナトリウム－水反応を模擬した詳細な評価を行うためには，今後引張試験時における引張速度，加熱昇温速度を更に実機条件に近づけた，瞬時高温化，高速引張による試験が必要と考えられる．引張強度特性におよぼす引張試験速度の影響は，土田[5]およ

びHollomon[8]等が指摘しており，また加納ら[9]は，燃料被覆管の引張試験でひずみ速度をパラメータとした試験を実施している．これらの結果によれば，引張強さおよび0.2%耐力は，引張速度が遅くなるほど低くなる傾向を報告しており，今後，引張試験速度を考慮した詳細評価を試験点数の拡充を図り実施すべきである．

5. まとめ

ＦＢＲ蒸気発生器の伝熱管材料としてその適用，または適用が検討されているMod.9Cr-1Mo鋼，2¼Cr-1Mo鋼およびSUS321伝熱管について，ナトリウム-水反応を考慮した超高温時の伝熱管高温バーストを評価する上で超高温時の引張特性評価が必要となる．本報告では，超高温温度領域（800～1200℃）を対象に，超高温引張試験を実施し，引張特性を明らかにした．

得られた主な結果は，次の通りである．

1，Mod.9Cr-1Mo鋼，2¼Cr-1Mo鋼およびSUS321の1200℃までの超高温引張試験データを既設引張試験装置を改造することによって取得可能とし，ナトリウムー水反応の高温バーストを評価するための基礎データを得ることができた．しかし，実機では伝熱管内圧が負荷された状態でナトリウムー水反応が起こり伝熱管が破損すると想定され，今後このような実機を模擬した高速引張特性の評価試験を行う必要があると考えられる．

2，2¼Cr-1Mo鋼，SUS321およびMod.9Cr-1Mo鋼の1200℃における引張強さは，各々約2.5，2，および2.5kg/mm^2 であった．また，0.2%耐力は，各々2，2.5および3kg/mm^2 程度であった．今回は，JISに準じた試験であるが，もっと速度を速くすると強度は上がる可能性はある．

3，引張強度ならびに0.2%耐力は，各鋼種ともの試験片均熱保持時間の10分から30分および加熱昇温速度の5分から50分の本試験範囲では，ほぼ同等の値を示し，均熱保持時間および加熱昇温速度の有意な影響は認められなかった．しかし，もっと短時間（１分以内）で高温になる場合は，試験できていない．この場合もっと強度が高くなる可能性はある．

4，これらの蒸気発生器材料の実機使用条件（圧力150kg/cm^2 として）におけるMod.9Cr-1Mo鋼，2¼Cr-1Mo鋼およびSUS321の高温引張破壊温度は，伝熱管肉厚内温度一定の条件については，本試験範囲で各々約960，860℃及び1040℃となり，温度勾配を伴う条件では，もっと高くなることが期待できる．

6. おわりに

本試験は，機器システム開発室が実施する蒸気発生器伝熱管の高温ラプチャーに関する研究の一貫として，当室が伝熱管の超高温引張特性を評価したものである．プラント安全工学室の田辺裕美室長，浜田広次副主任研究員に謝意を表する．

本試験を実施するにあたって，試験の実施，データ整理において以下の常陽産業㈱職員の協力を得た．

佐藤勝美

鈴木高一

小林裕勝

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Table 1 Chemical Composition,Heat Treatment and Mechanical Properties of Mod.9Cr-1Mo steel.

a) Chemical composition

	C	Si	Mn	P	S	Ni	Cr	Mo	V	Nb	Al	N
product	0.09	0.34	0.46	0.005	0.004	0.09	8.43	0.90	0.20	0.079	0.010	0.062
check	0.08	0.34	0.49	0.005	0.004	0.09	8.34	0.89	0.23	0.069	0.008	0.059

b) Heat treatment

N.T : 1050℃×10min+770℃×60min

C) Mechanical properties

Temp. [℃]	0.2% proof stress [kg/mm^2]	Tensile strength [kg/mm^2]	Elongation [%]	Reduction of area [%]
R.T.	55.1	70.4	27.2	74.6
R.T.	54.5	70.1	27.0	74.6

Table 2 Chemical Composition,Heat Treatment and Mechanical Properties of 2¼Cr-1Mo steel.

a) Chemical composition

	C	Si	Mn	P	S	Cr	Mo
product	0.08	0.25	0.44	0.012	0.004	2.12	1.00

b) Heat treatment

N.T : 930℃×55min+710℃×105min

C) Mechanical properties

Temp. [℃]	0.2% proof stress [kg/mm²]	Tensile strength [kg/mm²]	Elongation [%]	Reduction of area [%]
R.T.	35.0	67.8	35.0	80.0

Table 3 Chemical Composition,Heat Treatment and Mechanical Properties of SUS321 stainless steel.

a) Chemical composition

	C	Si	Mn	P	S	Ni	Cr	Ti
product	0.04	0.48	1.28	0.027	0.003	9.50	17.71	0.45

b) Heat treatment

1050℃ (W.Q.)

C) Mechanical properties

Temp. [℃]	0.2% proof stress [kg/mm^2]	Tensile strength [kg/mm^2]	Elongation [%]	Reduction of area [%]
R.T.	25.0	58.0	60.0	—

Table 4 Program of Tensile Test at High Temperature.

Condition	Parameter	Test Temperature (℃)				
		800	900	1000	1100	1200
Heat Hold Time (Heat Ratio, 50℃/min)	min					
	10				2	
	30				2	
Heat Ratio (Heat Hold Time ,10min)	℃/min					
	5				2	
	50	2	2	2		2

Table 5 Specification of Tensile Test Machine.

Tensile Test Machine	Tensile Test Machine
1. Test Machine	
(1)Type	DSS-25T
(2)Capacity Loading	25000kgf
(3)Cross Head Speed	0.005～500mm/min
2. Heat Apparatus	
(1)Heating Method	Induction Heating
(2)Temperature	800～1600℃
(3)Heater	$MoSi_2$
(4)Maximum Current	5kVA
3. Temperature Controller	
(1)Type	PID and SCR Control
(2)Control Range	0～9999℃
(3)Degree of Precision	±0.5℃
(4)Temperature Detector	Type B
4. Temperature Measuring Method	
(1)Temperature Recorder	6 Point Measuring Type (0～2000)
5. Elongation Measuring Apparatus	
(1)Type	LVDT DT-5 DT-25
(2)Recorder	X_1X_2 TY-P

Table 6 Tensile Test Results of Mod.9Cr-1Mo Steel.

Specimen No. No.	Heat Ratio (℃/min)	Heat Hold Time (min)	Test Temperature T (℃)	Proportional Limit σ_p (kg/mm²)	0.2% Offset Yield Strength $\sigma_{0.2}$ (kg/mm²)	Ultimate Tensile Strength σ_B (kg/mm²)	Uniform Elongation ε_{unif} (%)	Fracture Elongation δ (%)	Reduction of Area ϕ (%)	Apparent Elastic Modulus $E_a \times 10^4$ (kg/mm²)	Fracture Location	True Fracture strength σ^t_f (kg/mm²)	True Uniform Elongation ε^t_{unif} (%)
HCRA01	50	10	800	6.1	8.8	10.4	3.7	55.1	99.4	0.28	A	—	3.7
HCRA02				5.5	8.5	10.5	5.3	56.6	99.3	0.27	A	—	5.2
HCRA03			900	6.0	7.8	9.5	8.6	99.7	98.9	0.40	A	—	8.3
HCRA04				6.0	7.9	9.6	8.9	106.7	98.9	0.40	A	—	8.6
HCRA05			1000	3.9	5.2	6.1	4.3	96.8	98.0	0.32	A	—	4.2
HCRA06				4.3	5.3	6.2	4.4	98.5	98.5	0.25	A	—	4.3
HCRA07			1100	2.6	3.2	3.5	5.9	69.1	99.4	0.17	A	—	5.7
HCRA08				2.5	3.0	3.5	7.2	85.8	99.4	0.19	A	—	7.0
HCRA09		30	1100	2.3	2.9	3.6	12.4	88.5	99.5	0.25	A	—	11.7
HCRA10				2.6	3.2	4.1	14.1	74.9	99.1	0.30	A	—	13.2
HCRA11	5	10	1100	2.4	3.0	3.6	12.7	71.7	99.4	0.26	A	—	12.0
HCRA12				2.3	2.8	3.5	11.0	66.4	99.5	0.21	A	—	10.4
HCRA13	50		1200	1.5	1.6	2.2	16.3	90.6	99.9	0.18	A	—	15.1
HCRA30				1.5	1.6	2.3	16.1	82.1	99.9	0.18	A	—	15.0

Table 7 Tensile Test Results of 2¼Cr-1Mo Steel.

Specimen No. No.	Heat Ratio (℃/min)	Heat Hold Time (min)	Test Temperature T (℃)	Proportional Limit σ_p (kg/mm²)	0.2% Offset Yield Strength $\sigma_{0.2}$ (kg/mm²)	Ultimate Tensile Strength σ_B (kg/mm²)	Uniform Elongation ε_{unif} (%)	Fracture Elongation δ (%)	Reduction of Area ϕ (%)	Apparent Elastic Modulus $E_a \times 10^4$ (kg/mm²)	Fracture Location	True Fracture strength σ^t_f (kg/mm²)	True Uniform Elongation ε^t_{unif} (%)
CRMA01	50	10	800	4.6	6.5	6.9	0.8	105.1	96.0	0.44	A	—	0.8
CRMA02				4.8	6.6	6.8	3.2	98.8	95.9	0.38	A	—	3.2
CRMA03			900	3.5	4.5	7.8	21.8	80.9	80.1	0.31	A	—	19.7
CRMA04				3.2	4.5	7.8	20.9	83.4	79.2	0.32	A	—	19.0
CRMA05			1000	2.2	3.0	4.9	18.2	75.6	79.8	0.69	A	—	16.7
CRMA06				2.3	3.1	5.0	13.1	75.0	76.5	0.32	A	—	12.3
CRMA07			1100	1.2	1.5	3.0	18.7	60.1	99.7	0.50	A	—	17.2
CRMA08				1.3	1.6	3.1	17.8	64.1	99.7	0.18	A	—	16.4
CRMA09		30	1100	1.2	1.6	3.1	17.9	75.6	99.8	0.18	A	—	16.5
CRMA10				1.3	1.6	3.1	18.6	66.3	99.6	0.19	A	—	17.1
CRMA11	5	10	1100	1.2	1.6	3.1	19.6	64.1	99.7	0.19	A	—	17.9
CRMA12				1.3	1.6	3.0	18.1	68.7	99.8	0.14	A	—	16.7
CRMA13	50		1200	0.7	1.0	1.9	17.6	65.7	99.9	0.08	A	—	16.2
CRMA14				0.8	1.0	1.9	16.9	66.2	99.9	0.09	A	—	15.6

Table 8 Tensile Test Results of SUS321 Stainless Steel.

Specimen No. No.	Heat Ratio (℃/min)	Heat Hold Time (min)	Test Temperature T (℃)	Proportional Limit σ_p (kg/mm²)	0.2% Offset Yield Strength $\sigma_{0.2}$ (kg/mm²)	Ultimate Tensile Strength σ_B (kg/mm²)	Uniform Elongation ε_{unif} (%)	Fracture Elongation δ (%)	Reduction of Area ϕ (%)	Apparent Elastic Modulus $E_a \times 10^4$ (kg/mm²)	Fracture Location	True Fracture strength σ^t_f (kg/mm²)	True Uniform Elongation ε^t_{unif} (%)
SUSA01	50	10	800	13.1	15.9	19.1	11.6	58.5	83.2	0.63	A	17.8	11.0
SUSA02				12.6	15.5	19.1	12.3	59.3	83.6	0.76	A	15.7	11.6
SUSA03			900	8.0	10.7	11.3	1.1	79.2	98.1	0.62	A	—	1.1
SUSA04				7.5	10.5	11.1	0.6	83.0	98.2	0.51	A	—	0.6
SUSA05			1000	5.0	7.1	7.4	0.6	87.5	99.6	0.39	A	—	0.6
SUSA06				4.9	6.9	7.3	1.2	86.4	99.5	0.40	A	—	1.1
SUSA07			1100	2.5	3.3	4.0	11.4	108.3	99.9	0.25	A	—	10.8
SUSA08				2.2	3.1	3.9	13.0	100.8	99.9	0.25	A	—	12.2
SUSA09		30	1100	2.7	3.1	3.9	12.4	107.8	99.9	0.25	A	—	11.7
SUSA10				2.4	3.1	3.9	12.3	104.9	100.0	0.25	A	—	11.6
SUSA11	5	10	1100	2.4	3.3	3.9	12.5	107.1	100.0	0.23	A	—	11.7
SUSA12				2.6	3.9	3.9	12.4	110.6	99.9	0.27	A	—	11.7
SUSA13	50		1200	1.4	2.3	2.3	14.9	95.3	99.9	0.15	A	—	13.9
SUSA14				1.4	2.3	2.3	8.6	98.6	99.9	0.15	A	—	8.2

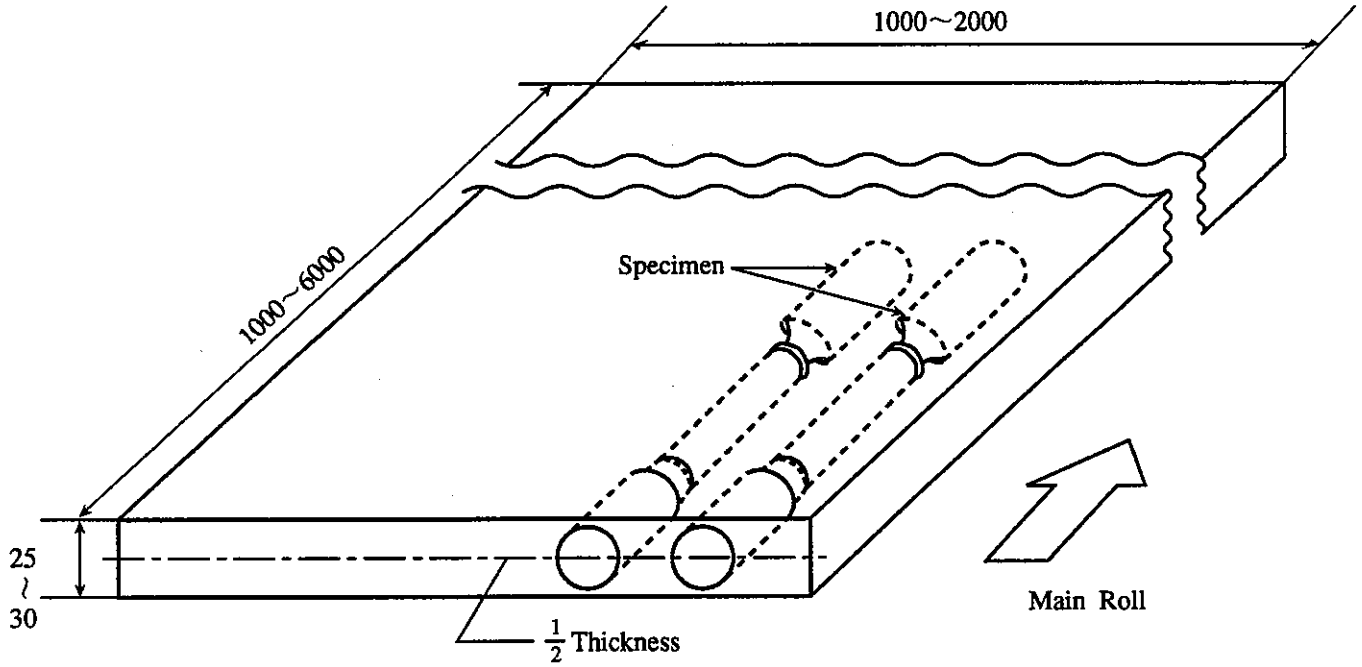


Fig.1 Sampling Method of Tensile Specimens.

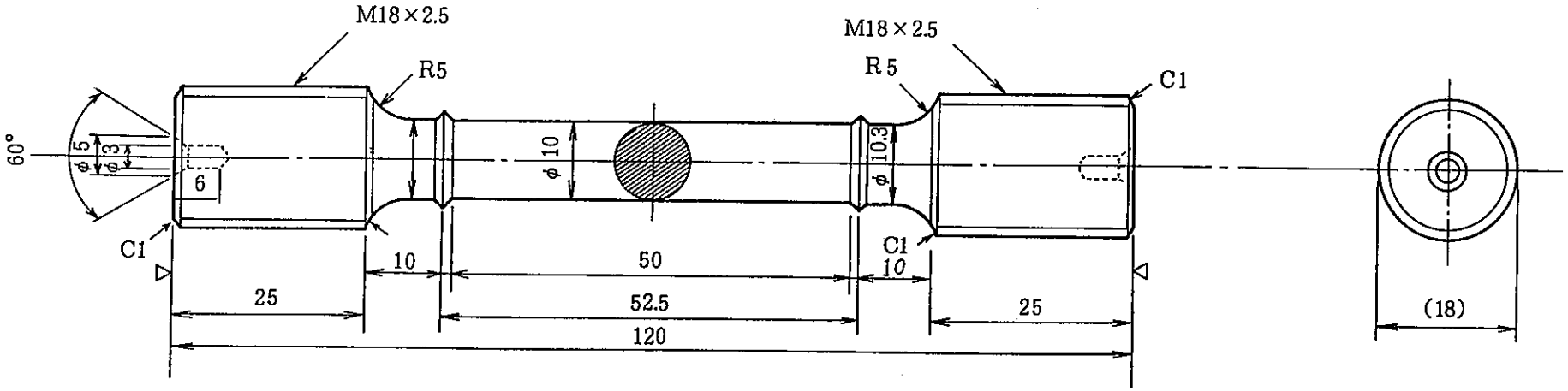


Fig.2 Size and Configuration of the Test Specimens.

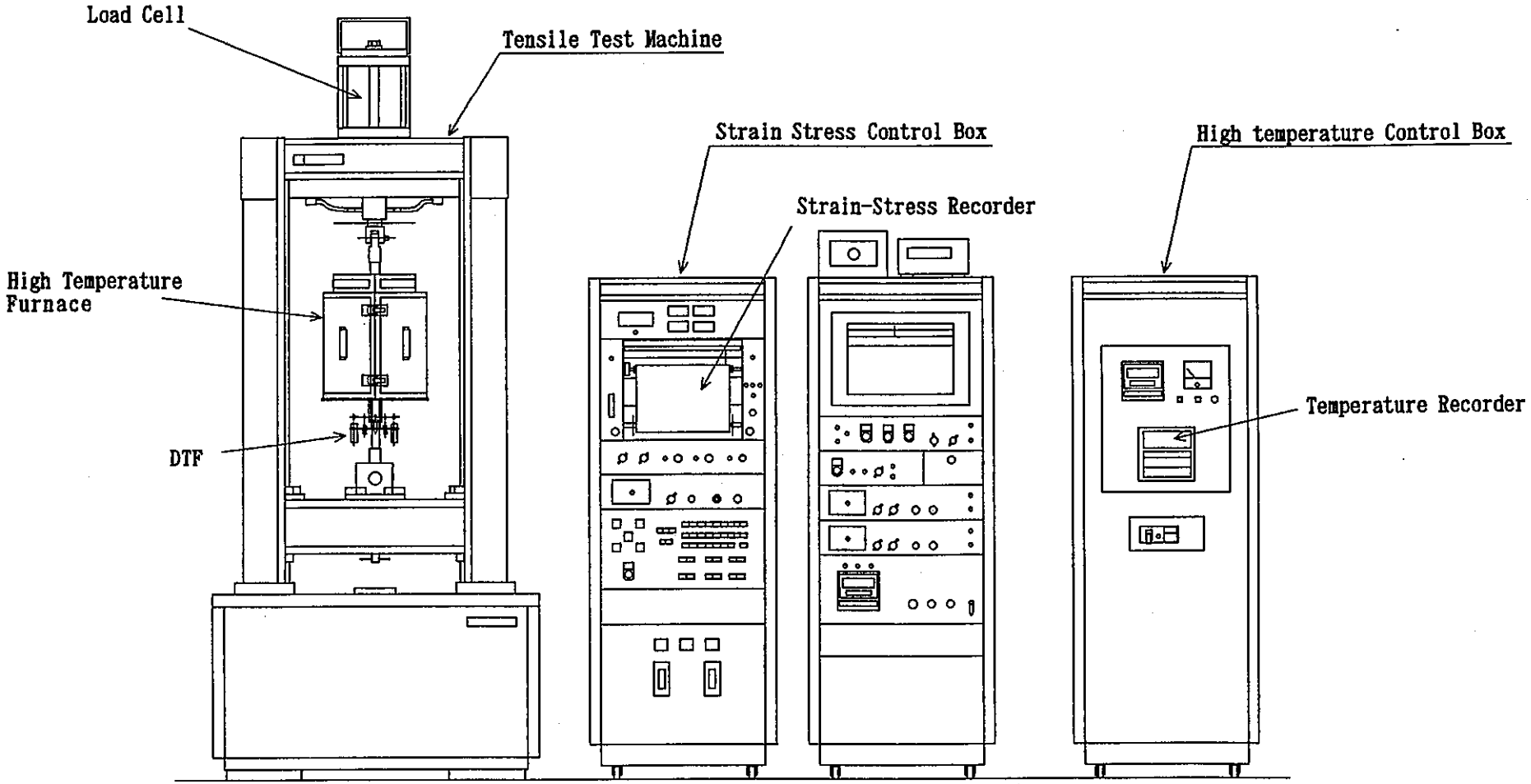


Fig.3 Tensile Test Machine.

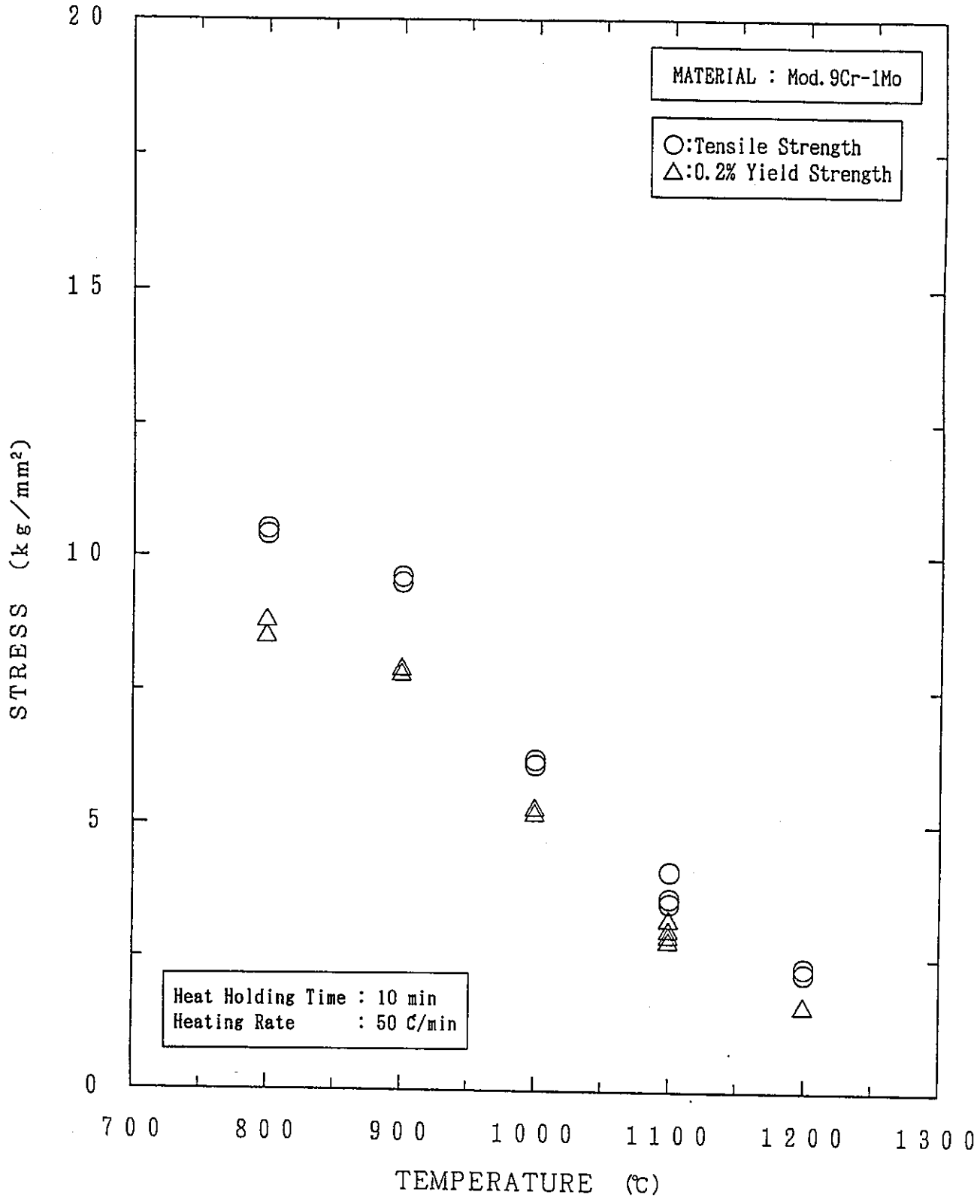


Fig.4 Tensile Strength and 0.2% Yield Strength of Mod.9Cr-1Mo Steel.

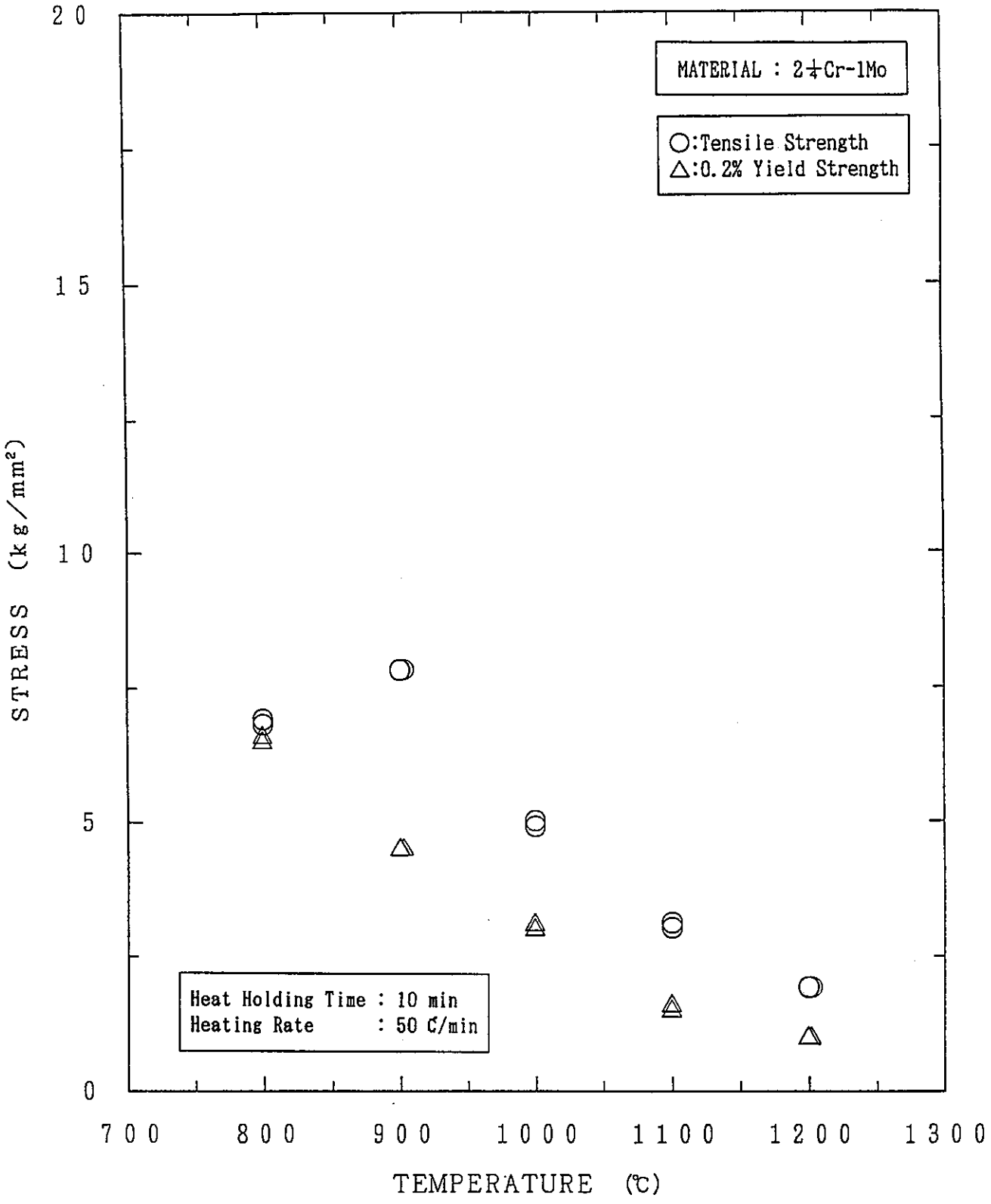


Fig.5 Tensile Strength and 0.2% Yield Strength of 2¼Cr-1Mo Steel.

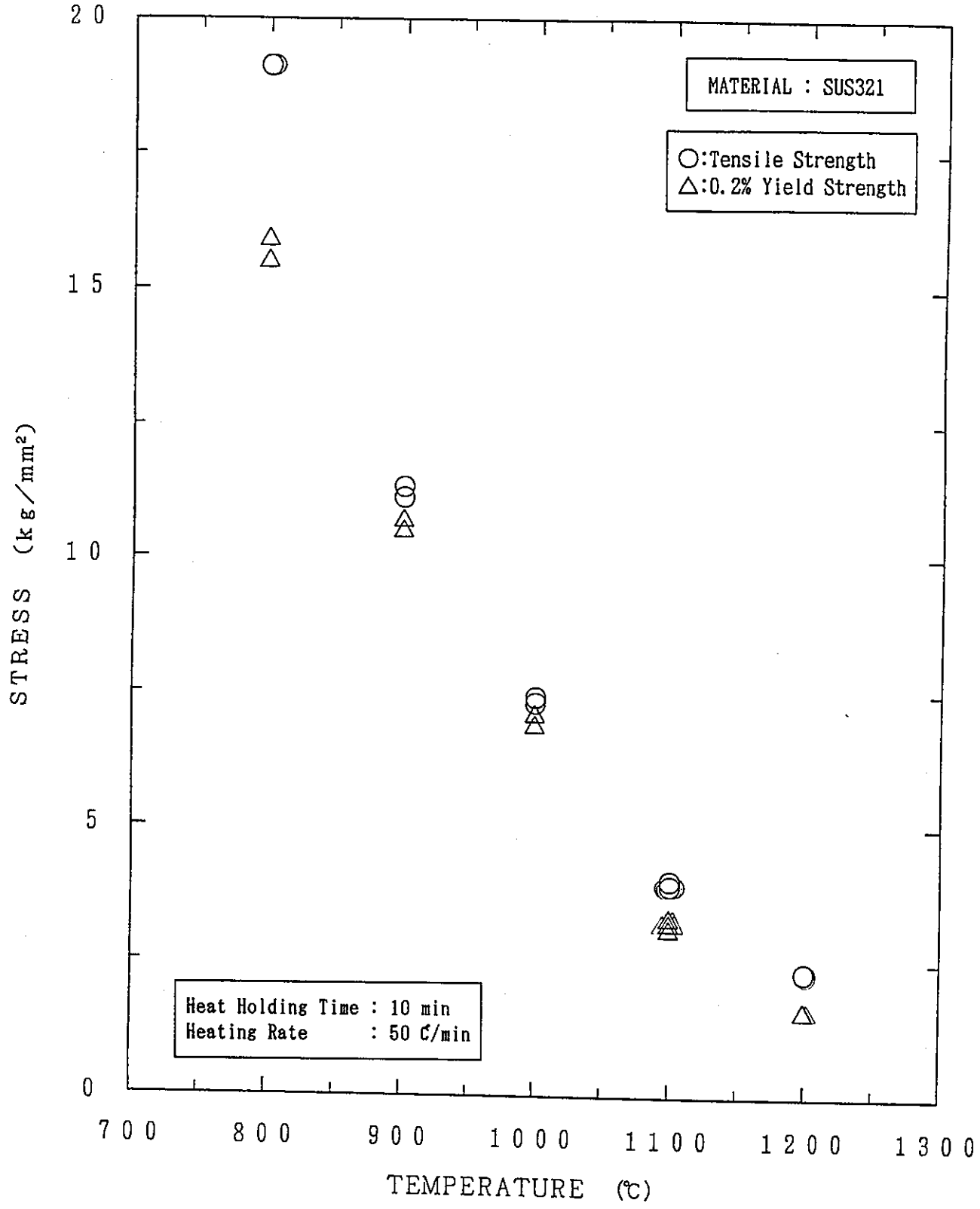


Fig.6 Tensile Strength and 0.2% Yield Strength of SUS321 Stainless Steel.

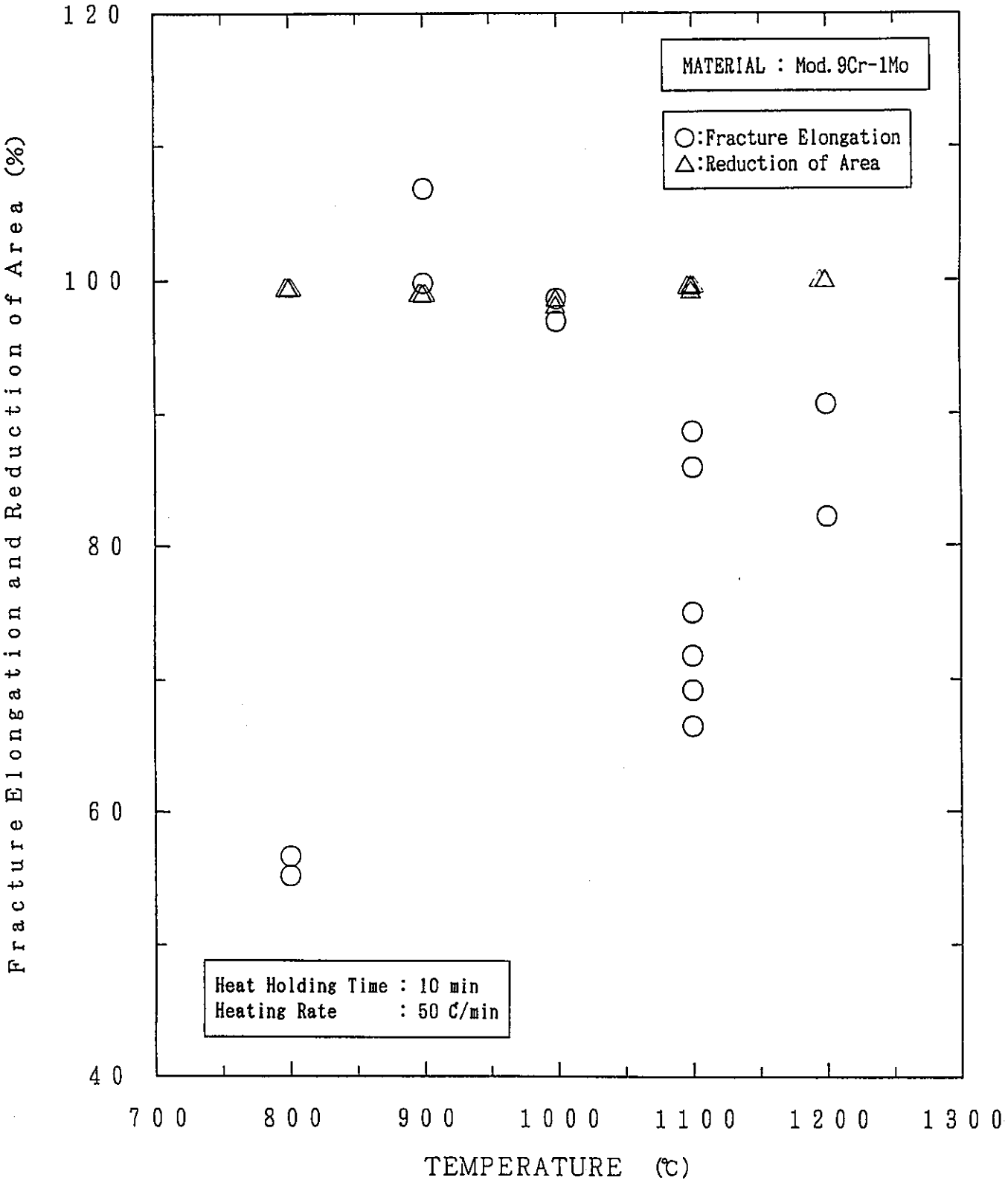


Fig.7 Fracture Elongation and Reduction of Area of Mod.9Cr-1Mo Steel.

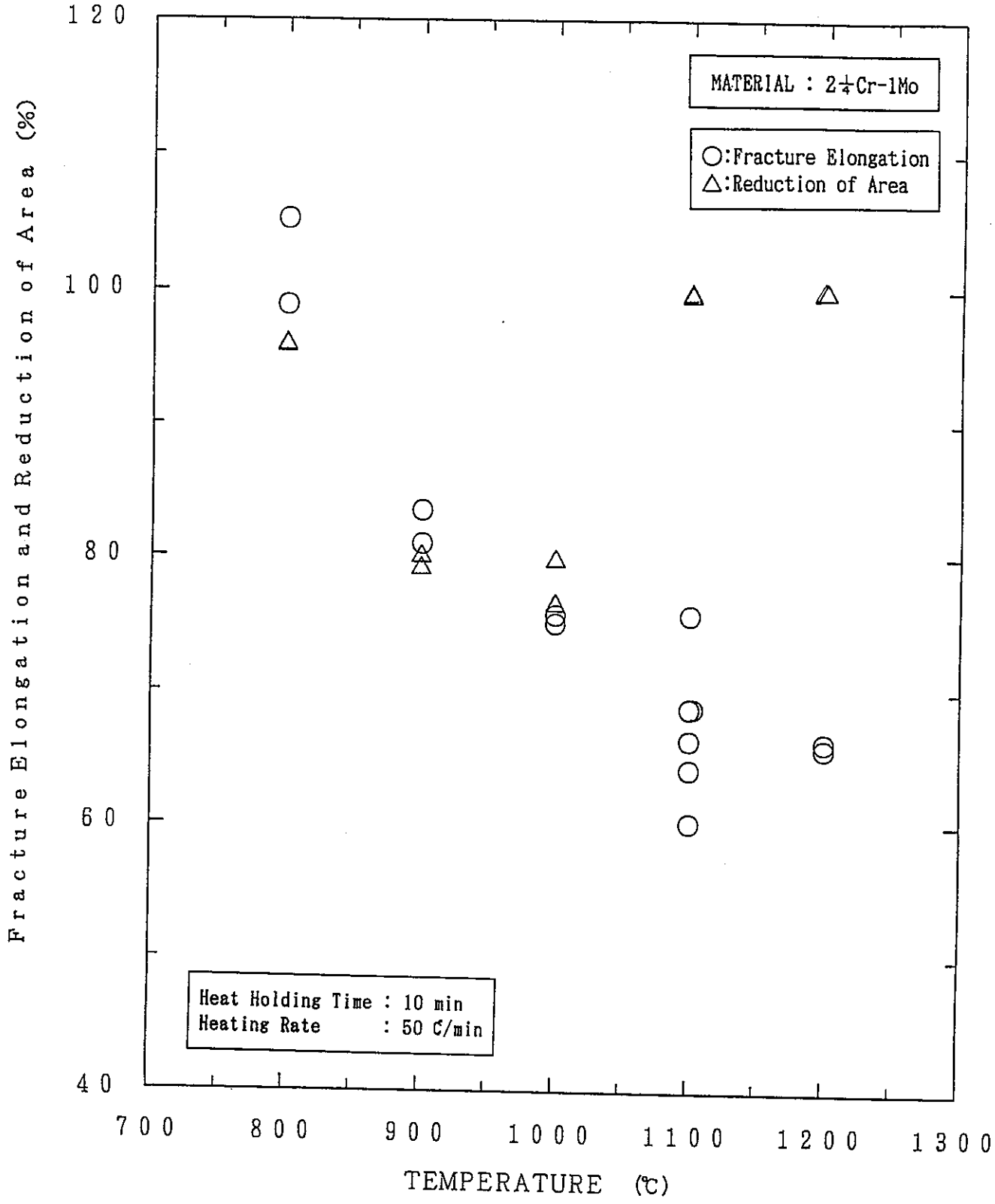


Fig.8 Fracture Elongation and Reduction of Area of 2¼Cr-1Mo Steel.

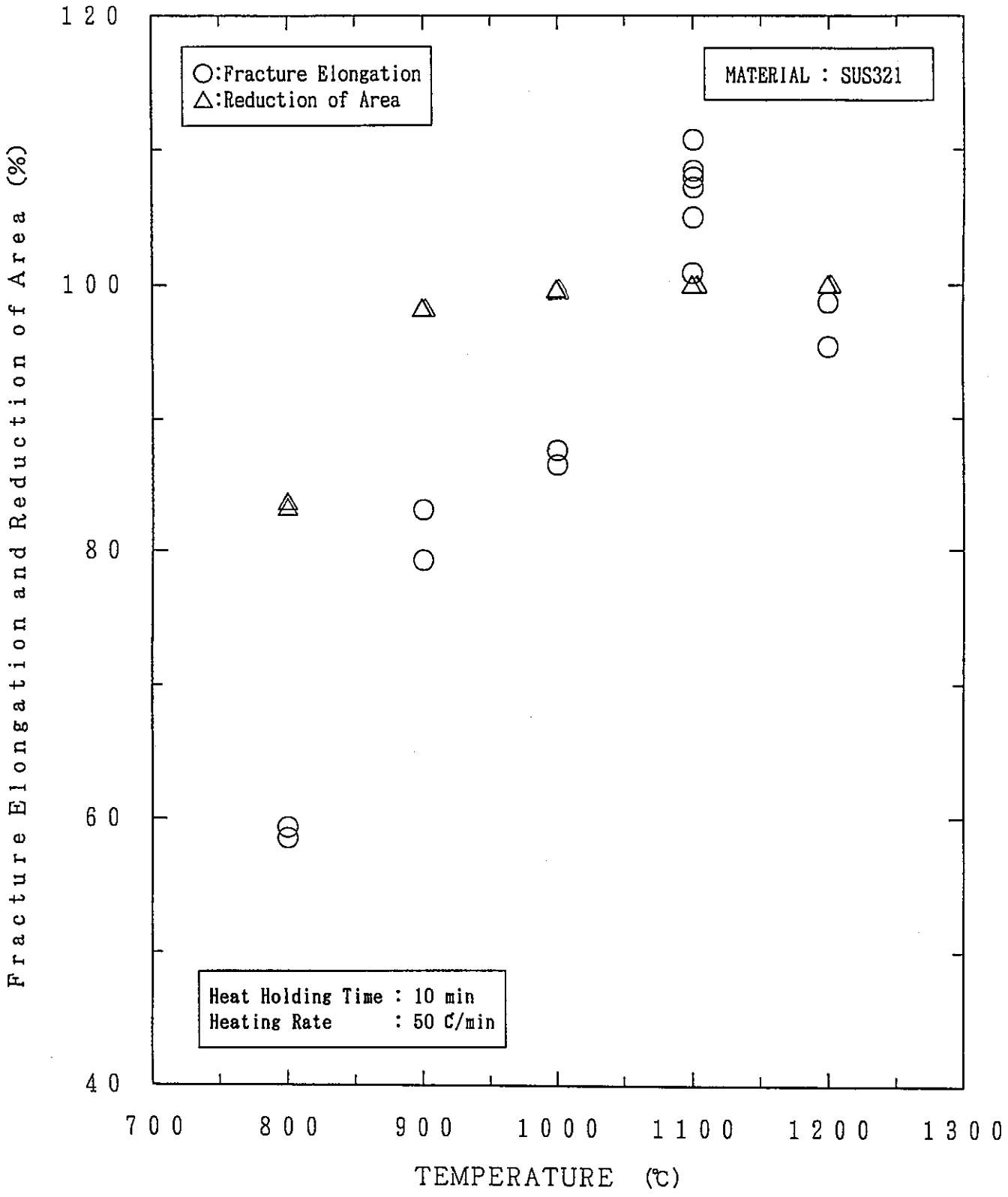


Fig.9 Fracture Elongation and Reduction of Area of SUS321 Stainless Steel.

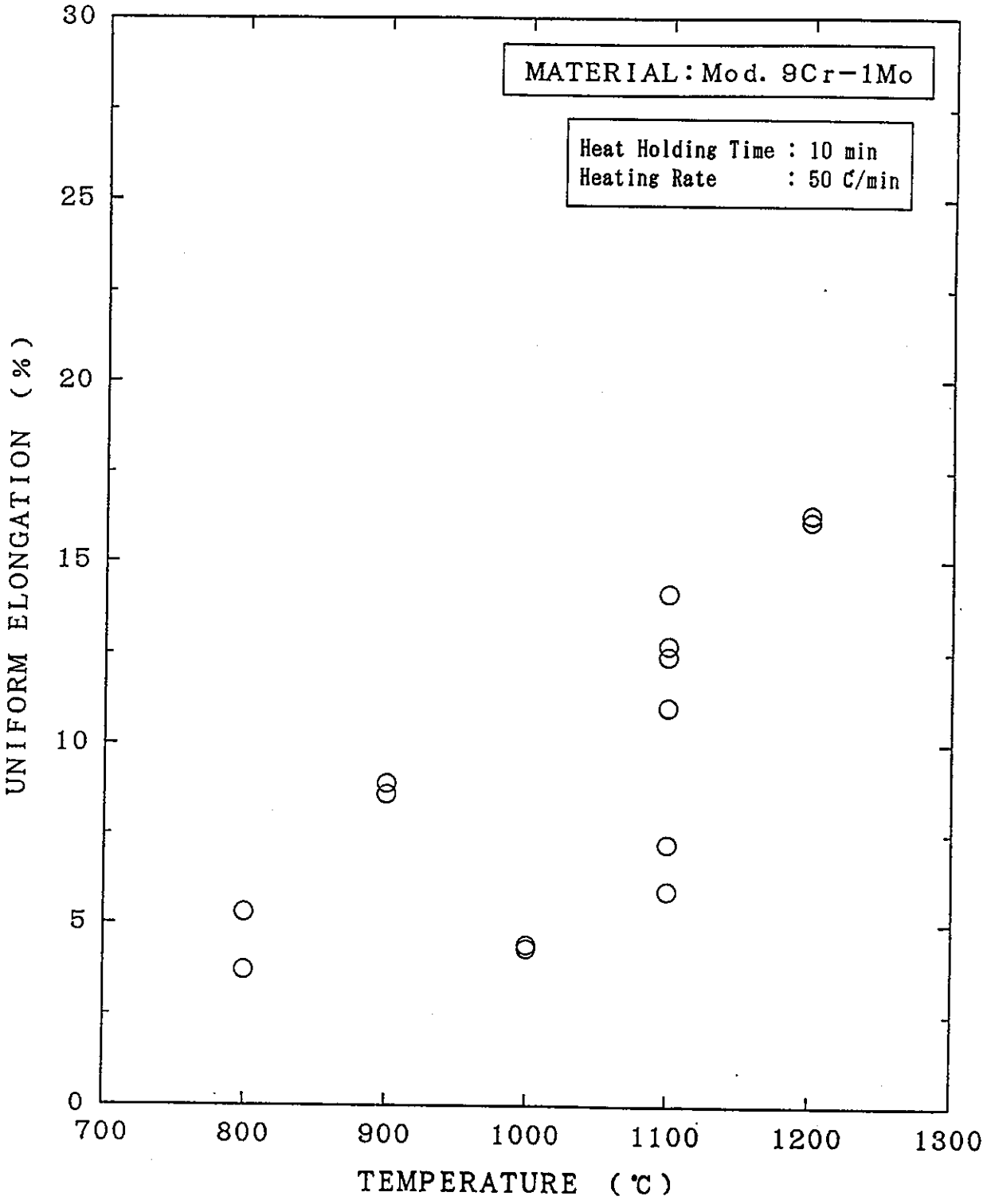


Fig.10 Uniform Elongation of Mod.9Cr-1Mo Steel.

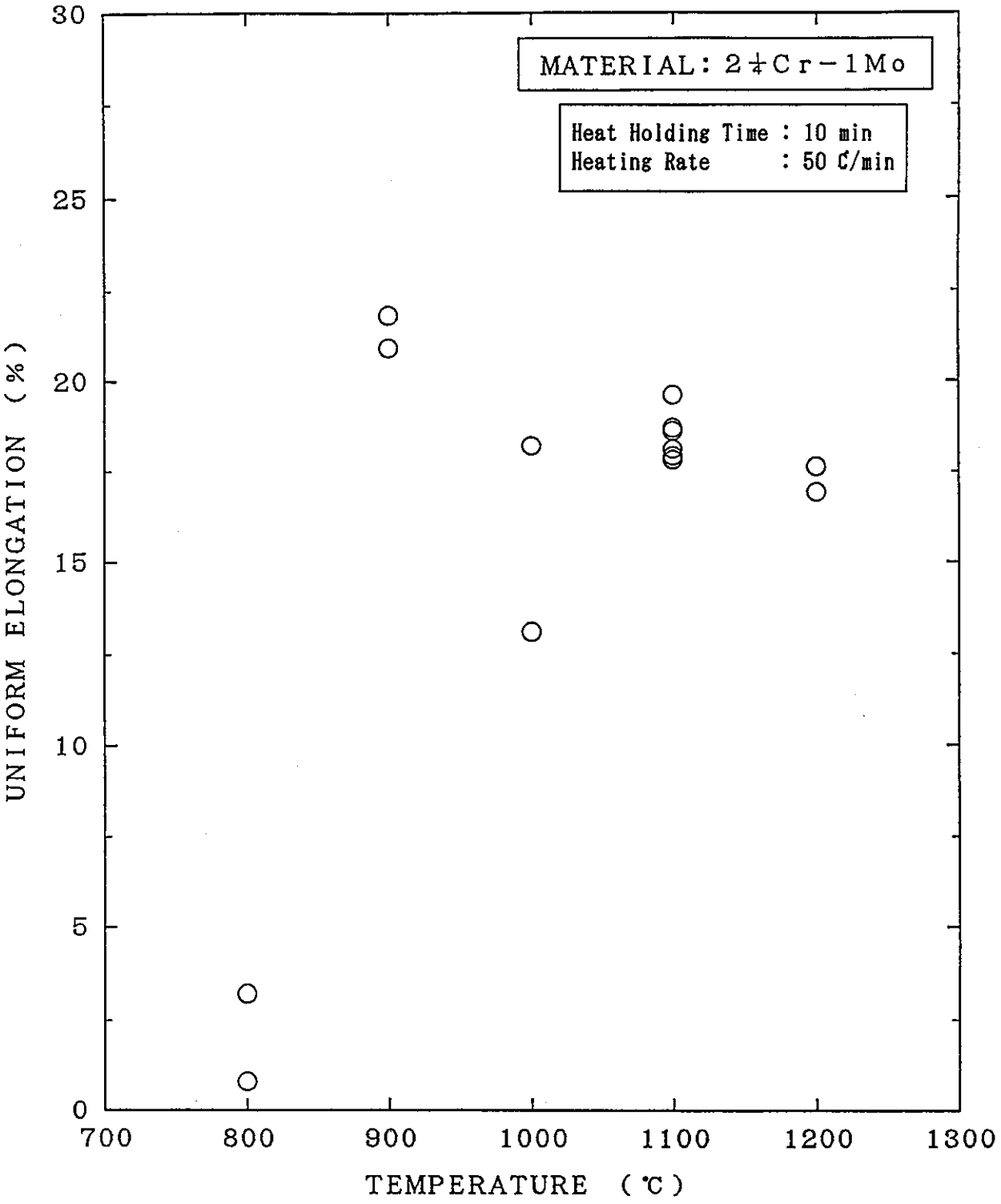


Fig.11 Uniform Elongation of 2¼Cr-1Mo Steel.

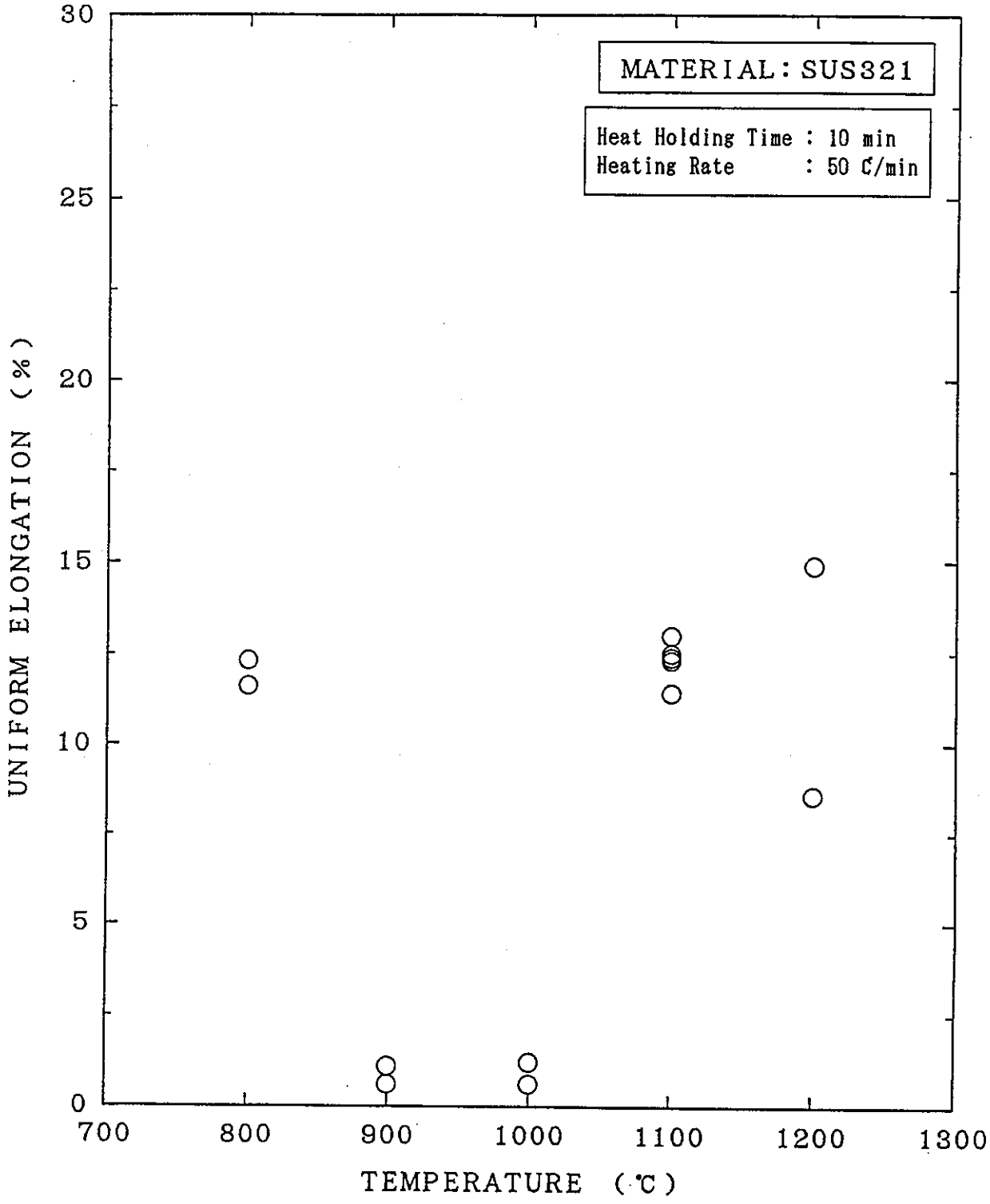


Fig.12 Uniform Elongation of SUS321 Stainless Steel.

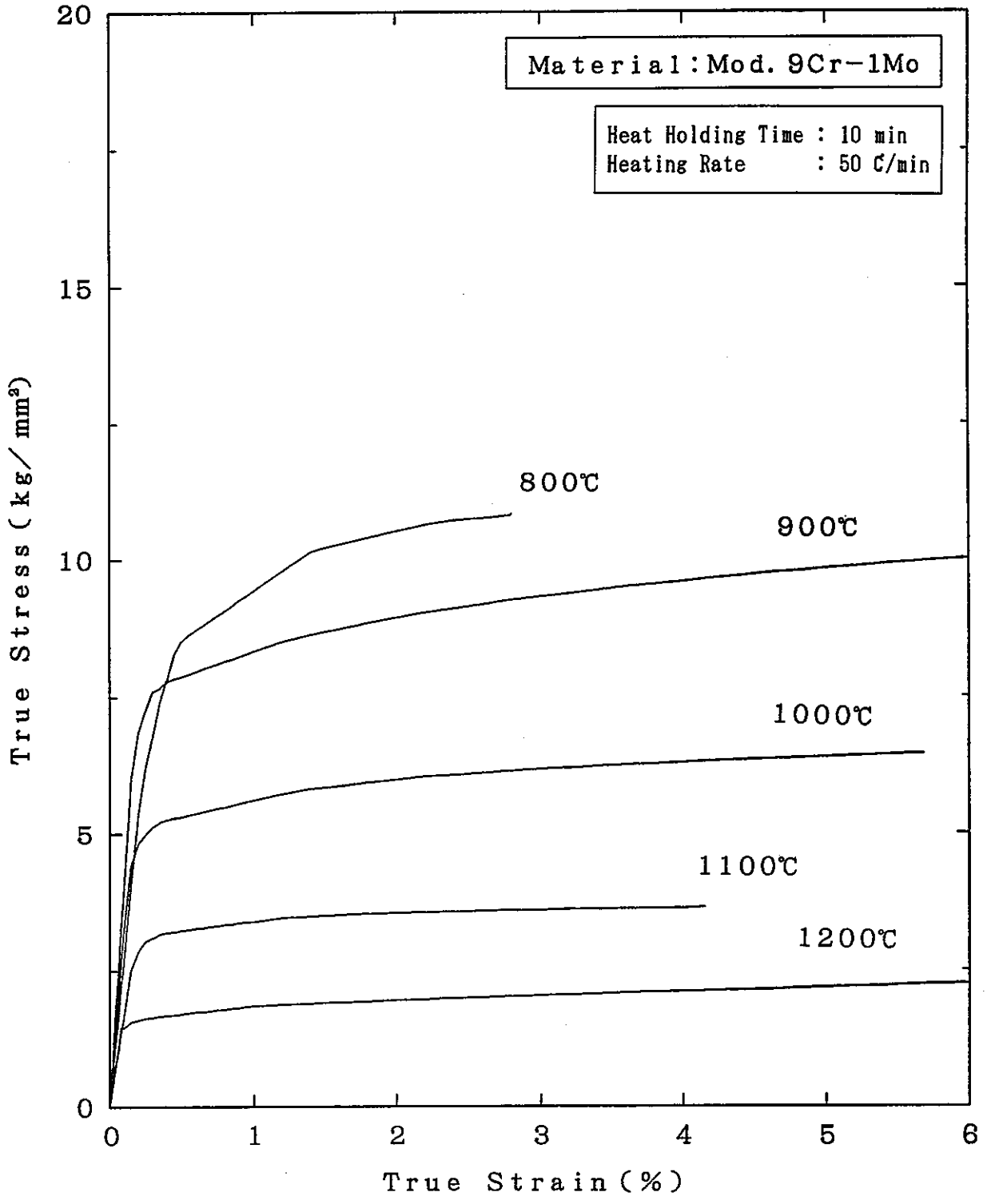


Fig.13 True Stress-True Strain Curves of Mod.9Cr-1Mo Steel.

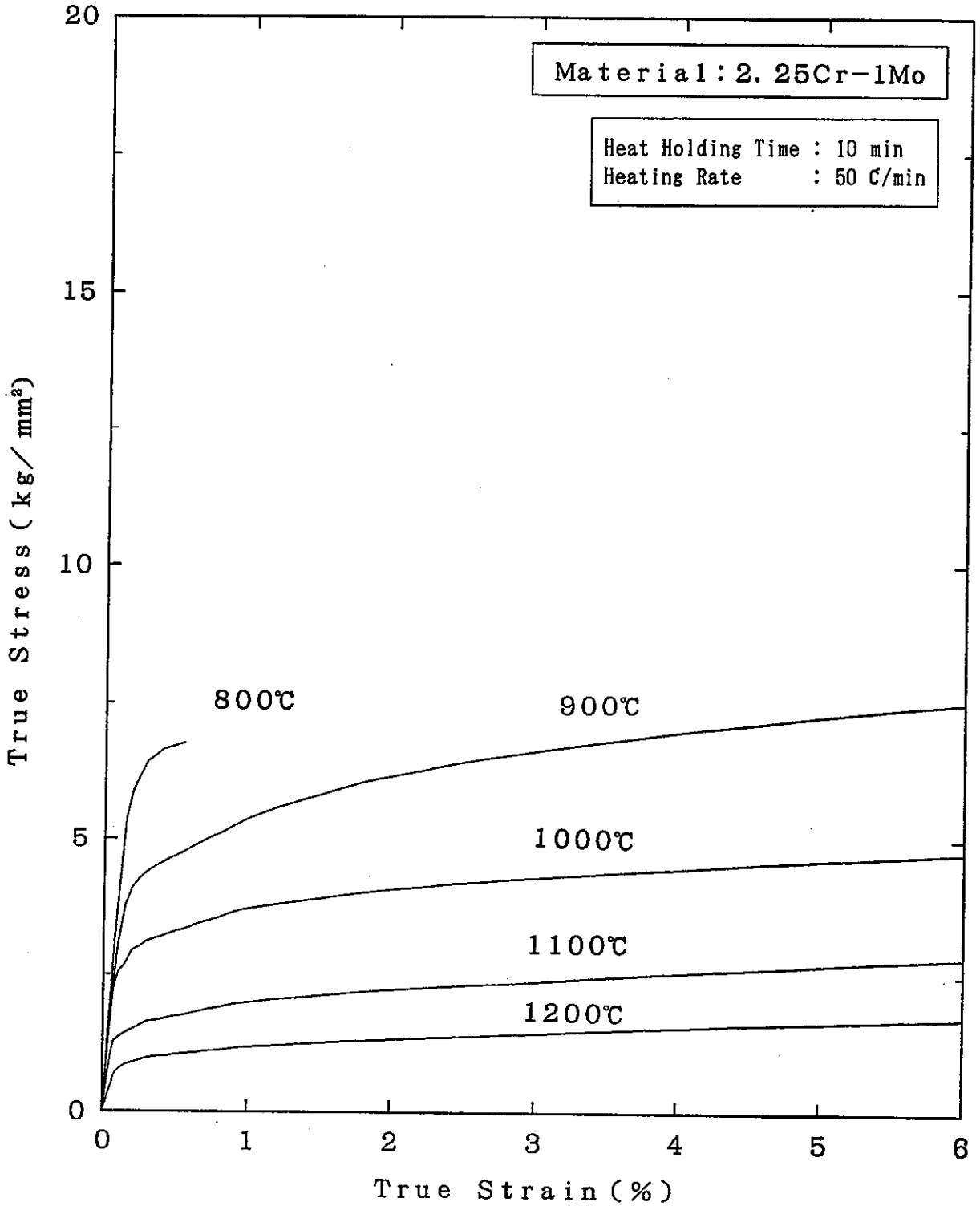


Fig.14 True Stress-True Strain Curves of 2¼Cr-1Mo Steel.

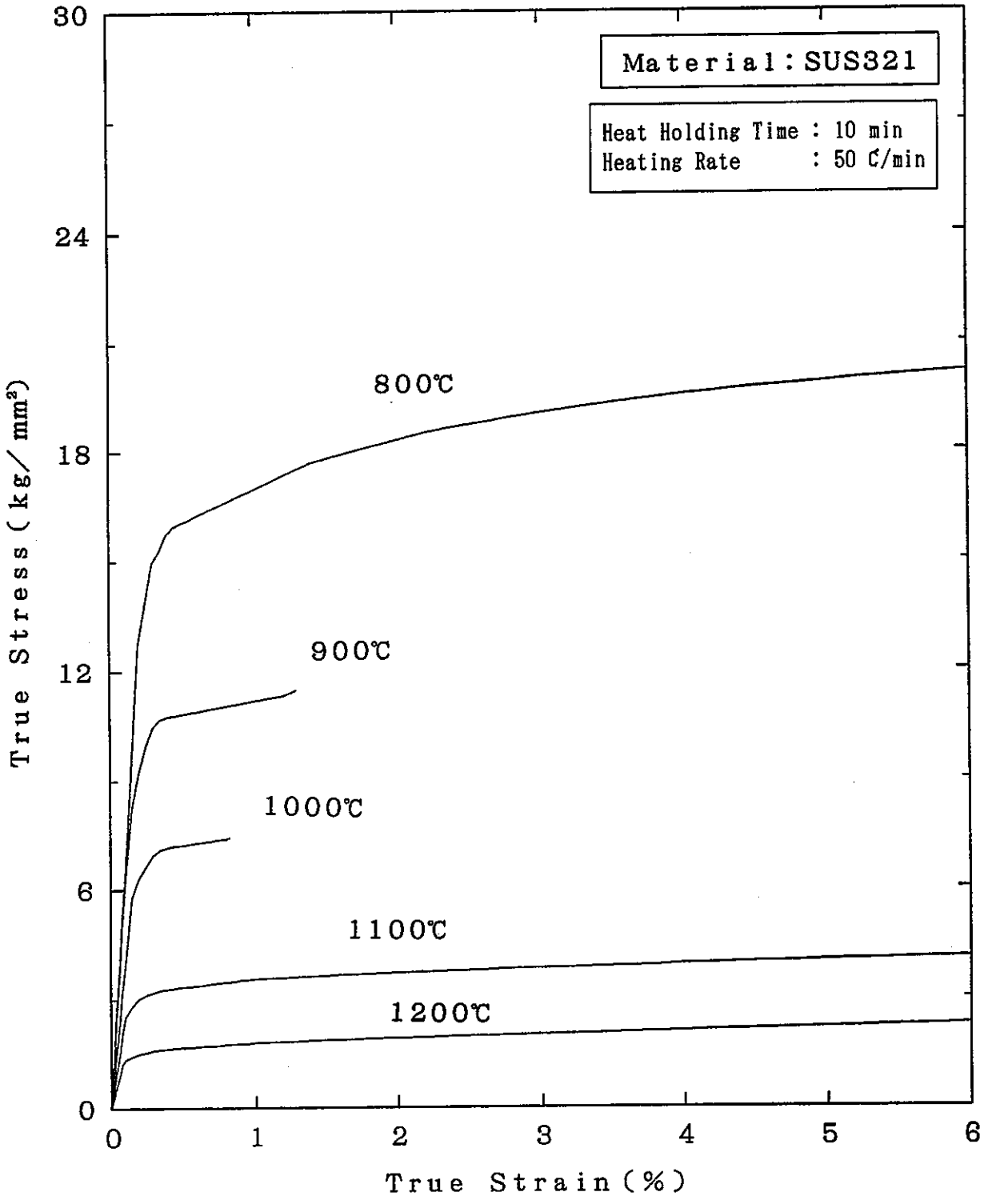


Fig.15 True Stress-True Strain Curves of SUS321 Stainless Steel.

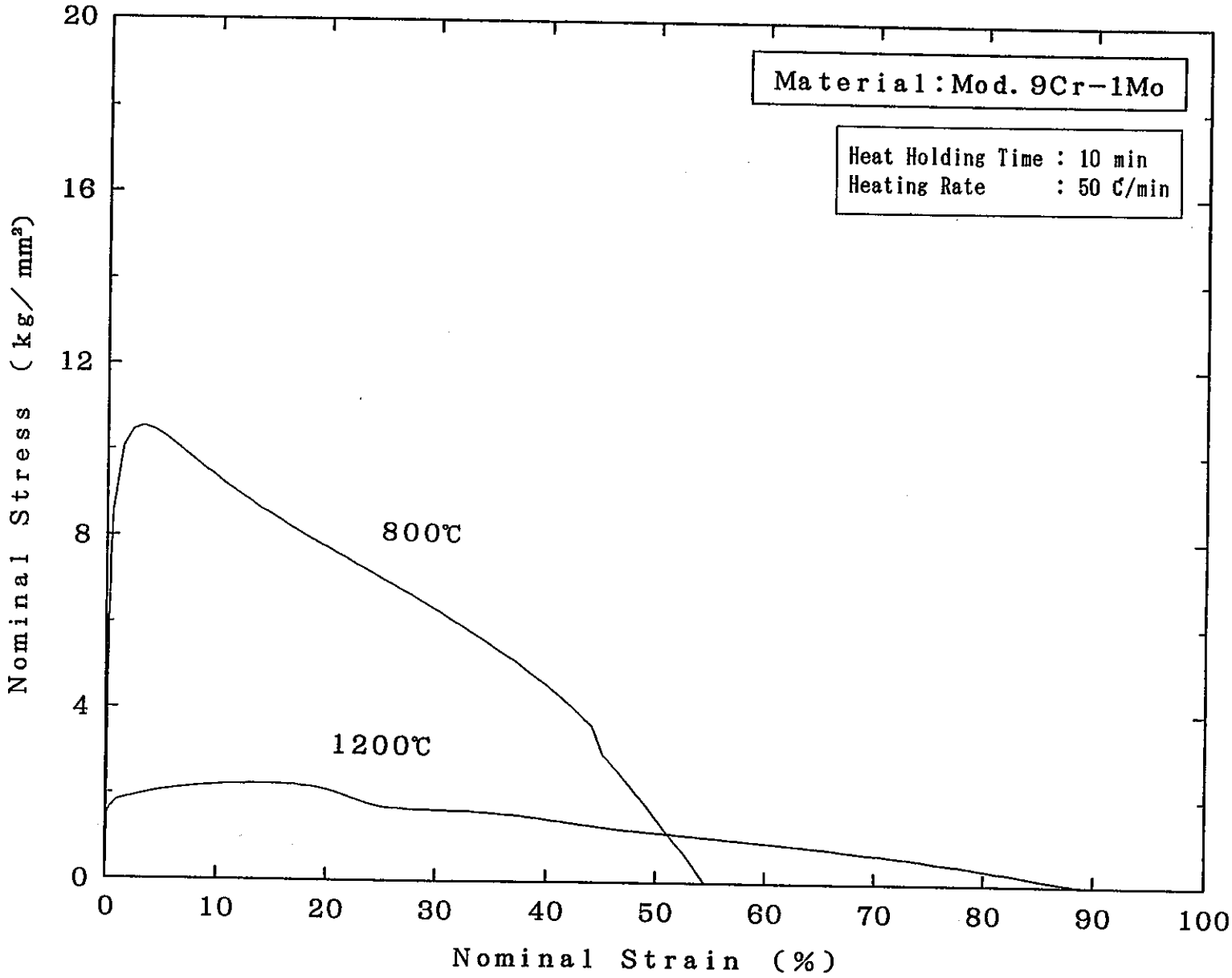


Fig.16 Stress-Strain Curves of Mod.9Cr-1Mo Steel.

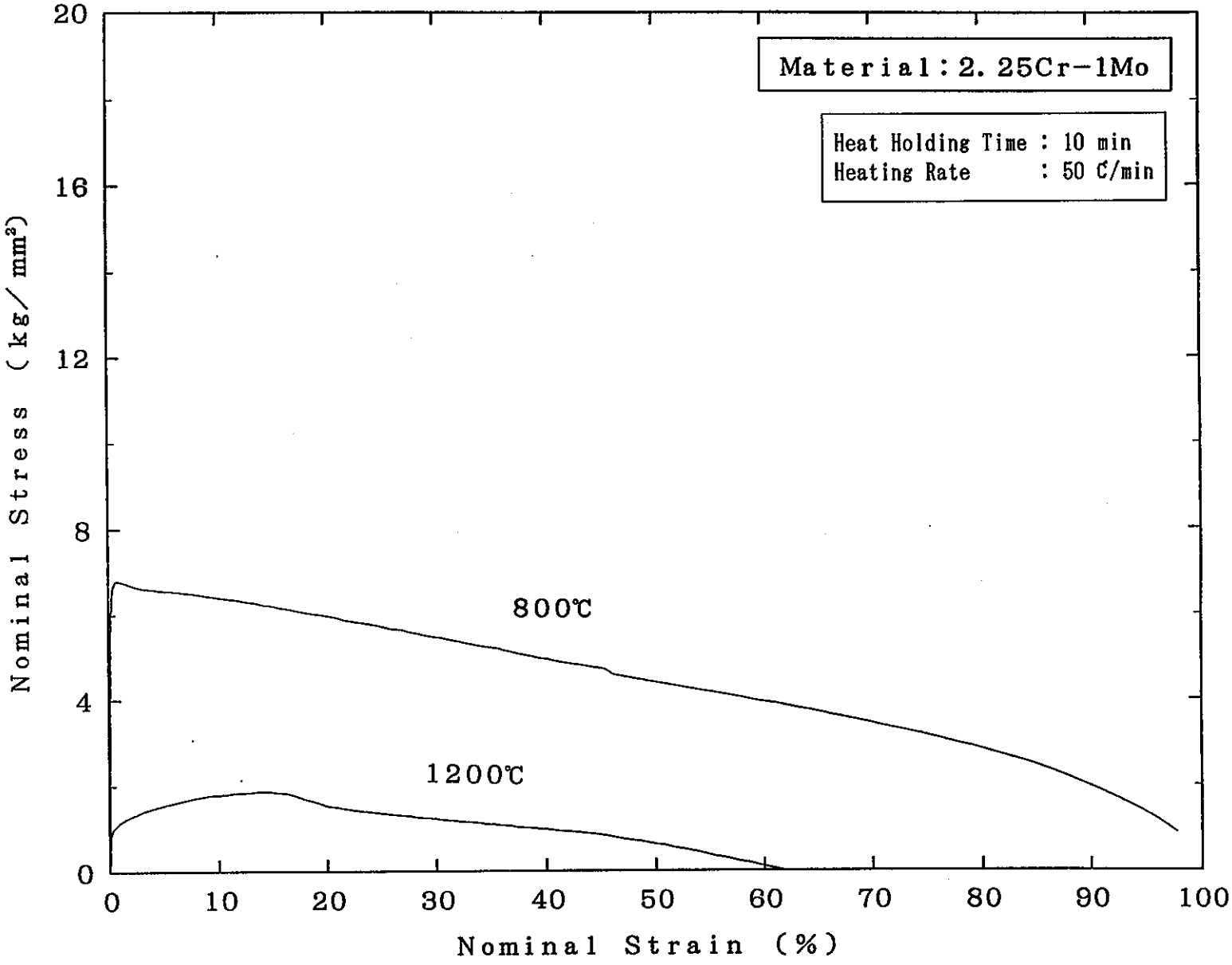


Fig.17 Stress-Strain Curves of 2¼Cr-1Mo Steel.

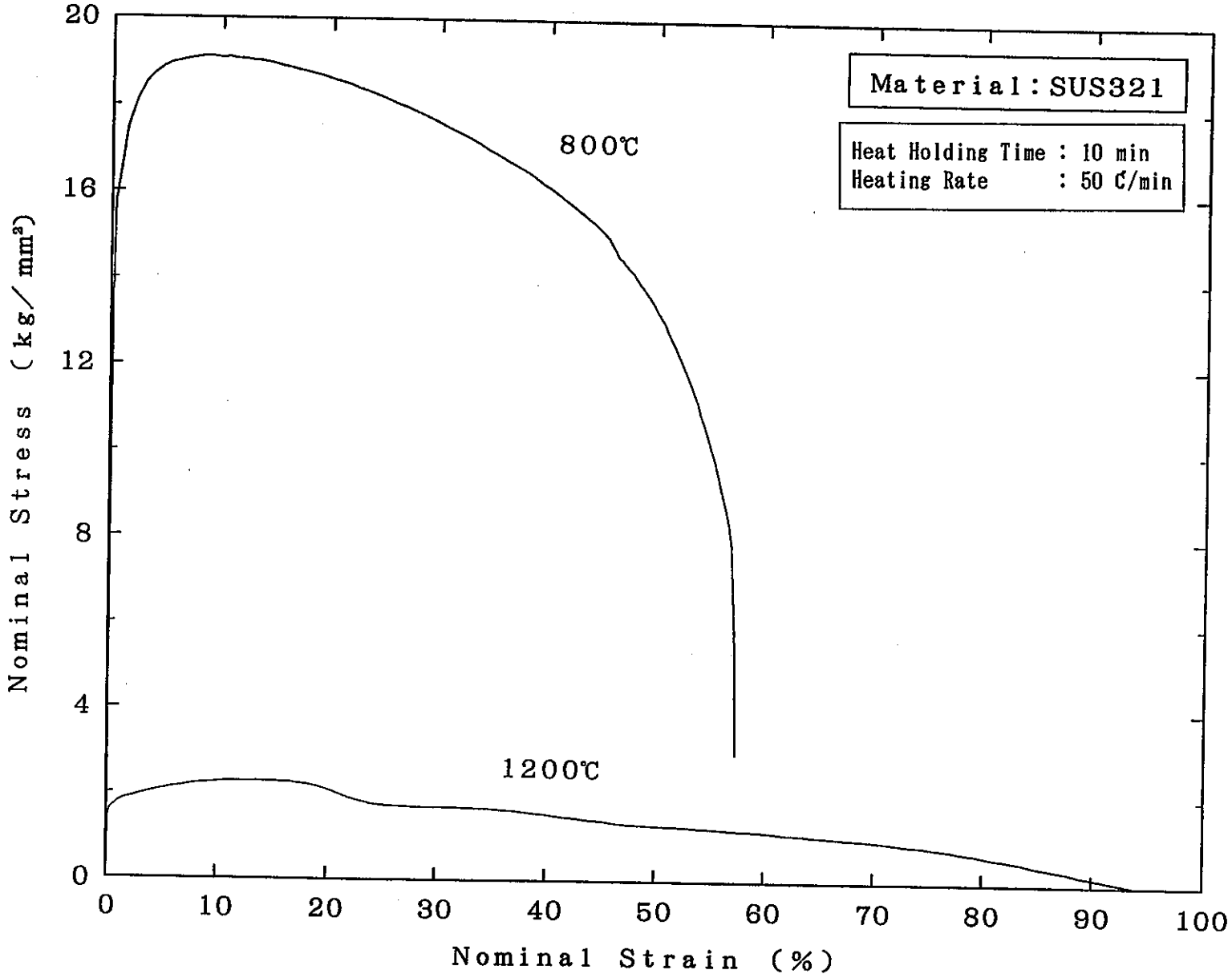


Fig.18 Stress-Strain Curves of SUS321 Stainless Steel.

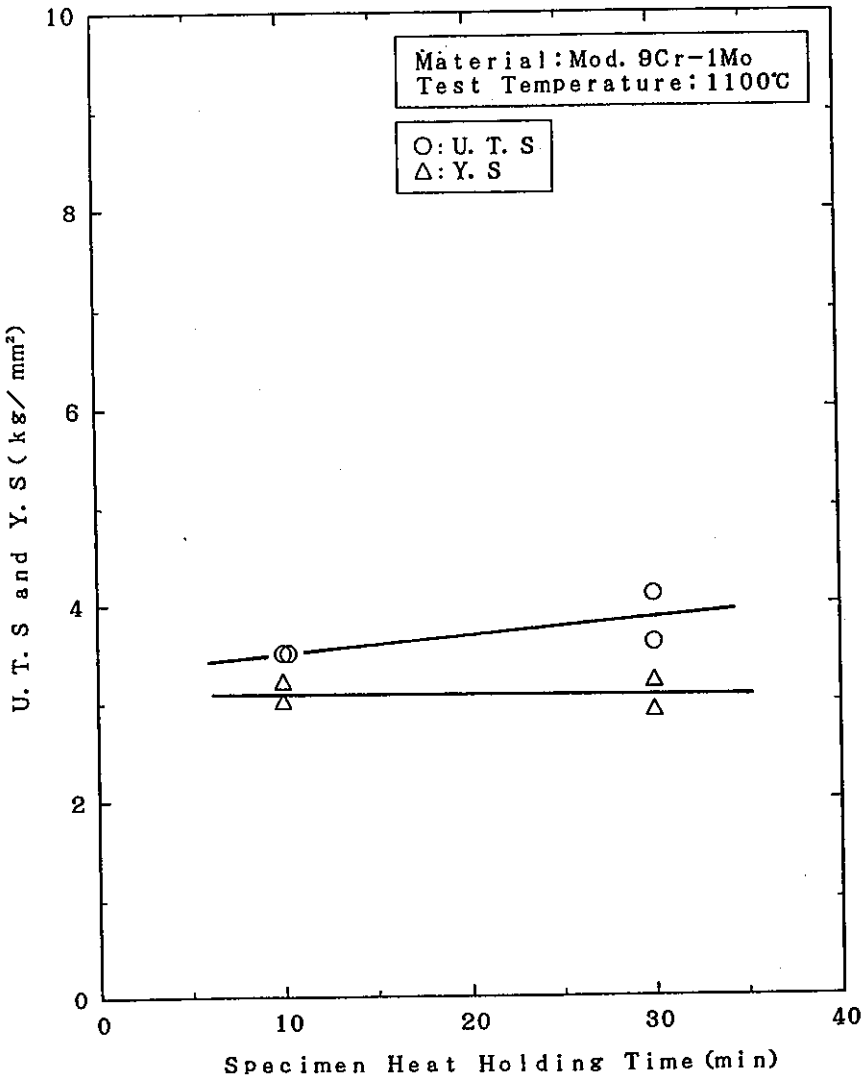


Fig.19 Effects of Specimen Heat Holding Time on Tensile Strength and Yield Strength of Mod.9Cr-1Mo Steel.

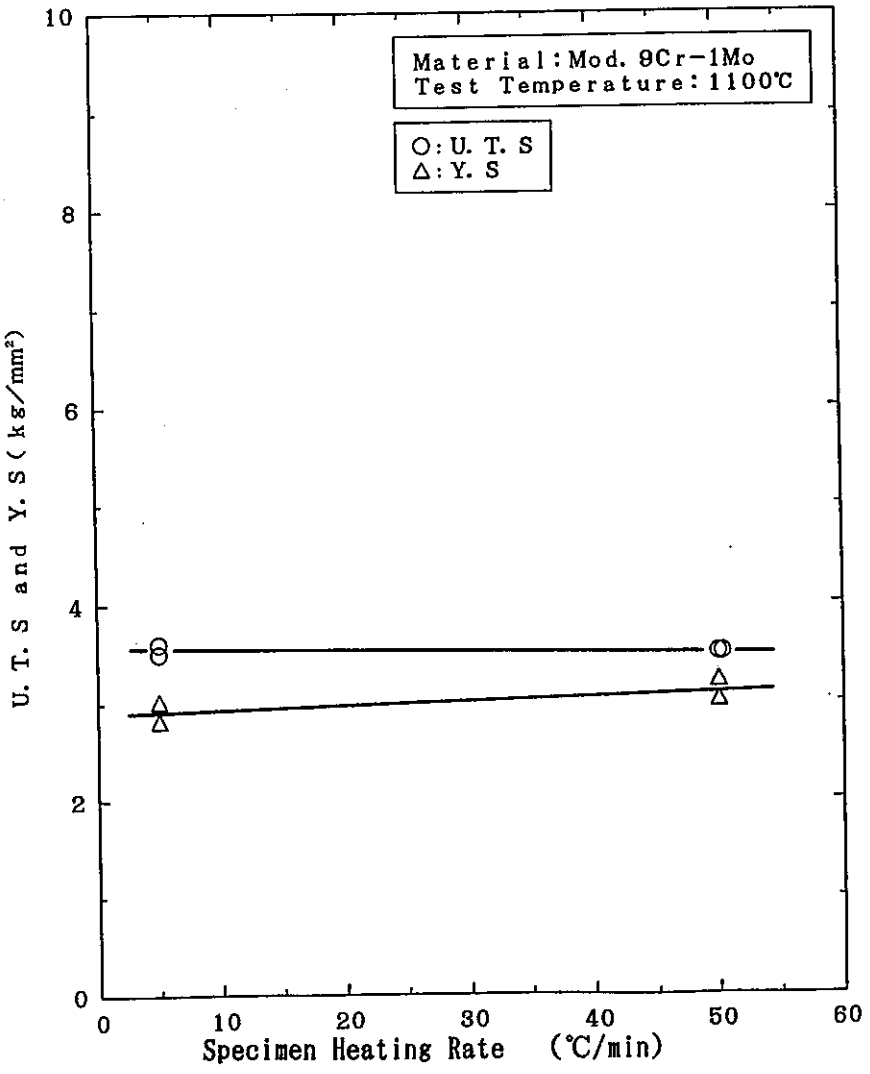


Fig.20 Effects of Specimen Heat Ratio on Tensile Strength and Yield Strength of Mod.9Cr-1Mo Steel.

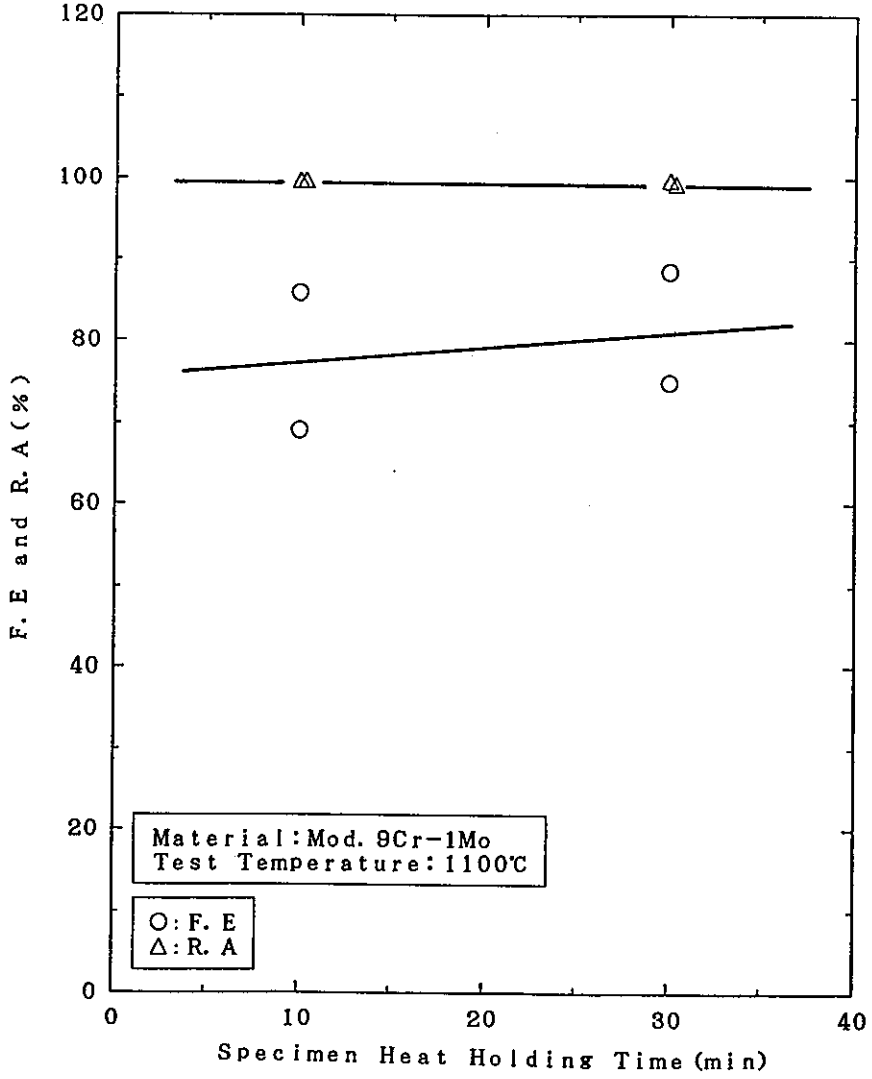


Fig.21 Effects of Specimen Heat Holding Time on Flacture Elongation and Reduction of Area of Mod.9Cr-1Mo Steel.

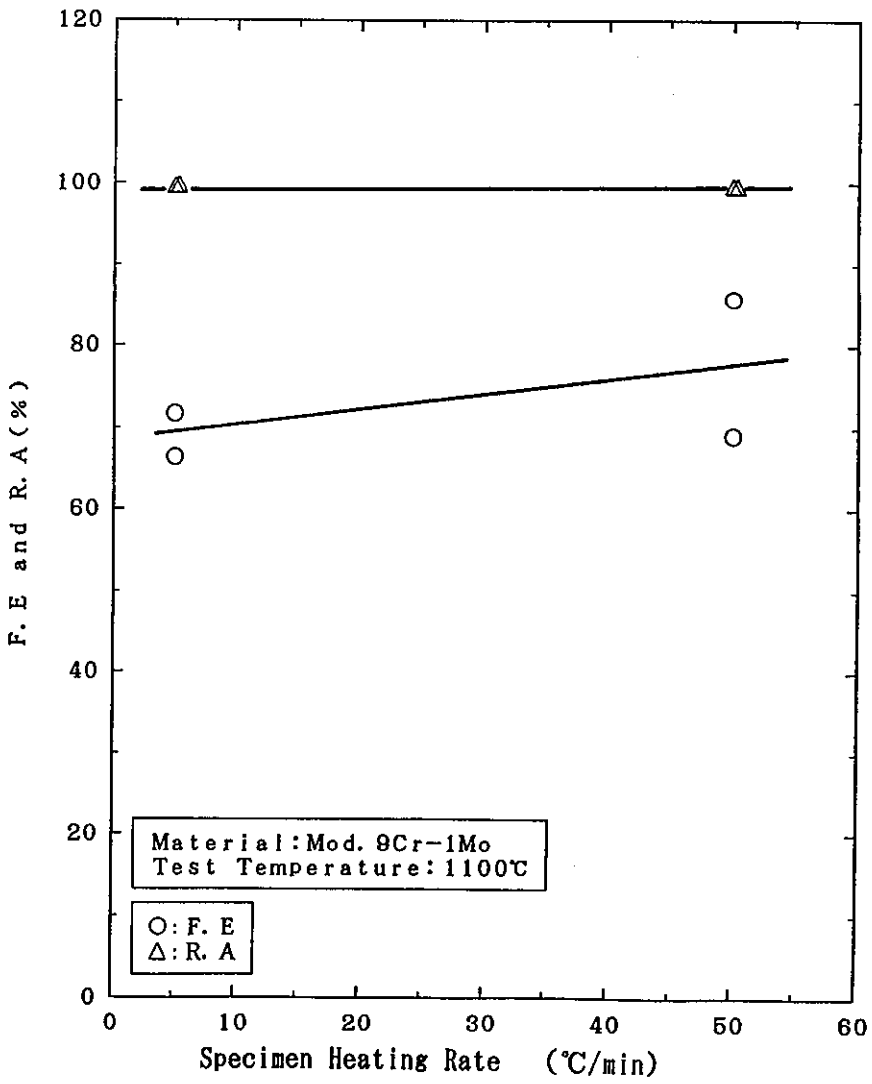


Fig.22 Effects of Specimen Heat Ratio on Flacture Elongation and Reduction of Area of Mod.9Cr-1Mo Steel.

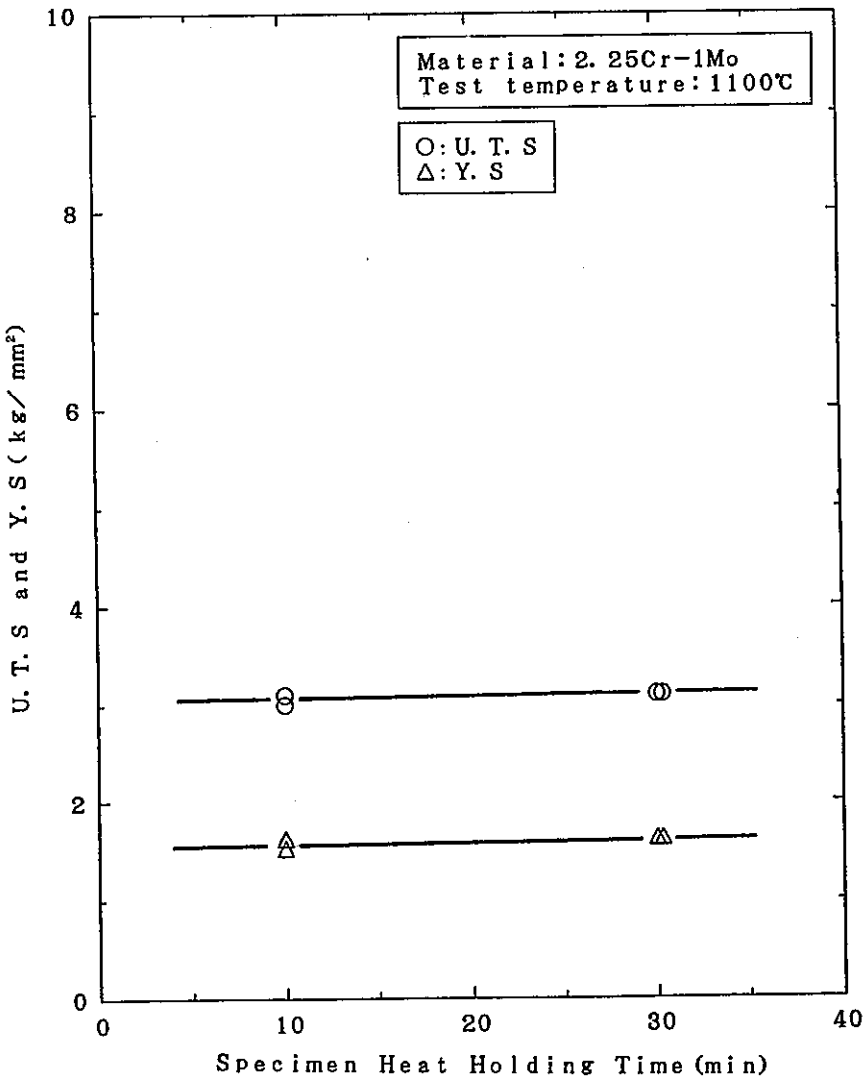


Fig.23 Effects of Specimen Heat Holding Time on Tensile Strength and Yield Strength of 2¼Cr-1Mo Steel.

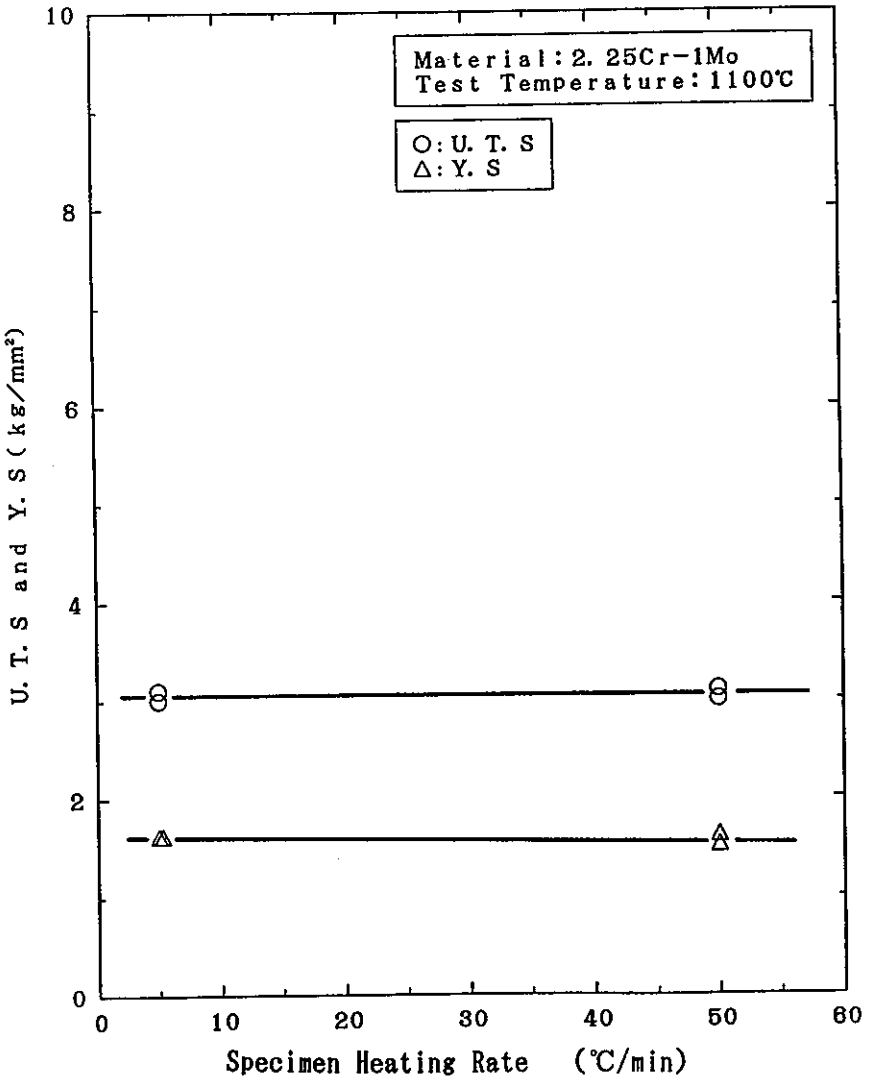


Fig.24 Effects of Specimen Heat Ratio on Tensile Strength and Yield Strength of 2¼Cr-1Mo Steel.

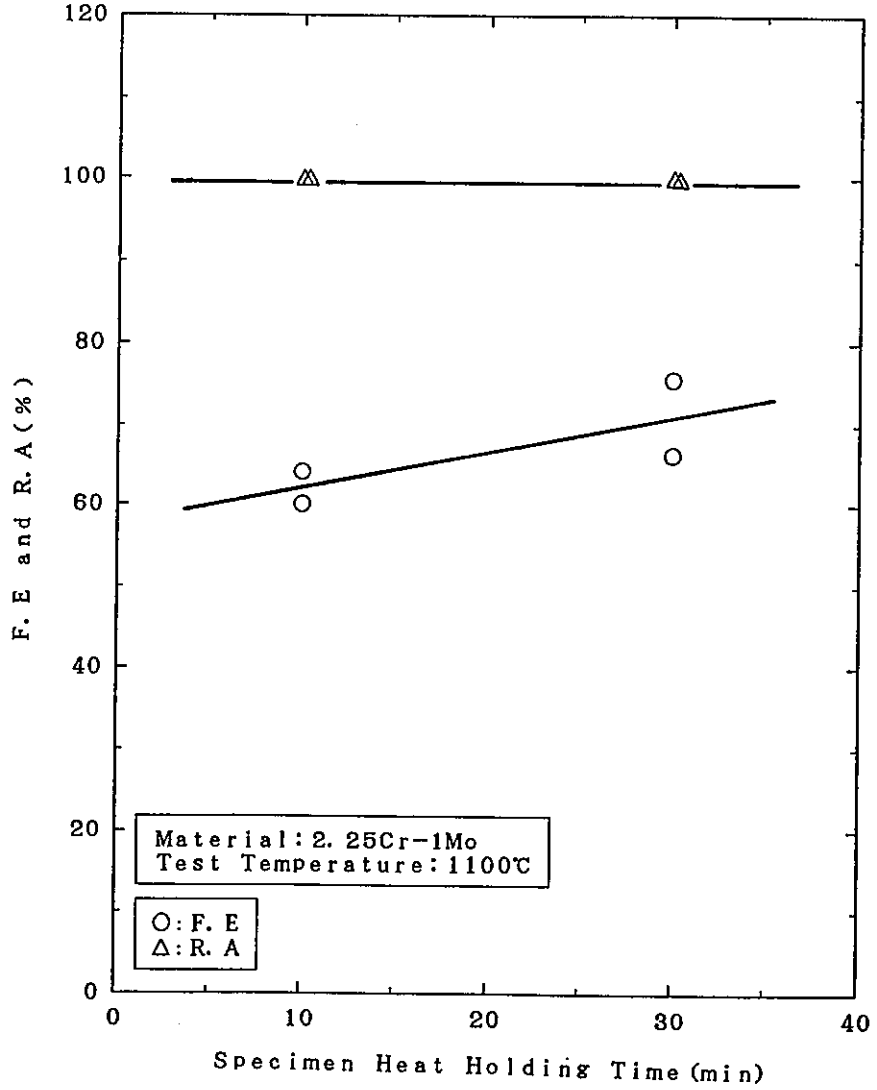


Fig.25 Effects of Specimen Heat Holding Time on Fracture Elogation and Reduction of Area of 2¼Cr-1Mo Steel.

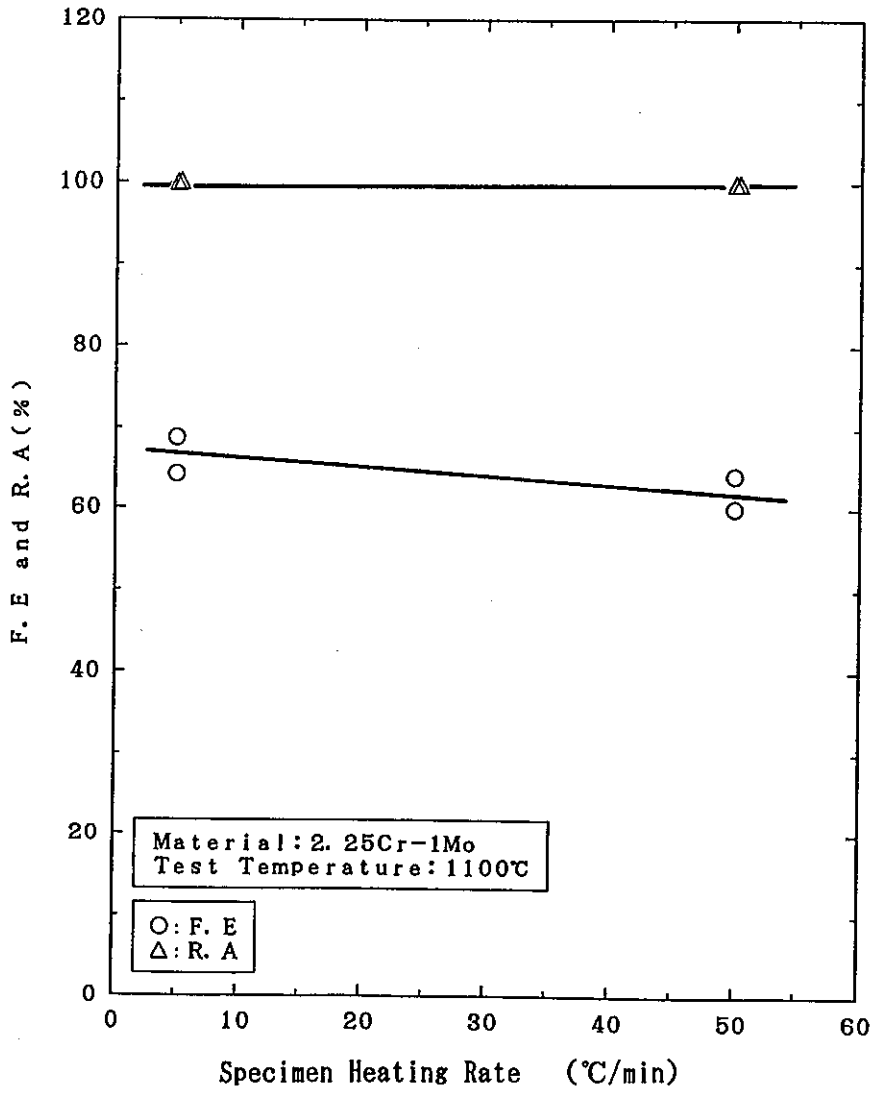


Fig.26 Effects of Specimen Heat Ratio on Fracture Elogation and Reduction of Area of 2¼Cr-1Mo Steel.

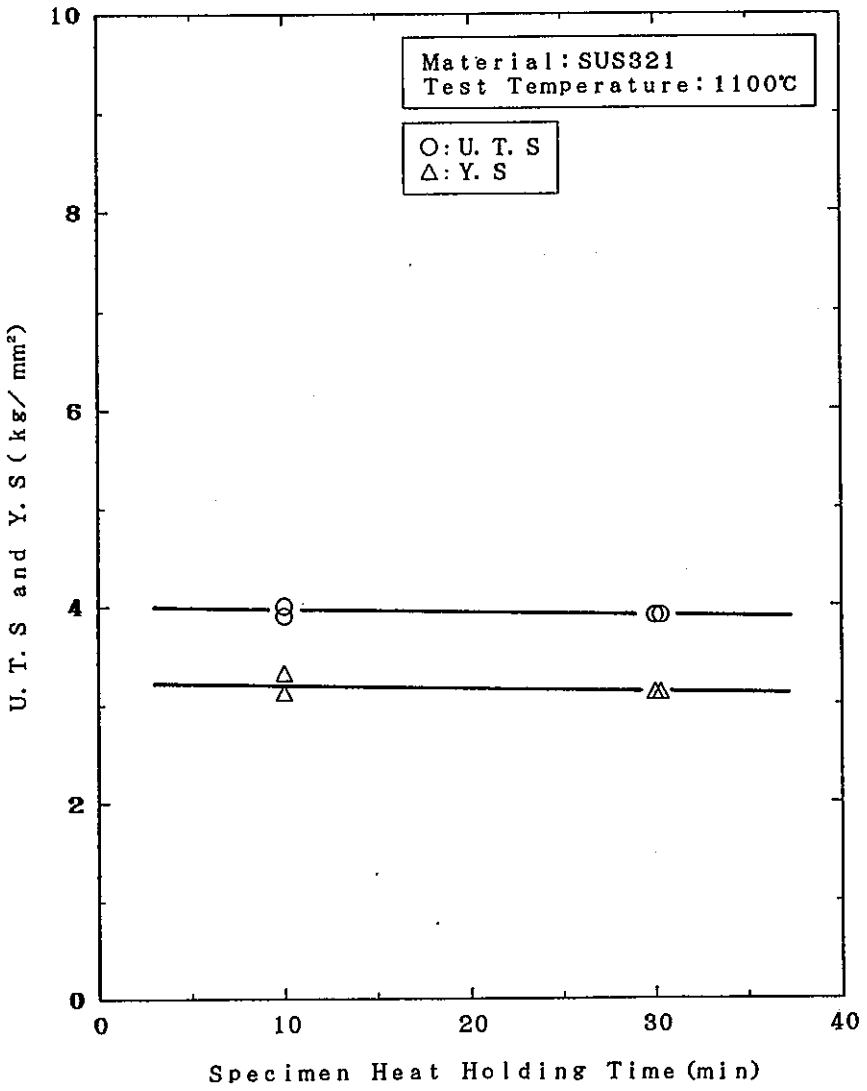


Fig.27 Effects of Specimen Heat Holding Time on Tensile Strength and Yield Strength of SUS321 Stainless Steel.

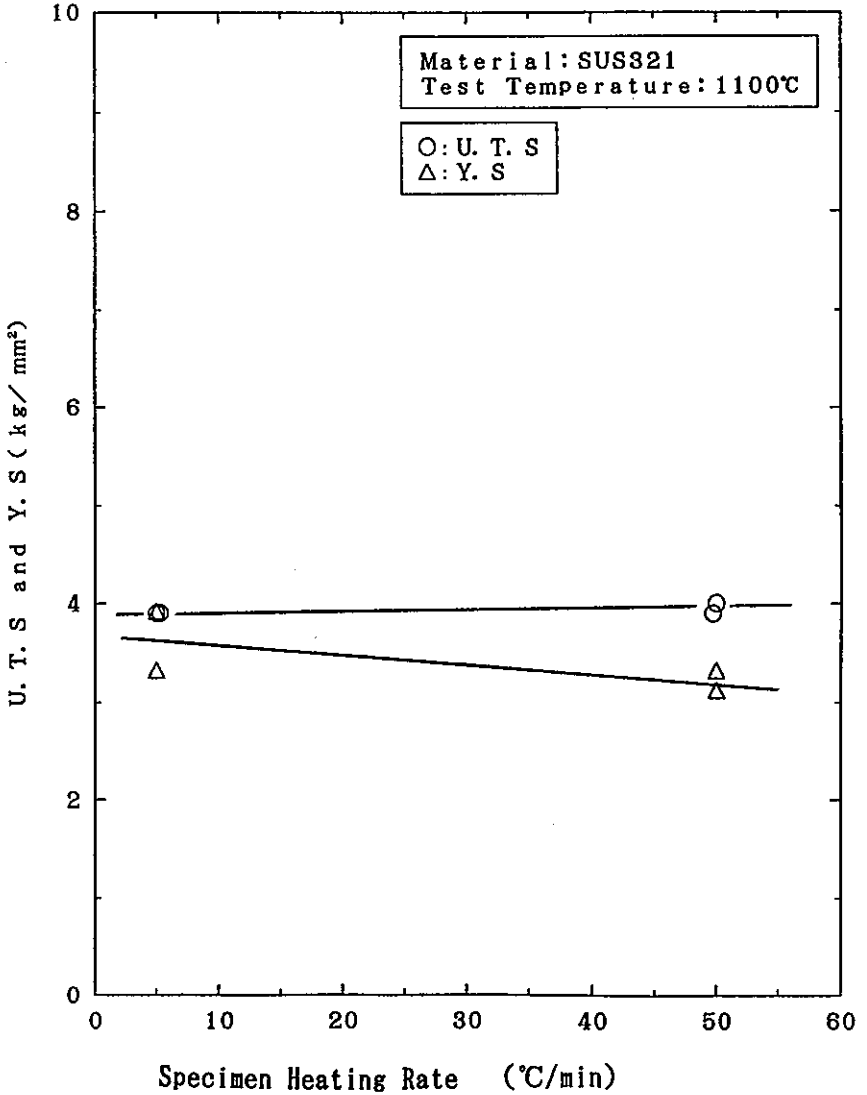


Fig.28 Effects of Specimen Heat Ratio on Tensile Strength and Yield Strength of SUS321 Stainless Steel.

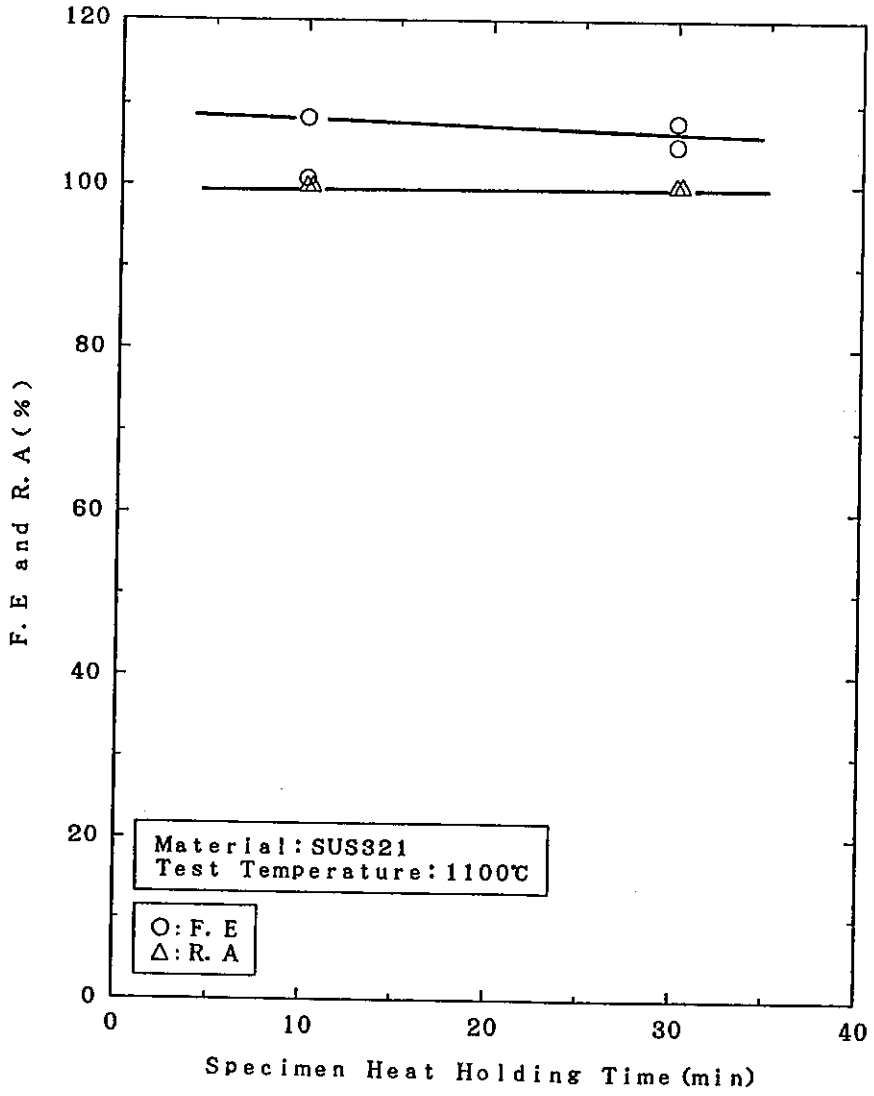


Fig.29 Effects of Specimen Heat Holding Time on Fracture Elogation and Reduction of Area of SUS321 Stainless Steel.

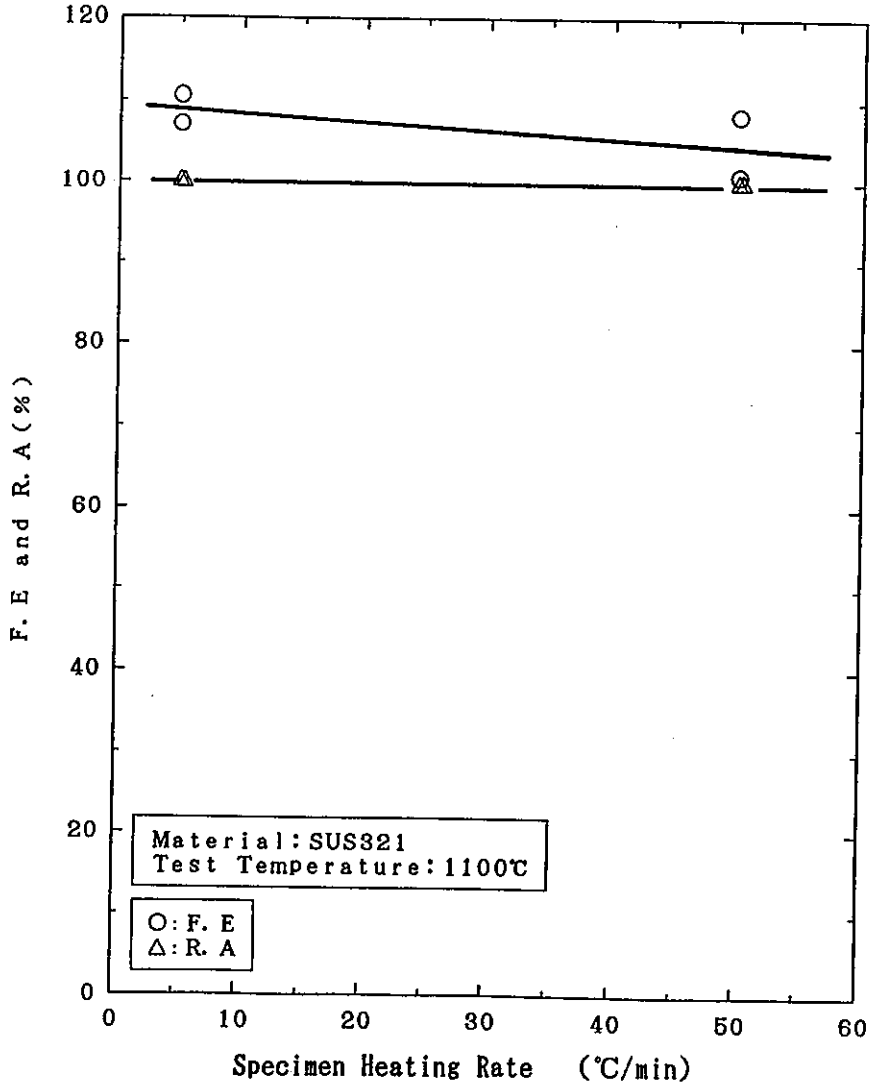


Fig.30 Effects of Specimen Heat Ratio on Fracture Elogation and Reduction of Area of SUS321 Stainless Steel.

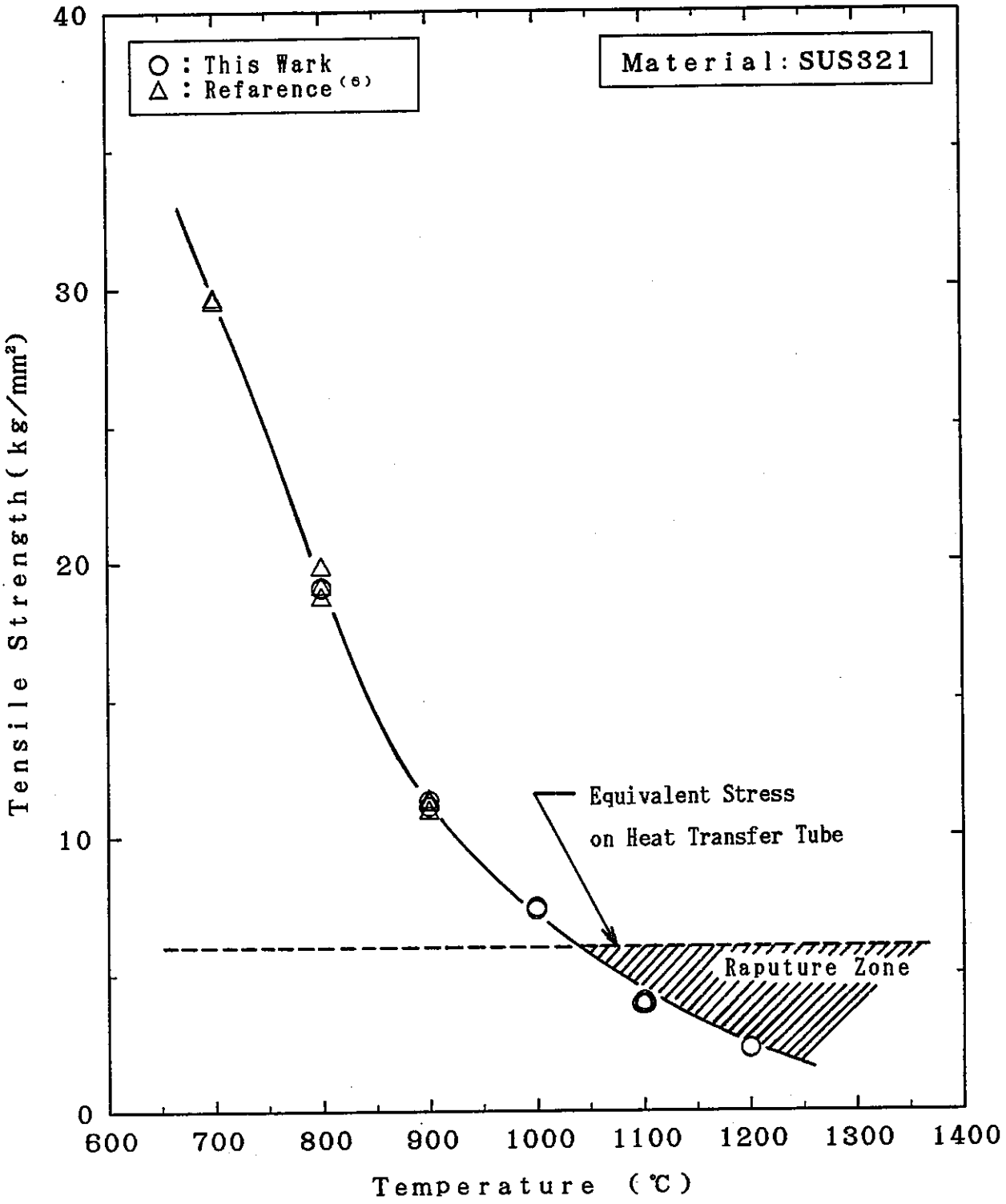


Fig.31 Relation Between Tensile Strength
at High Tempetature Test of SUS321 Stainless Steel.

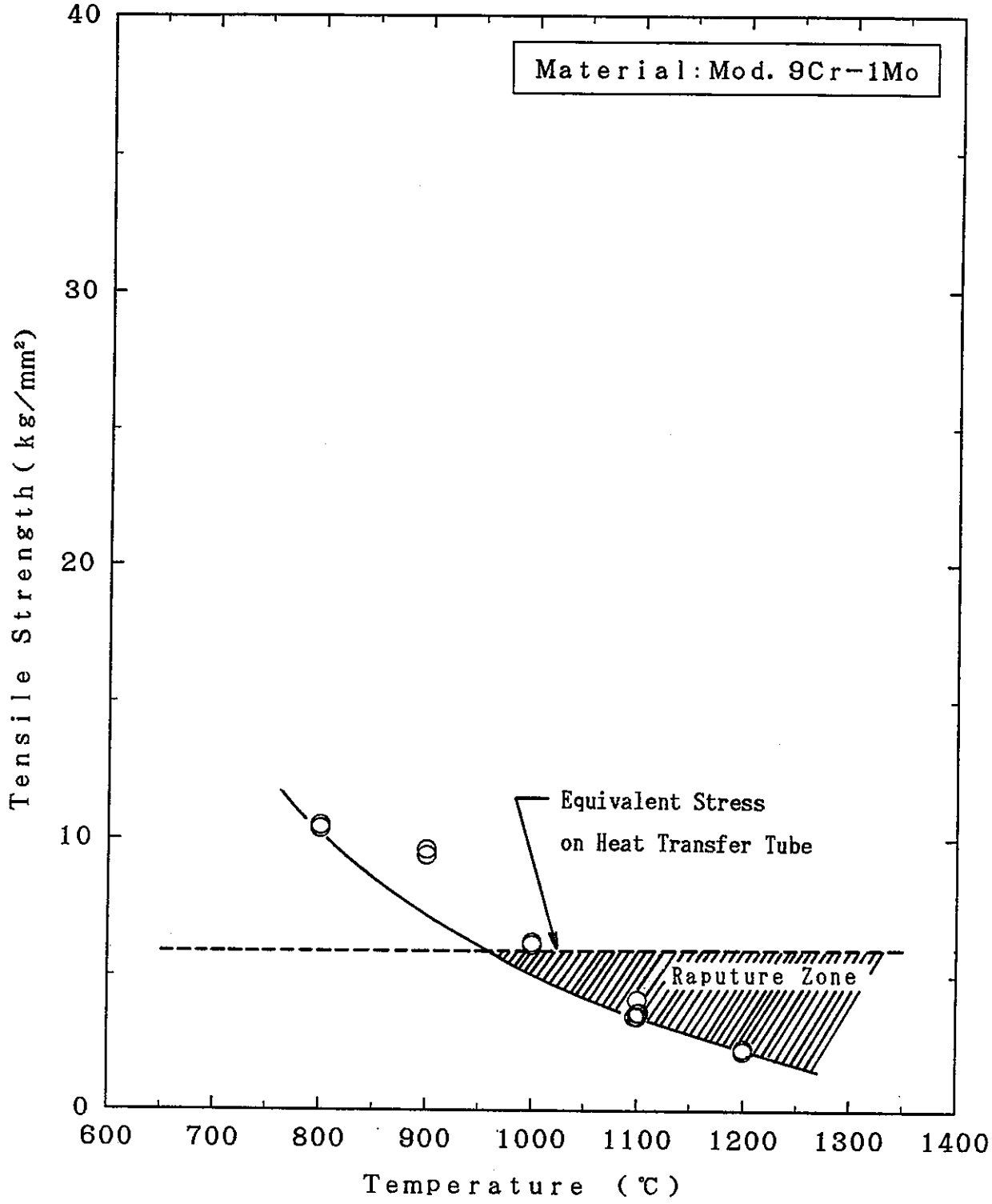


Fig.32 Relation Between Tensile Strength
at High Tempetature Test of Mod.9Cr-1Mo Steel.

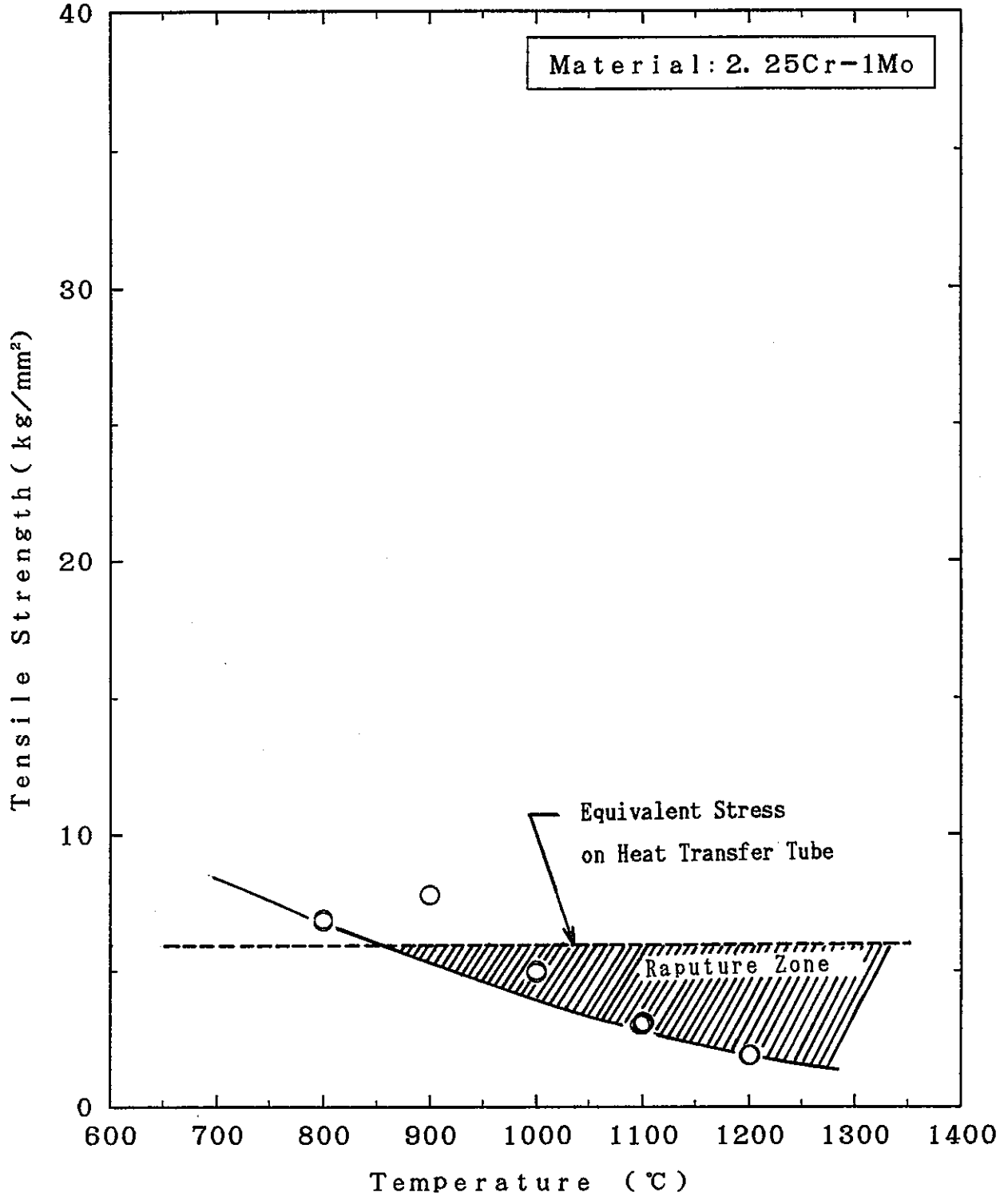
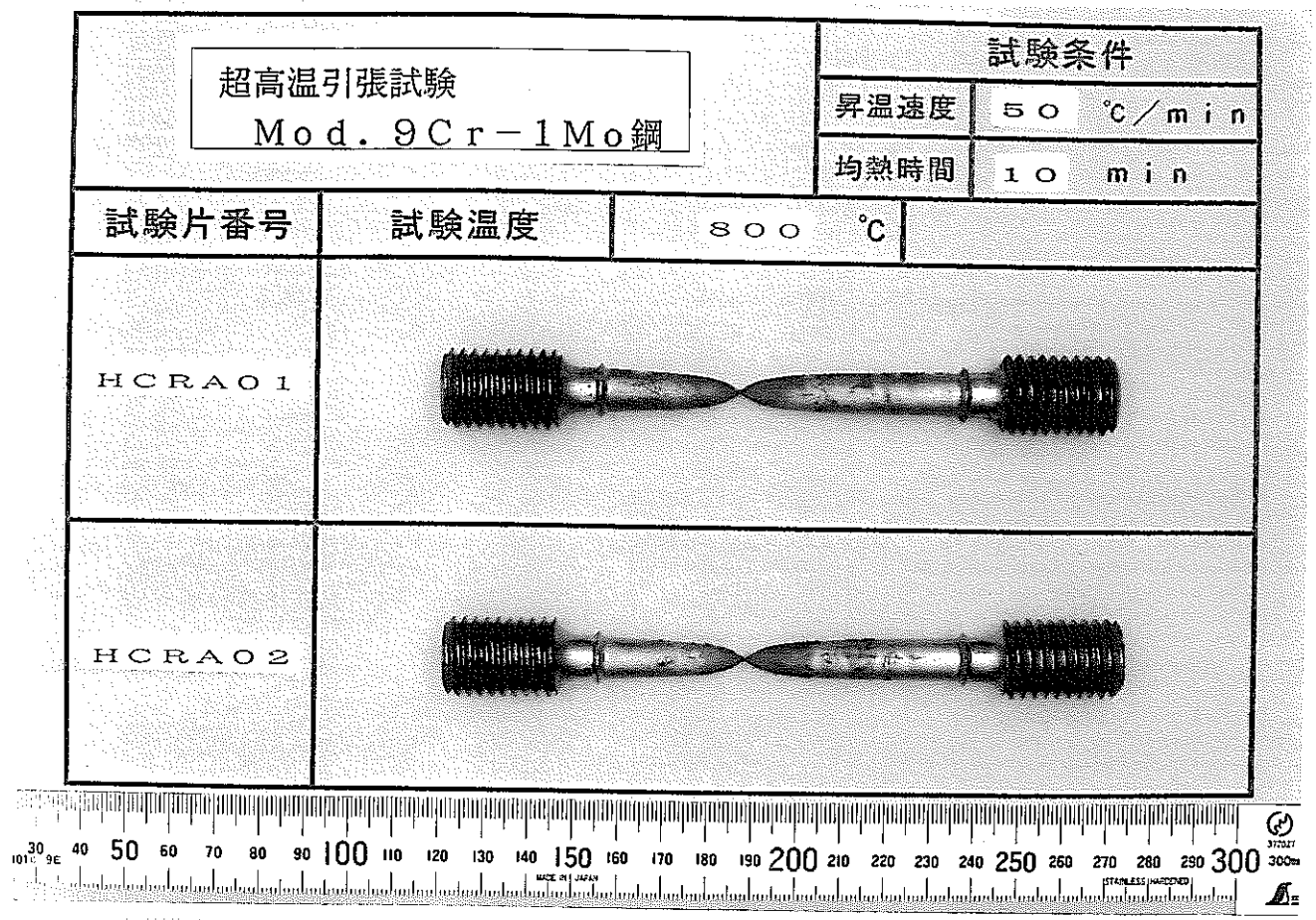


Fig.33 Relation Between Tensile Strength
at High Tempetature Test of 2¼Cr-1Mo Steel.



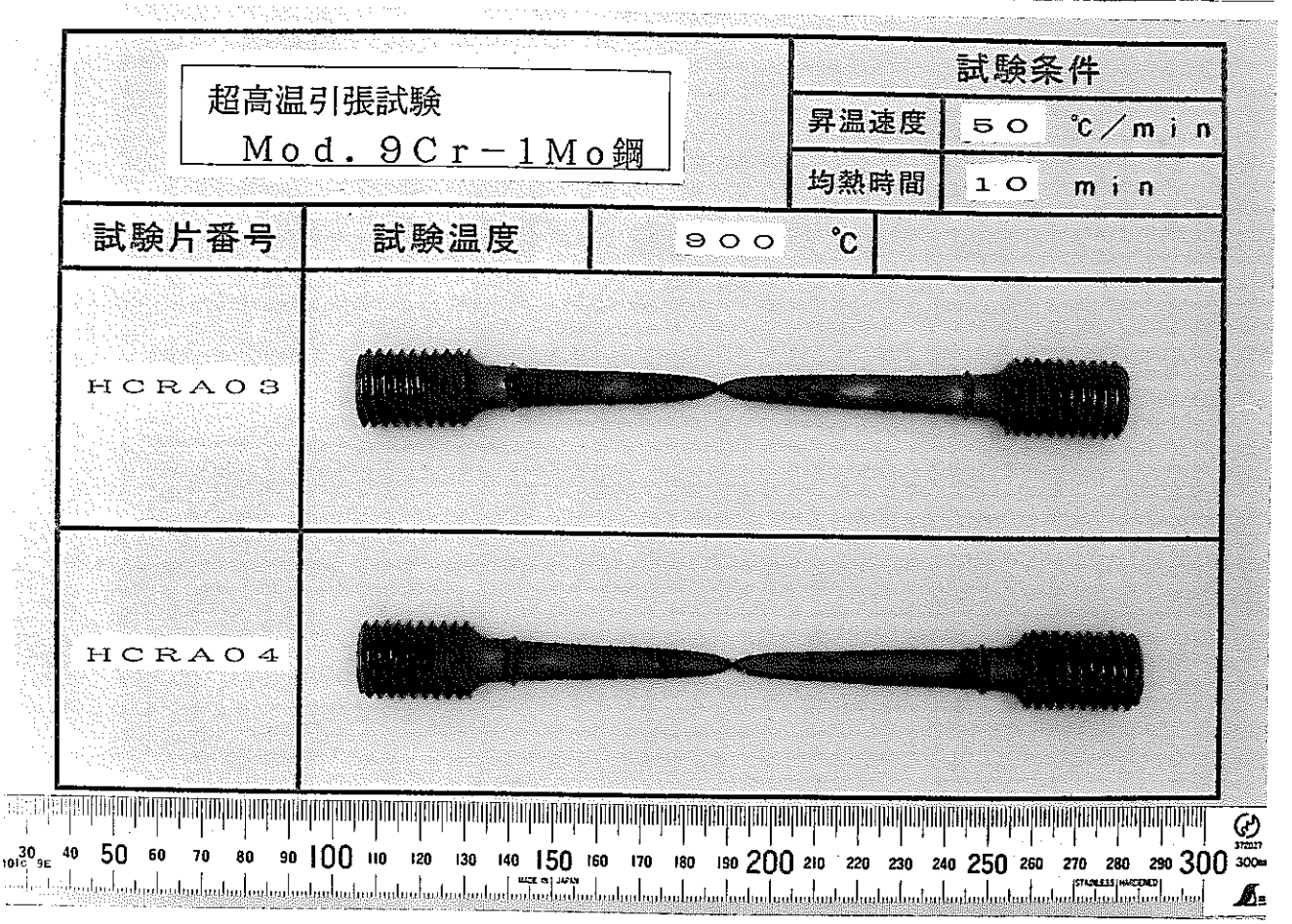
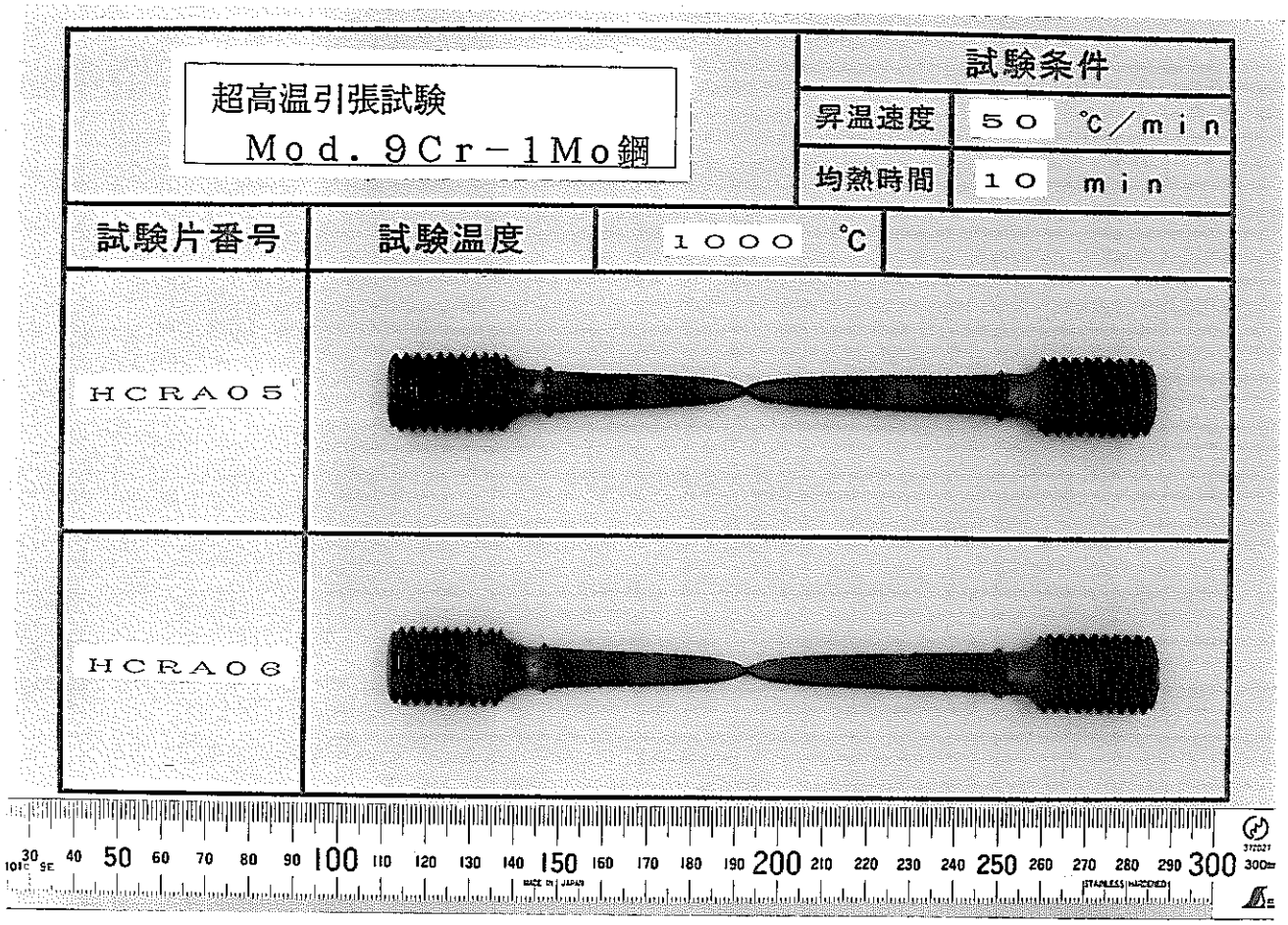


Photo. 1 Appearance of Mod.9Cr-1Mo Steel After Tensile Test at 800 and 900℃.



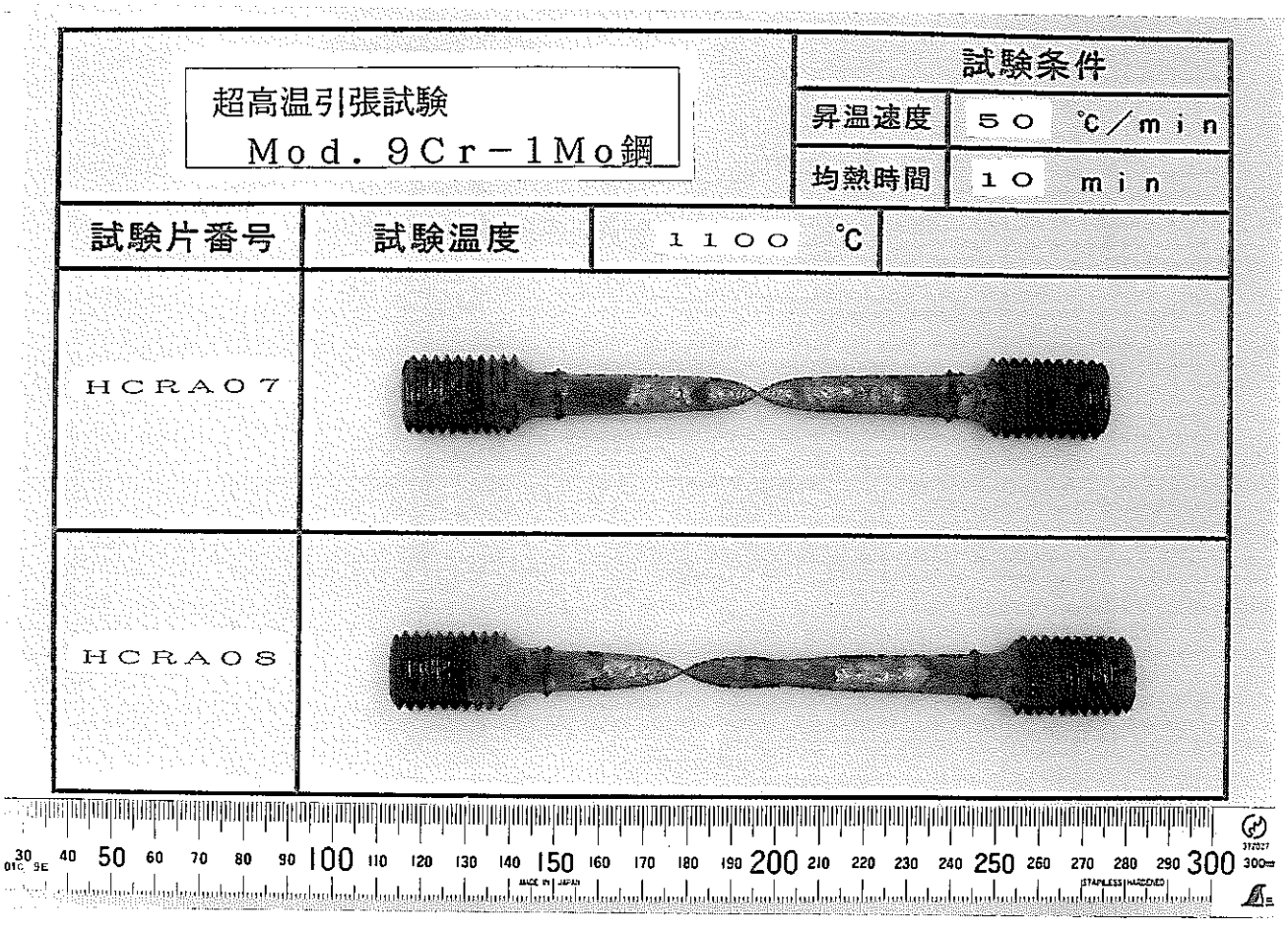
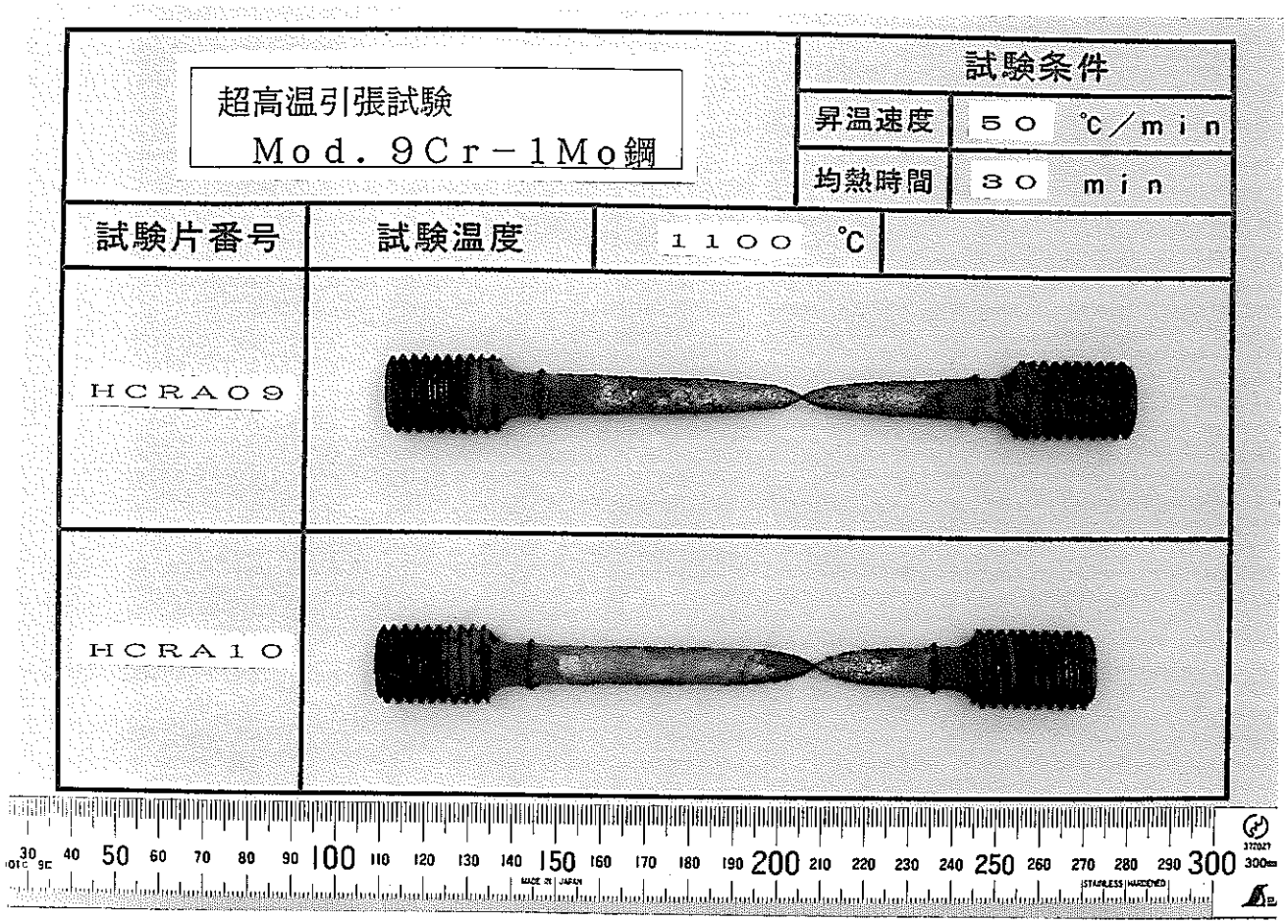


Photo. 2 Appearance of Mod.9Cr-1Mo Steel After Tensile Test at 1000 and 1100℃.



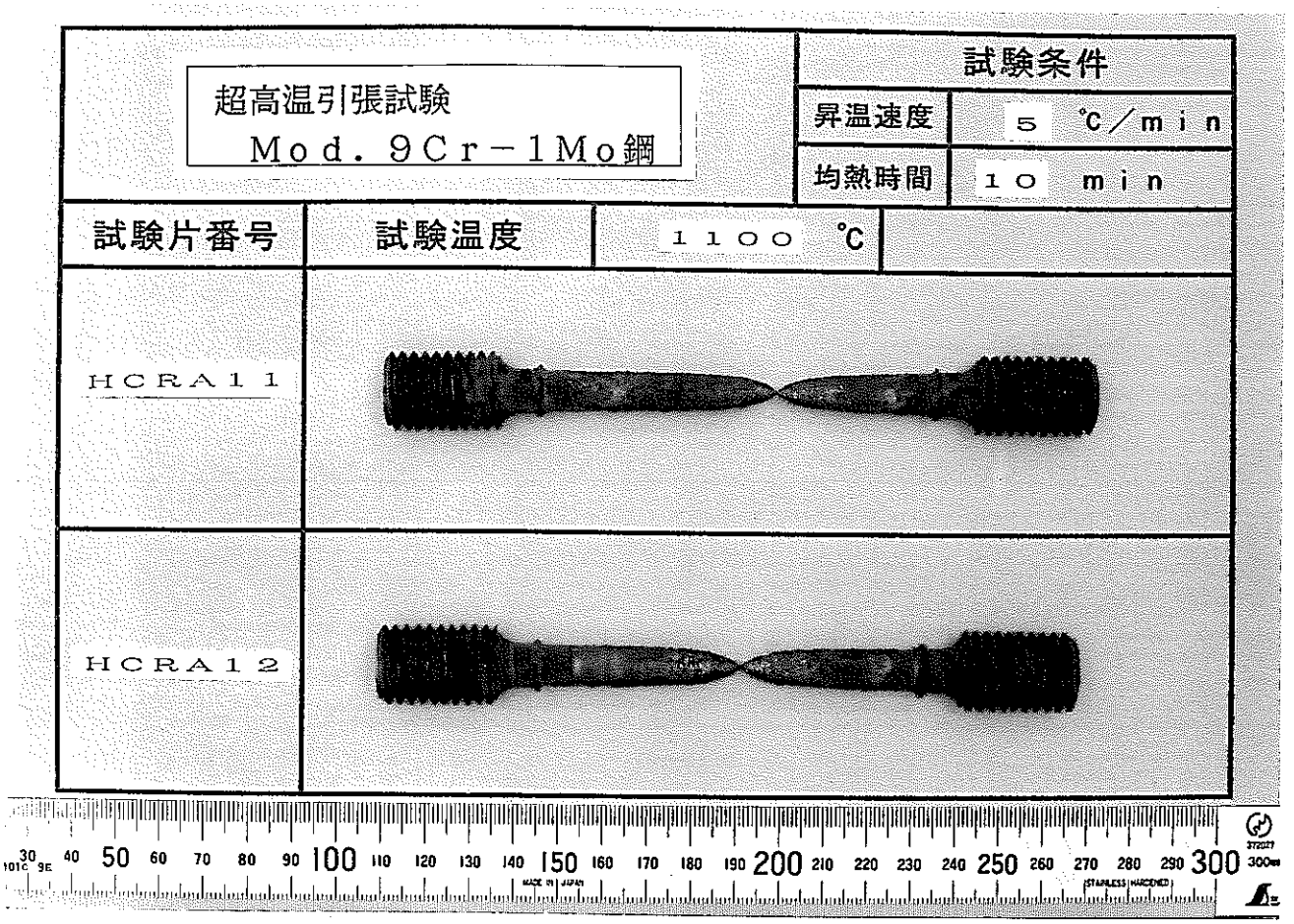


Photo. 3 Appearance of Mod.9Cr-1Mo Steel After Tensile Test at 1100℃.

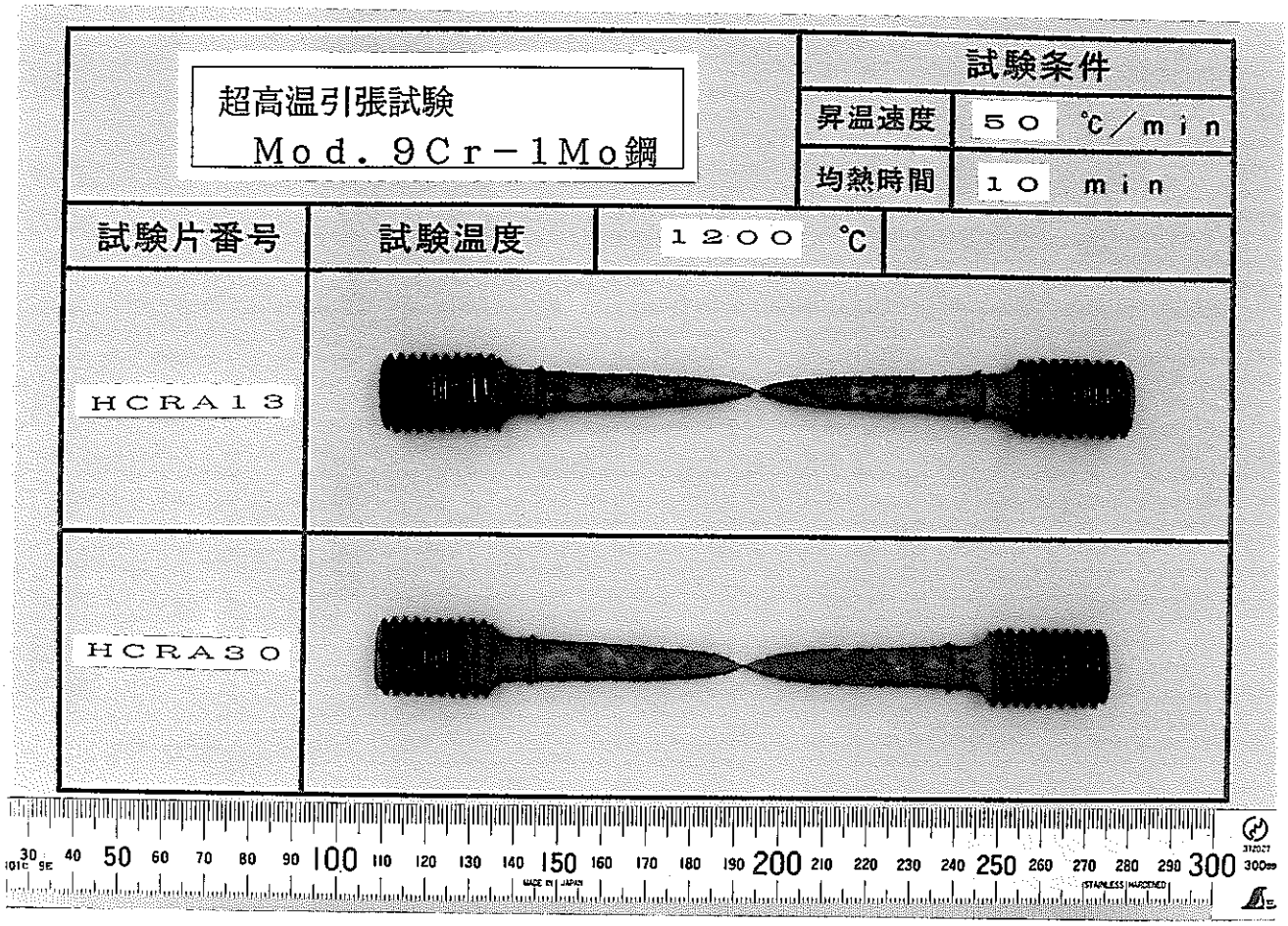
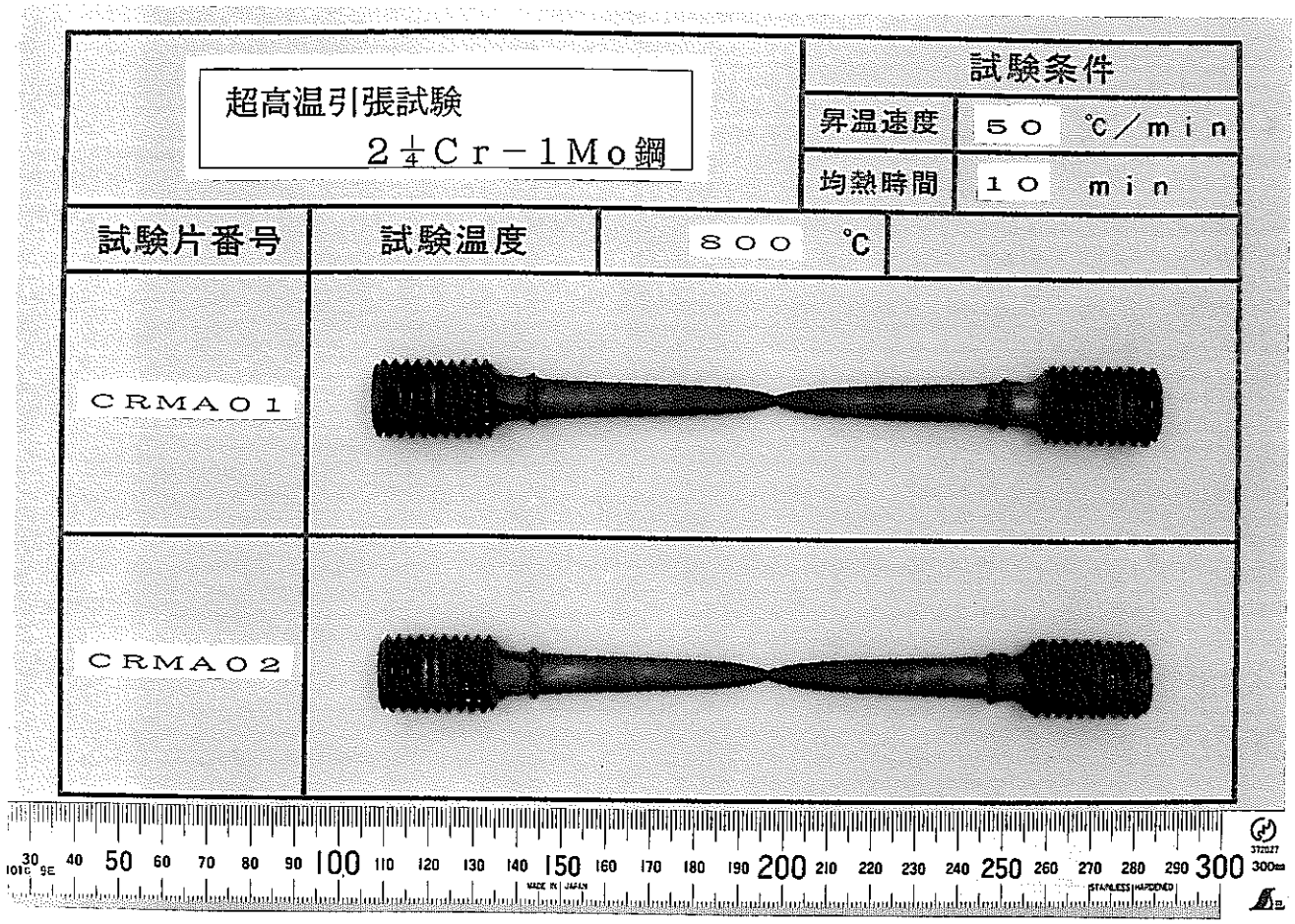


Photo. 4 Appearance of Mod.9Cr-1Mo Steel After Tensile Test at 1200℃.



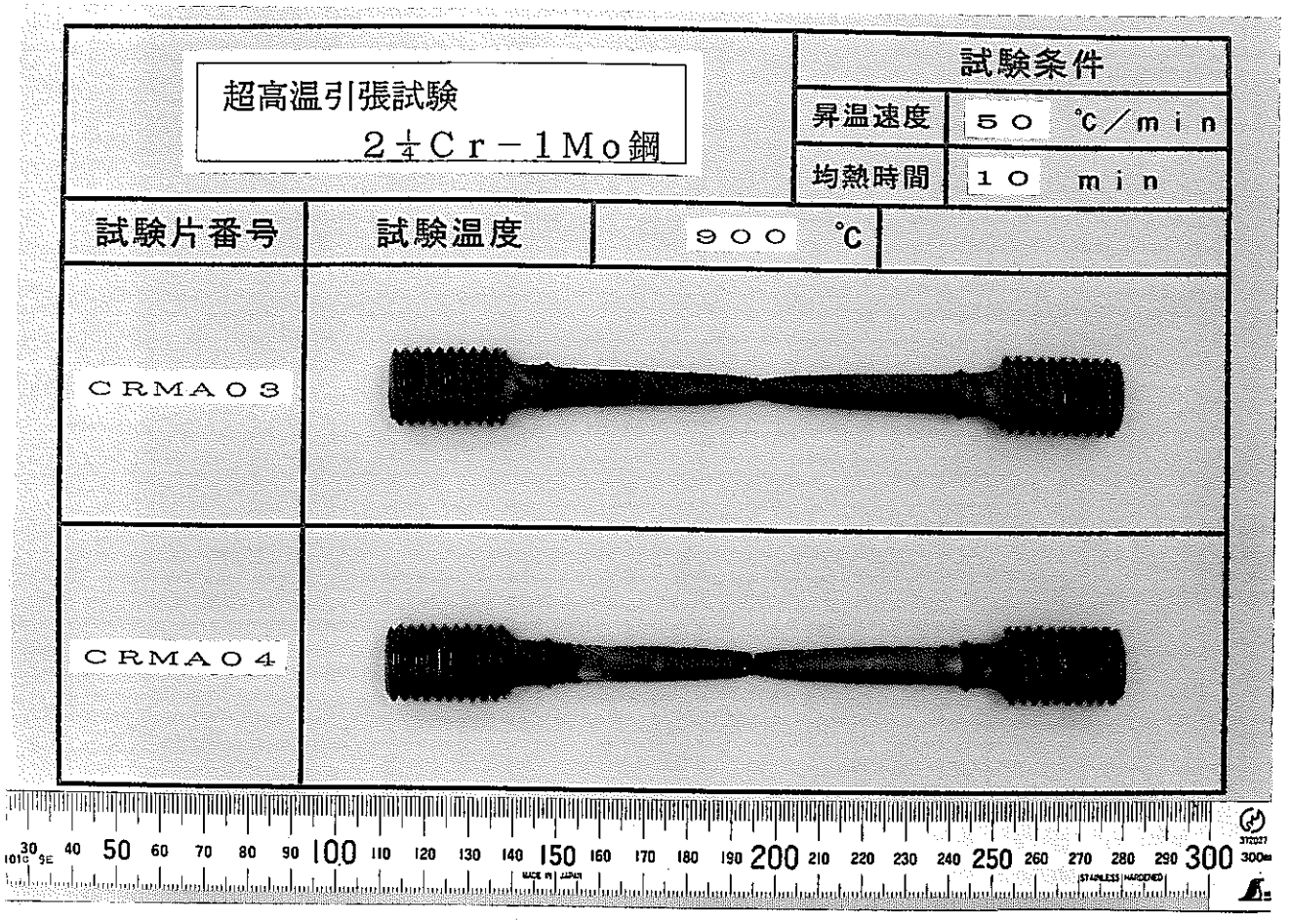
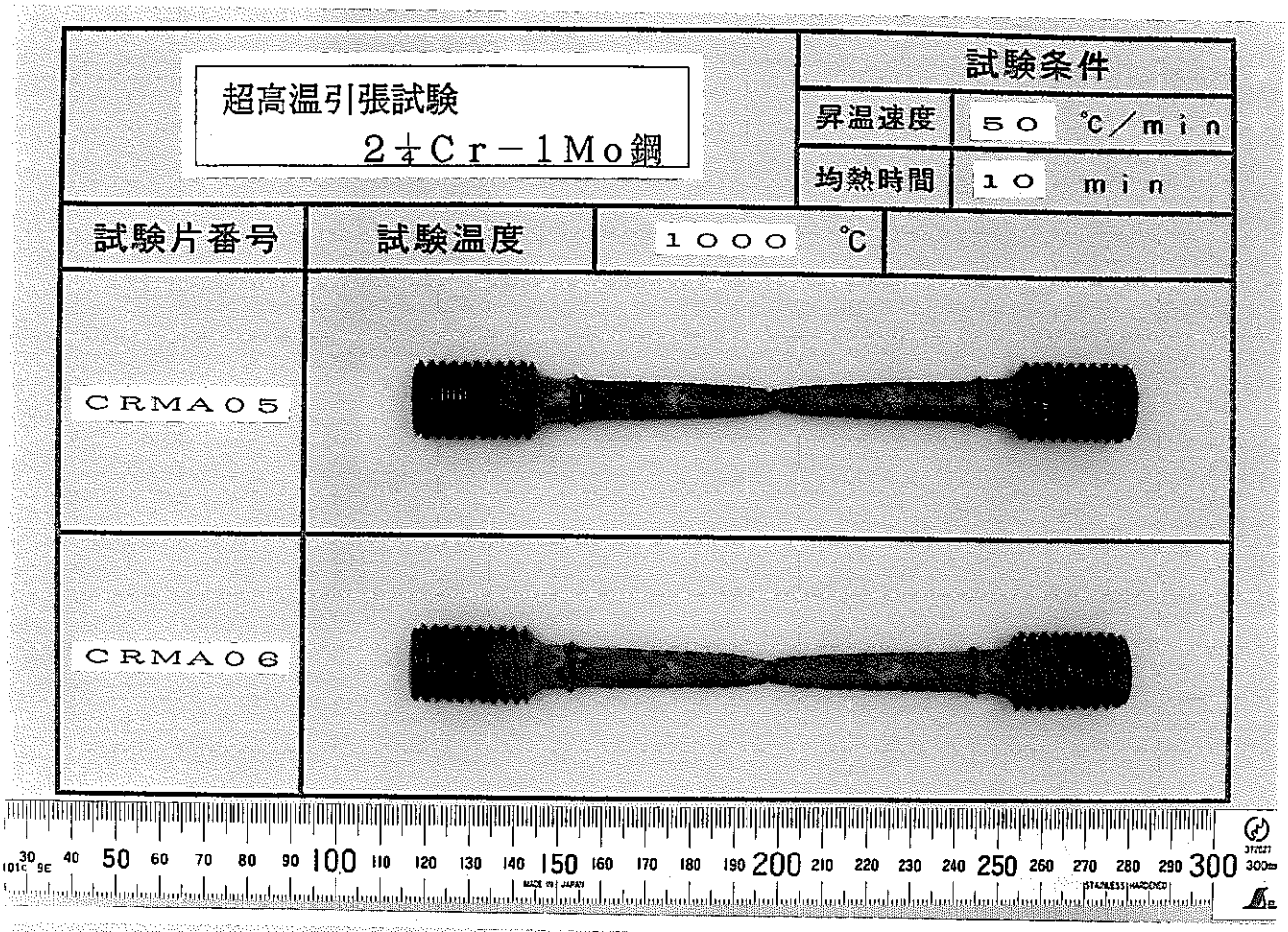


Photo. 5 Appearance of 2¼Cr-1Mo Steel After Tensile Test at 800 and 900℃.



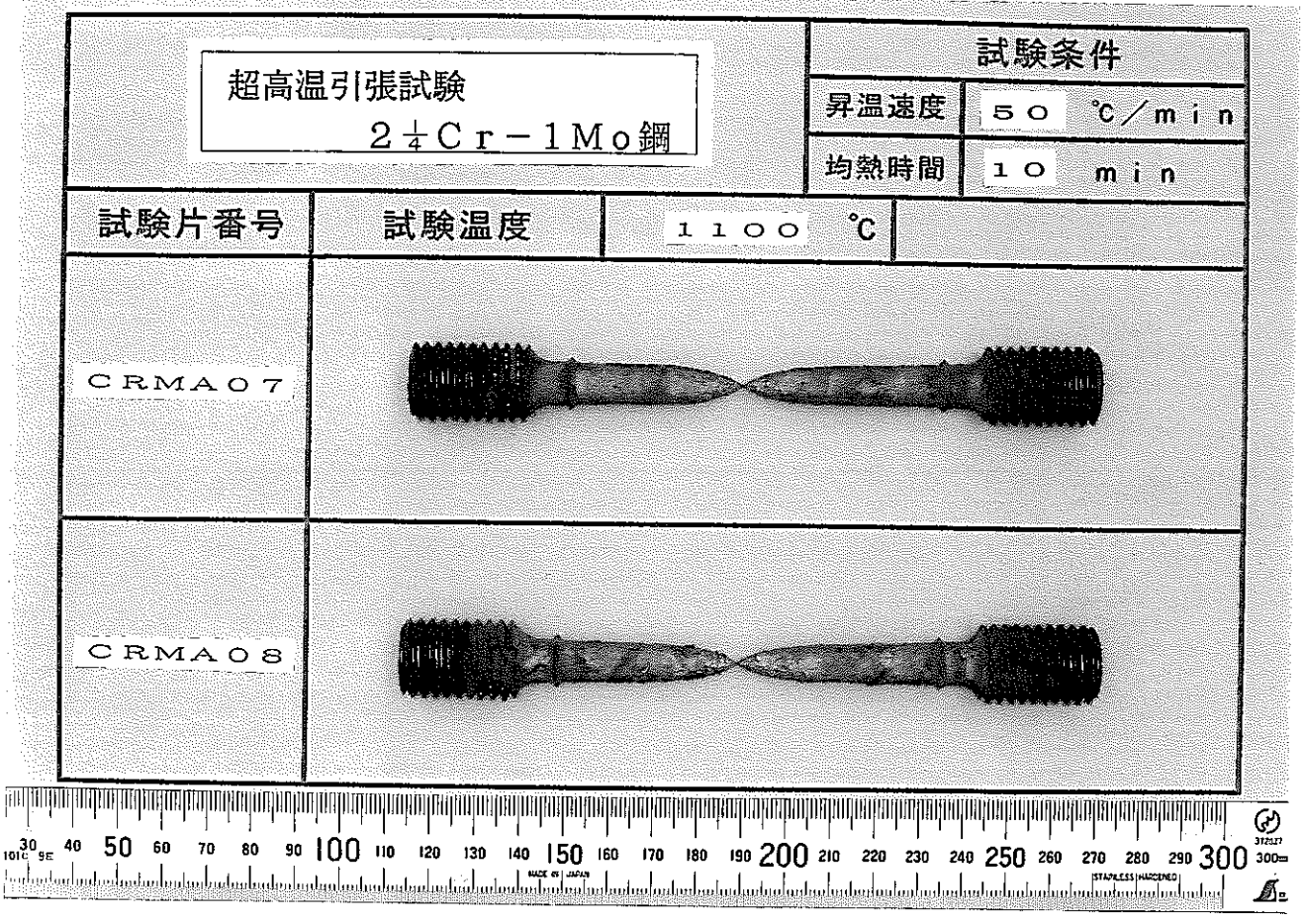
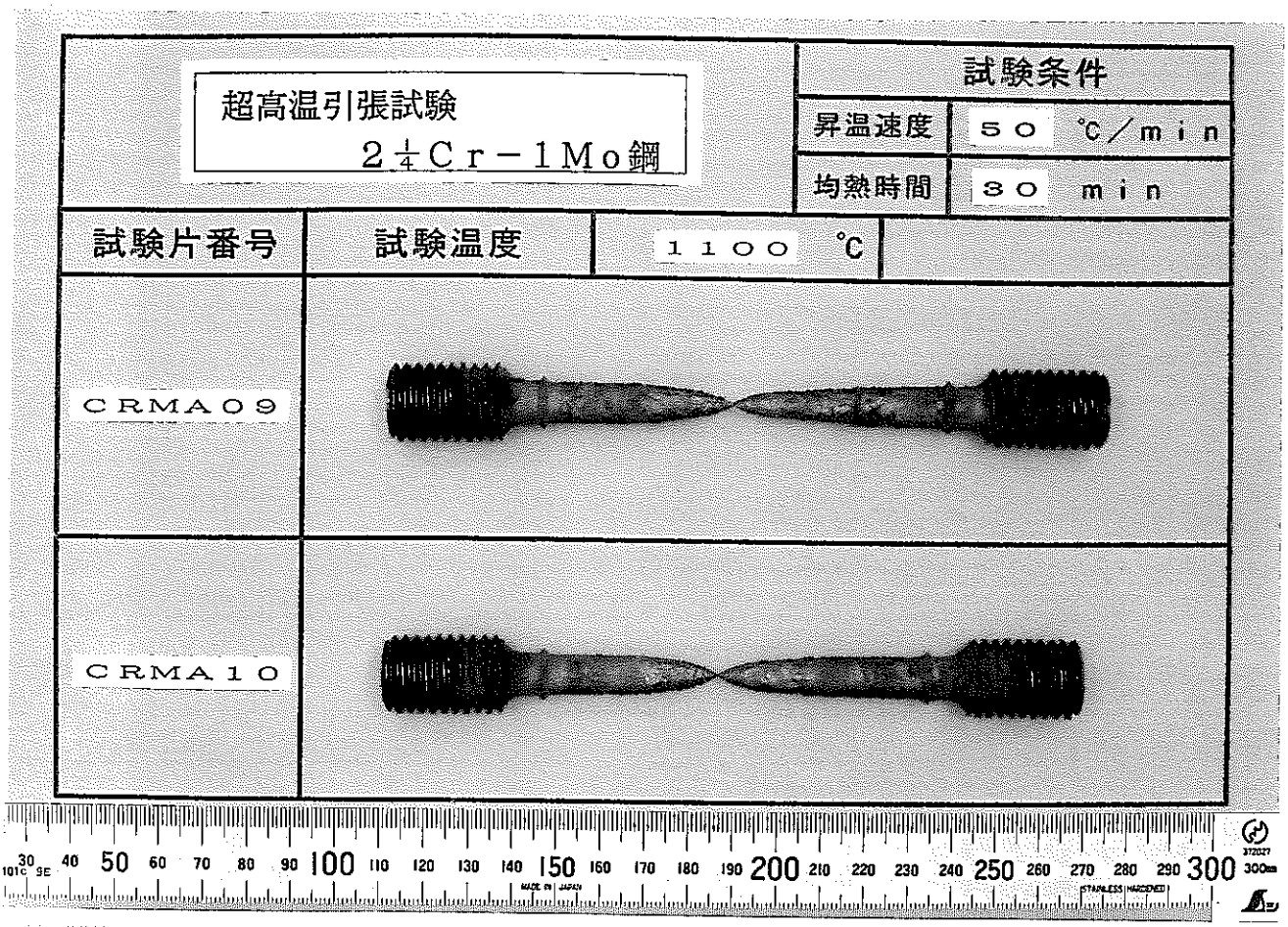


Photo. 6 Appearance of 2¼Cr-1Mo Steel After Tensile Test at 1000 and 1100℃.



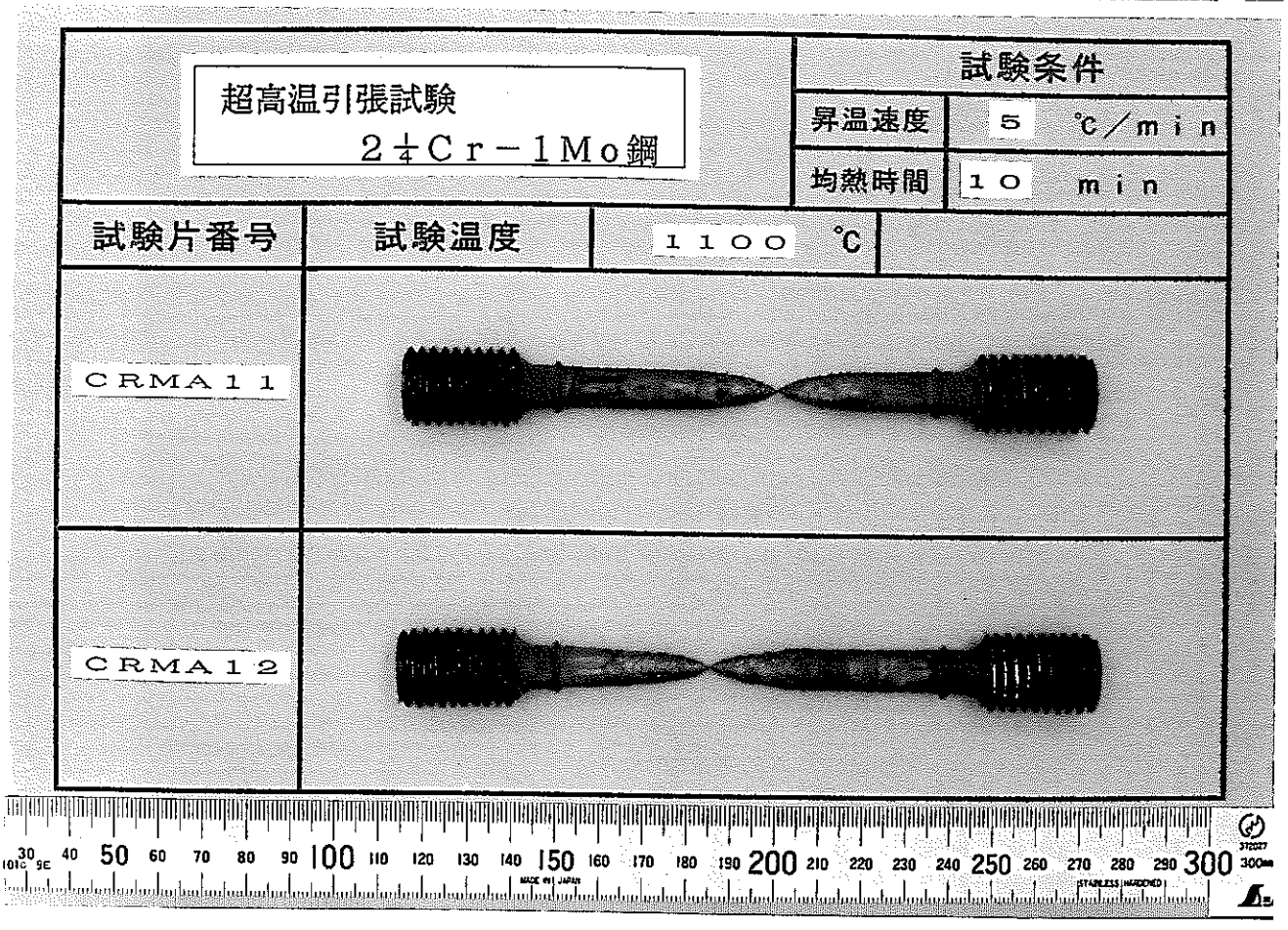


Photo. 7 Appearance of 2¼Cr-1Mo Steel After Tensile Test at 1100℃.

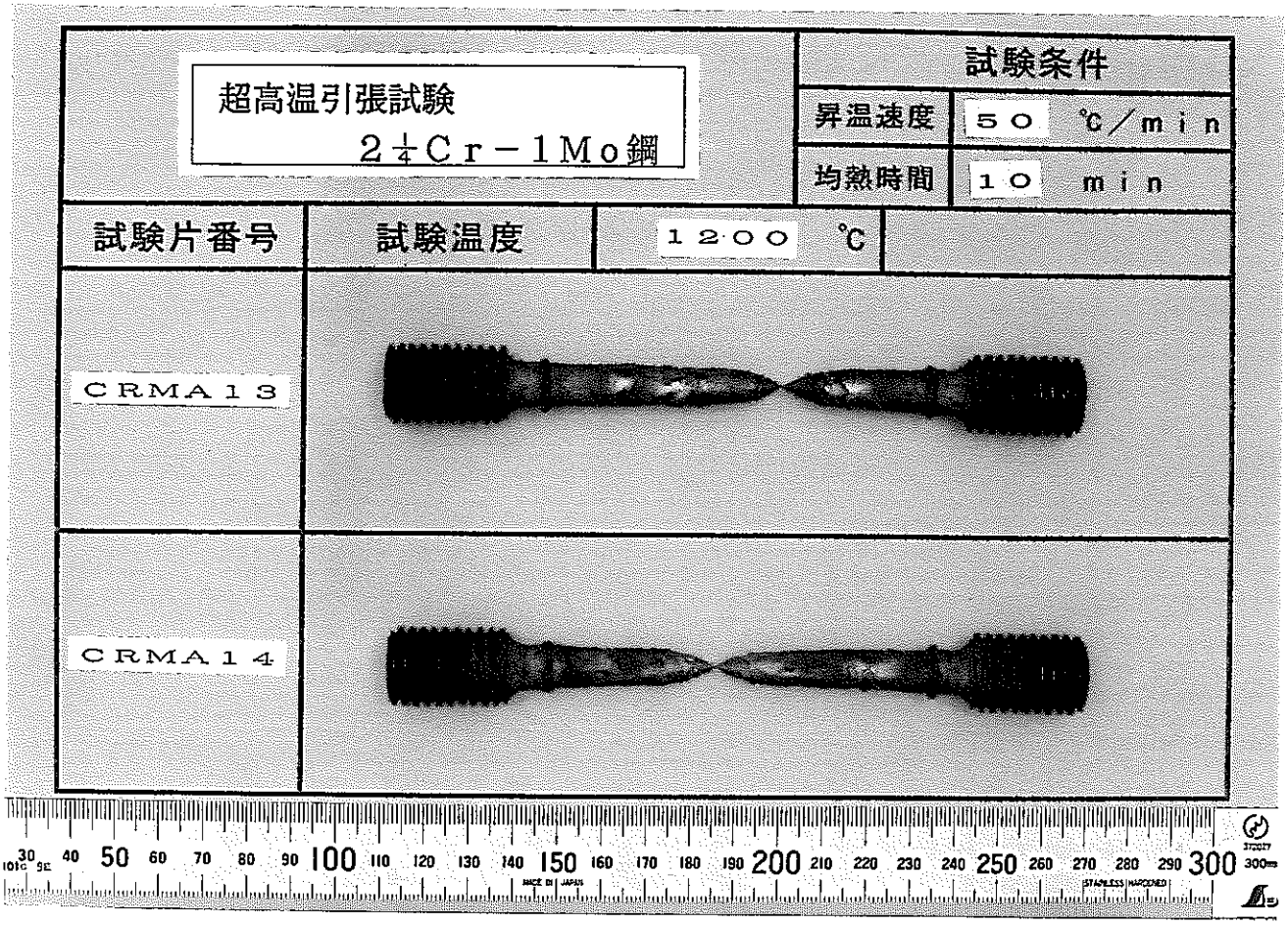
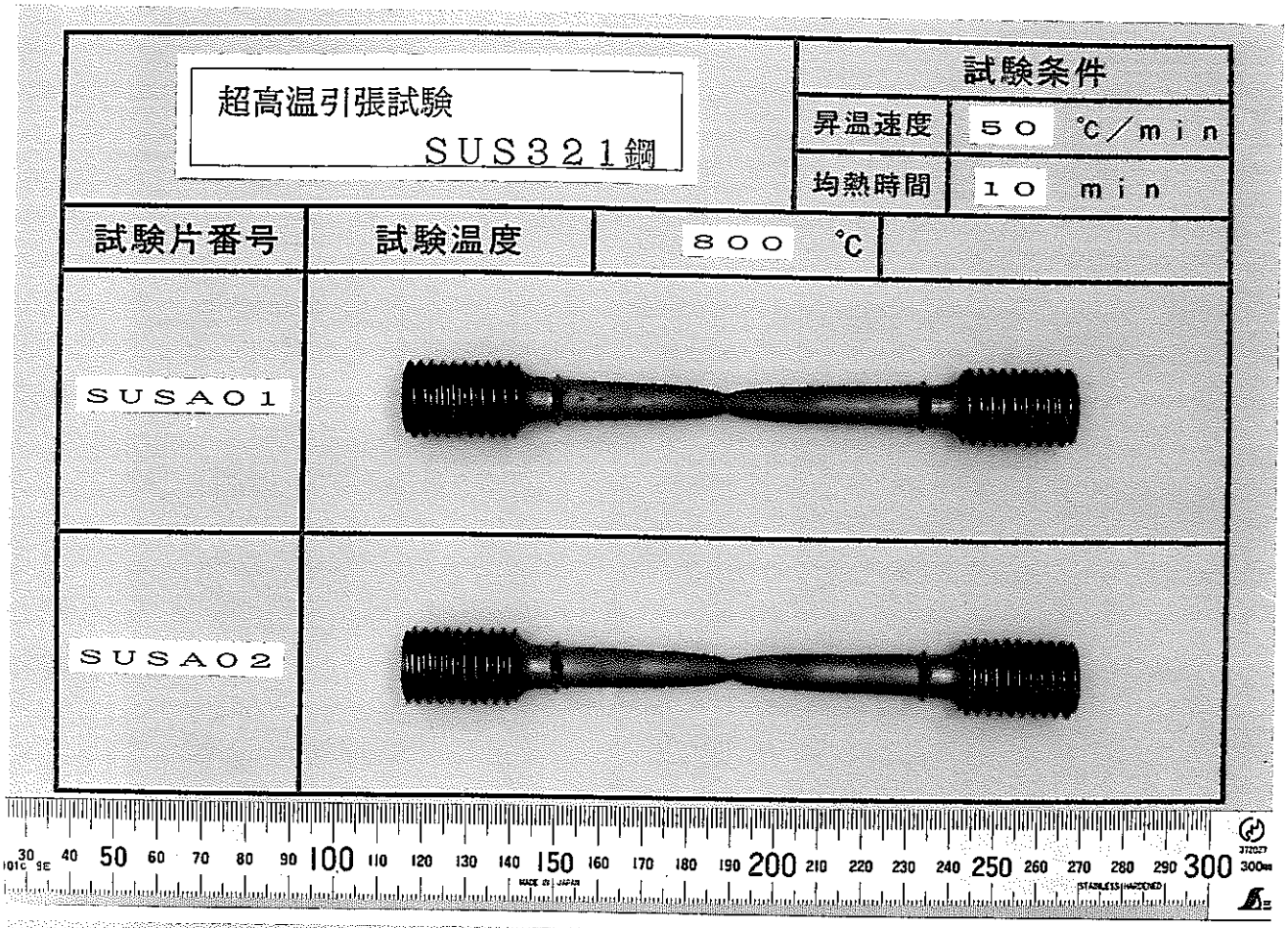


Photo. 8 Appearance of 2¼Cr-1Mo Steel After Tensile Test at 1200℃.



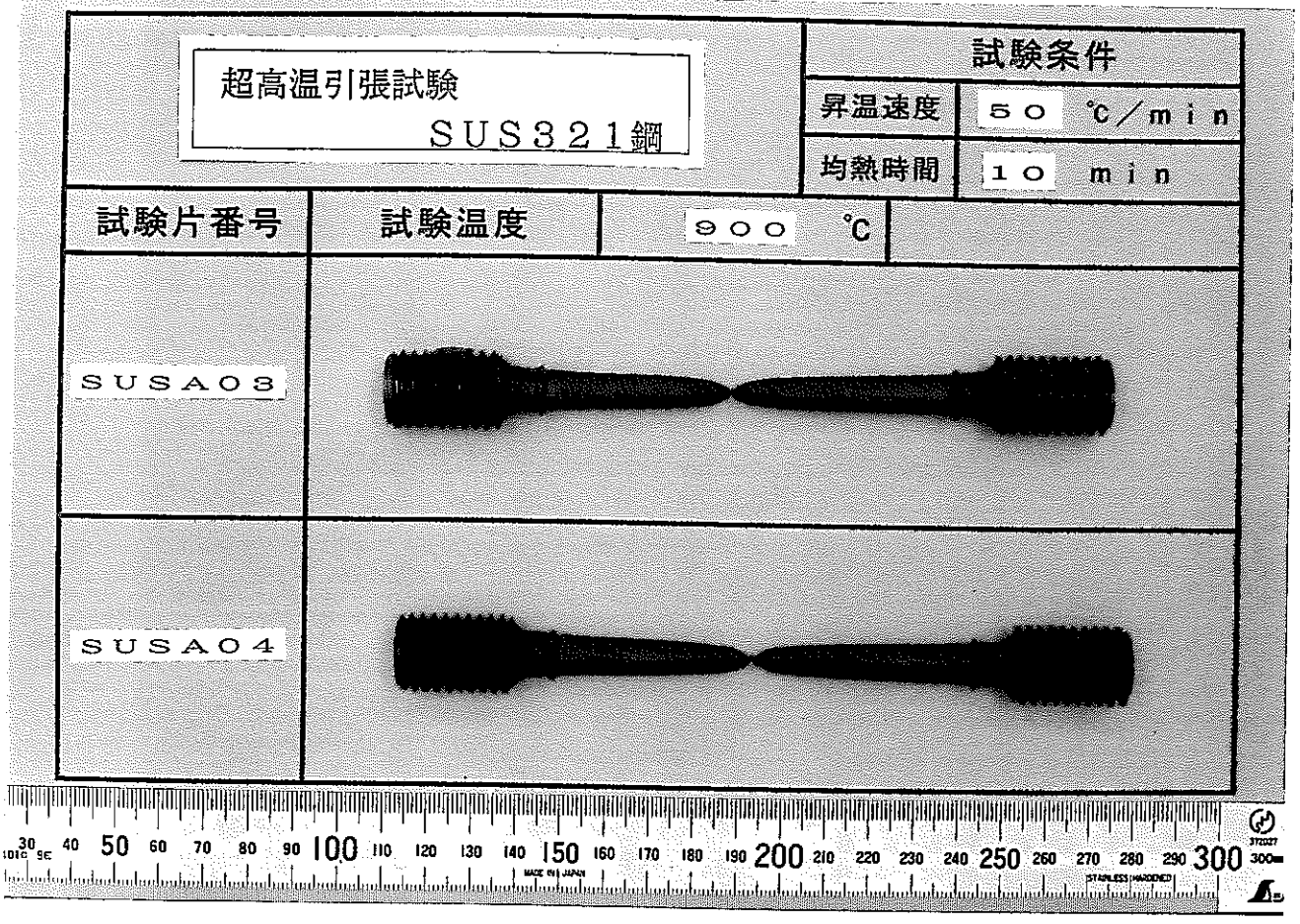
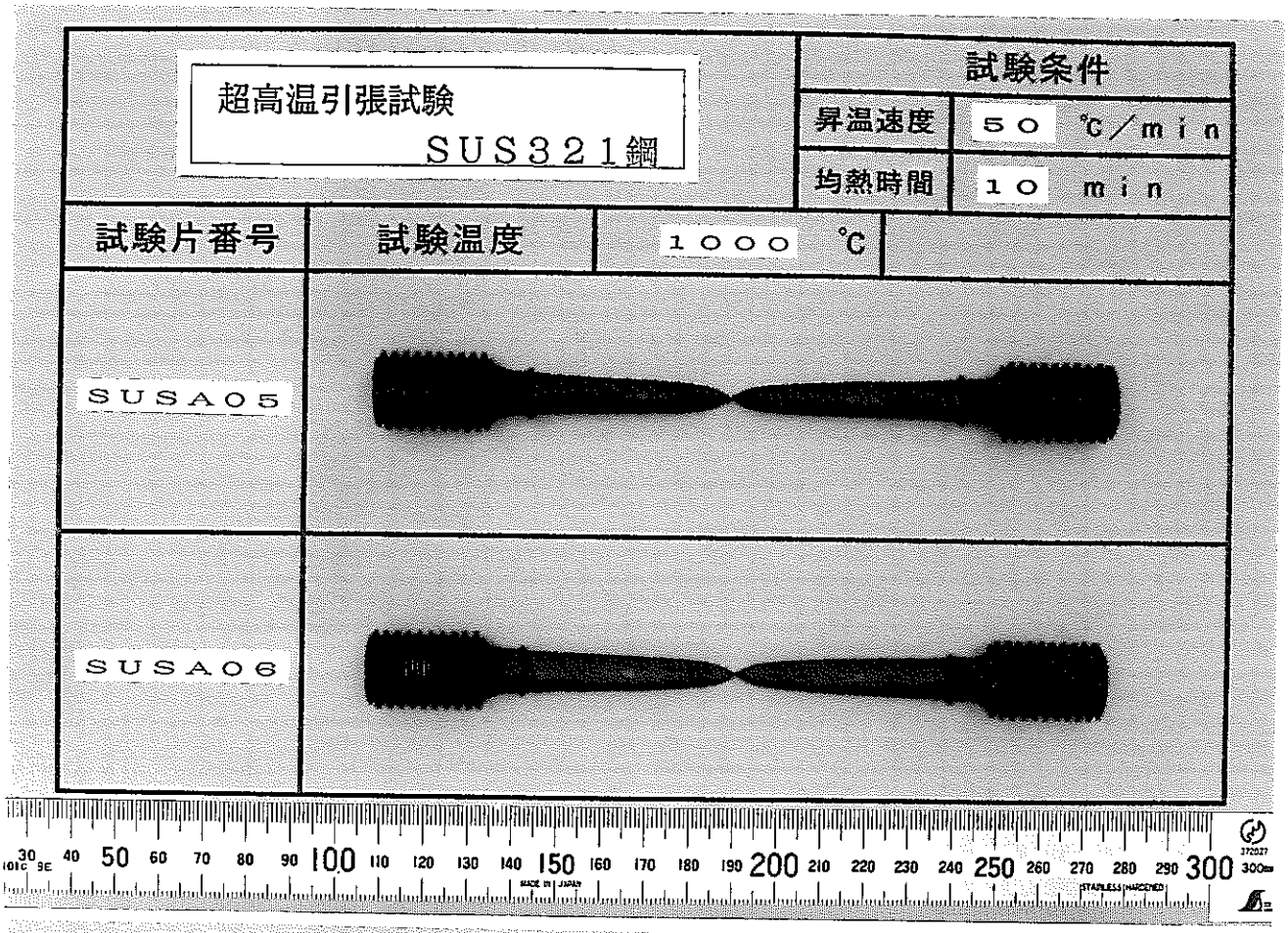


Photo. 9 Appearance of SUS321 Stainless Steel After Tensile Test at 800 and 900 ℃.



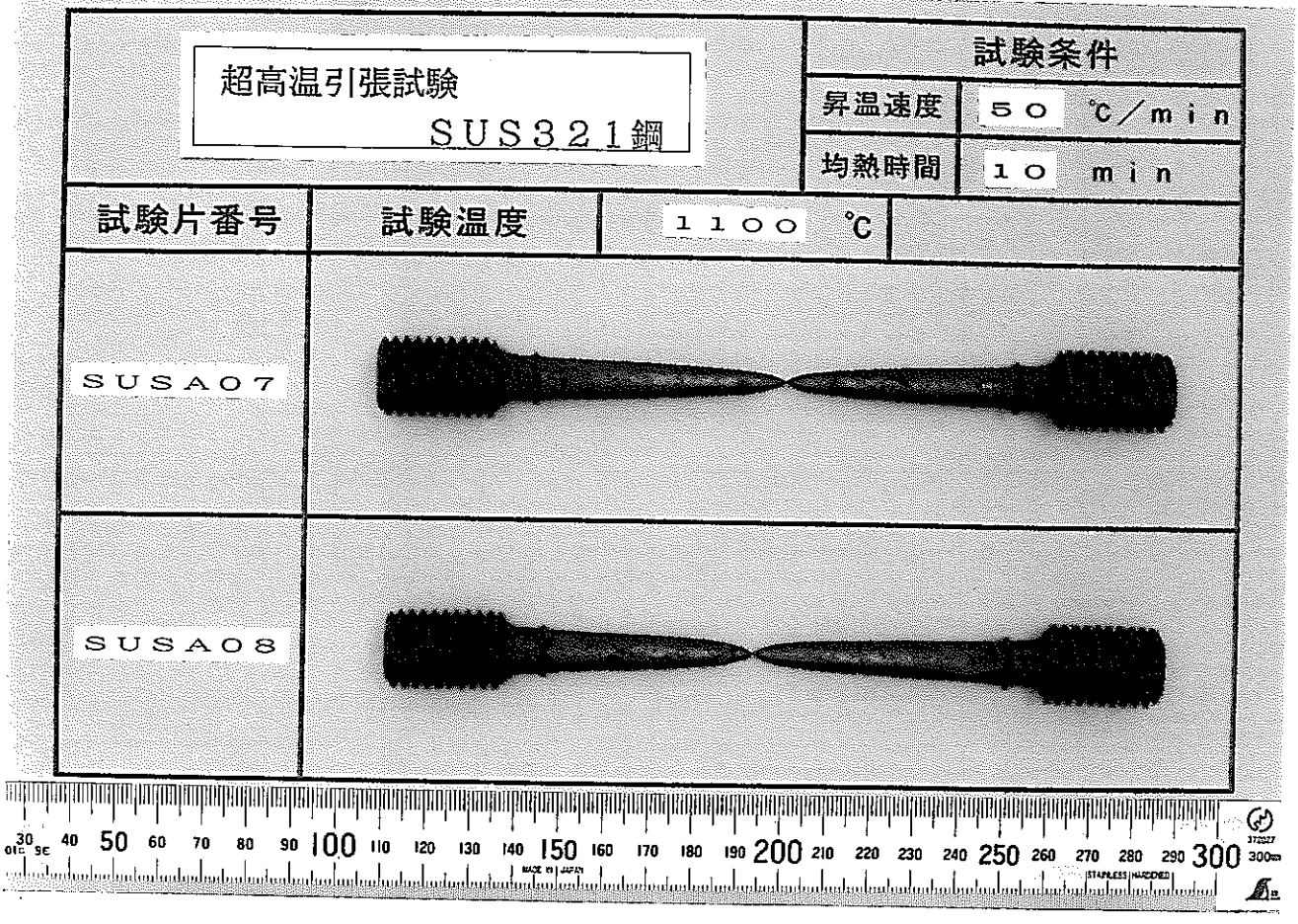
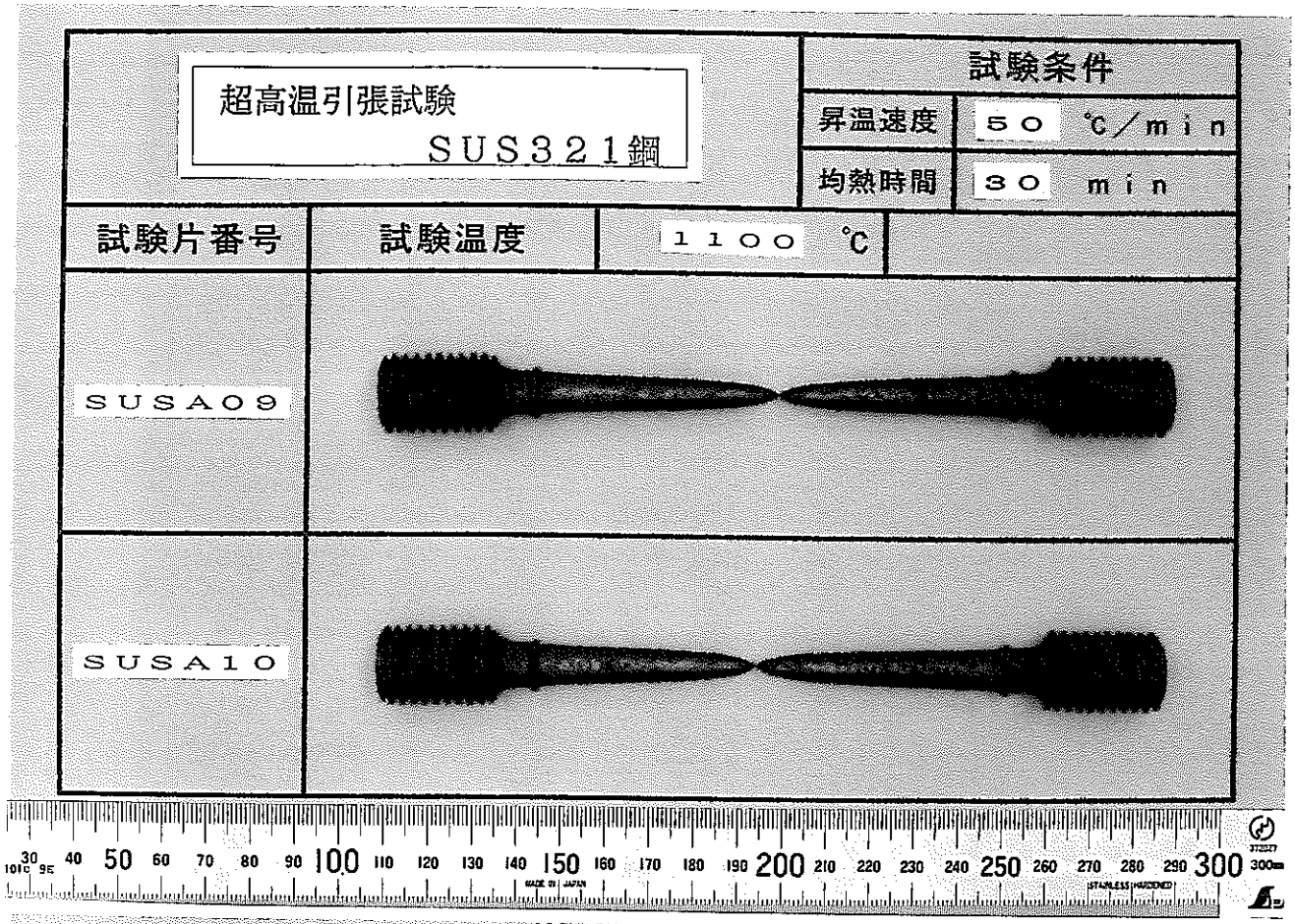


Photo.10 Appearance of SUS321 Stainless Steel After Tensile Test at 1000 and 1100℃.



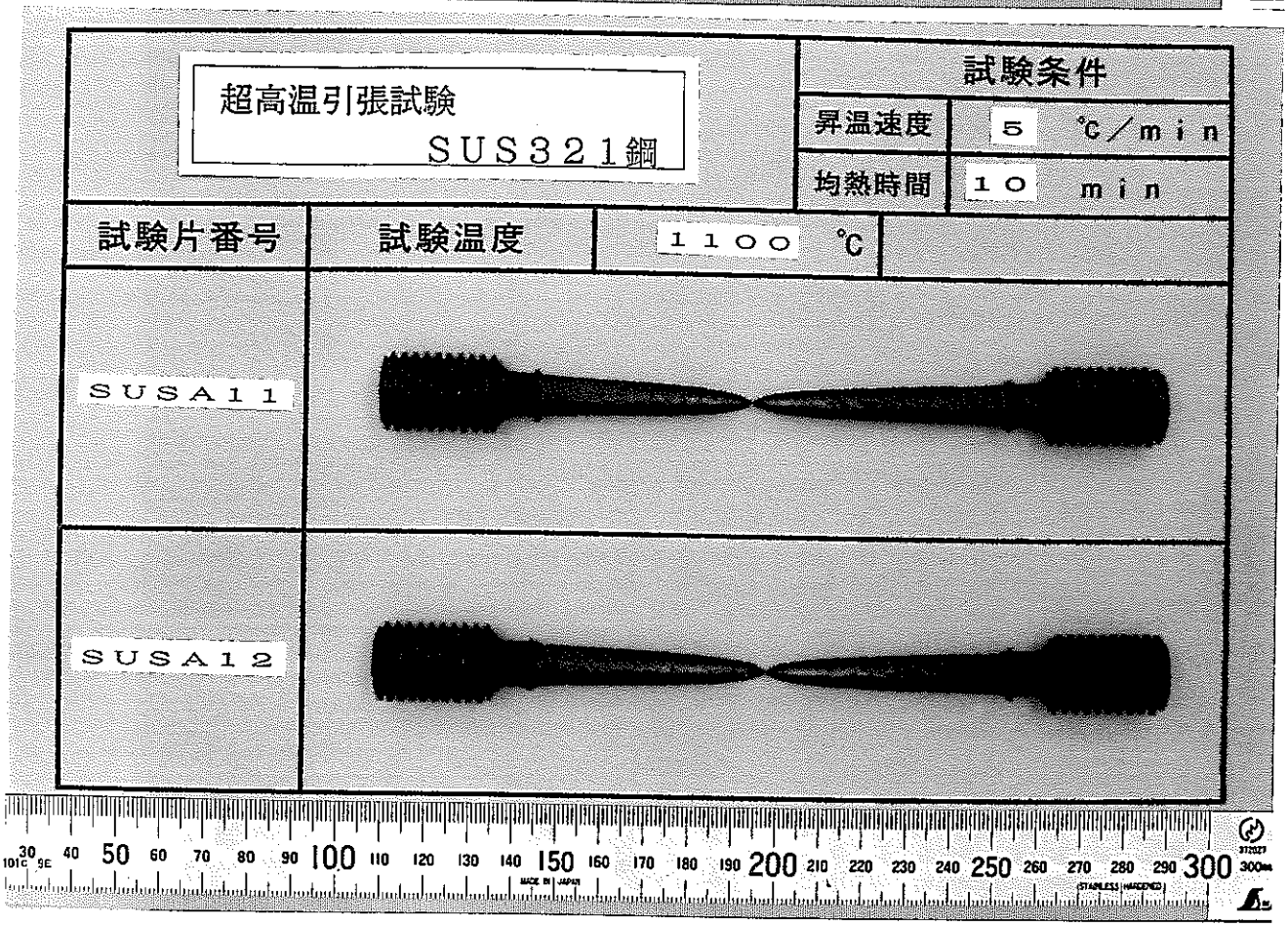


Photo.11 Appearance of SUS321 Stainless Steel After Tensile Test at 1100℃.

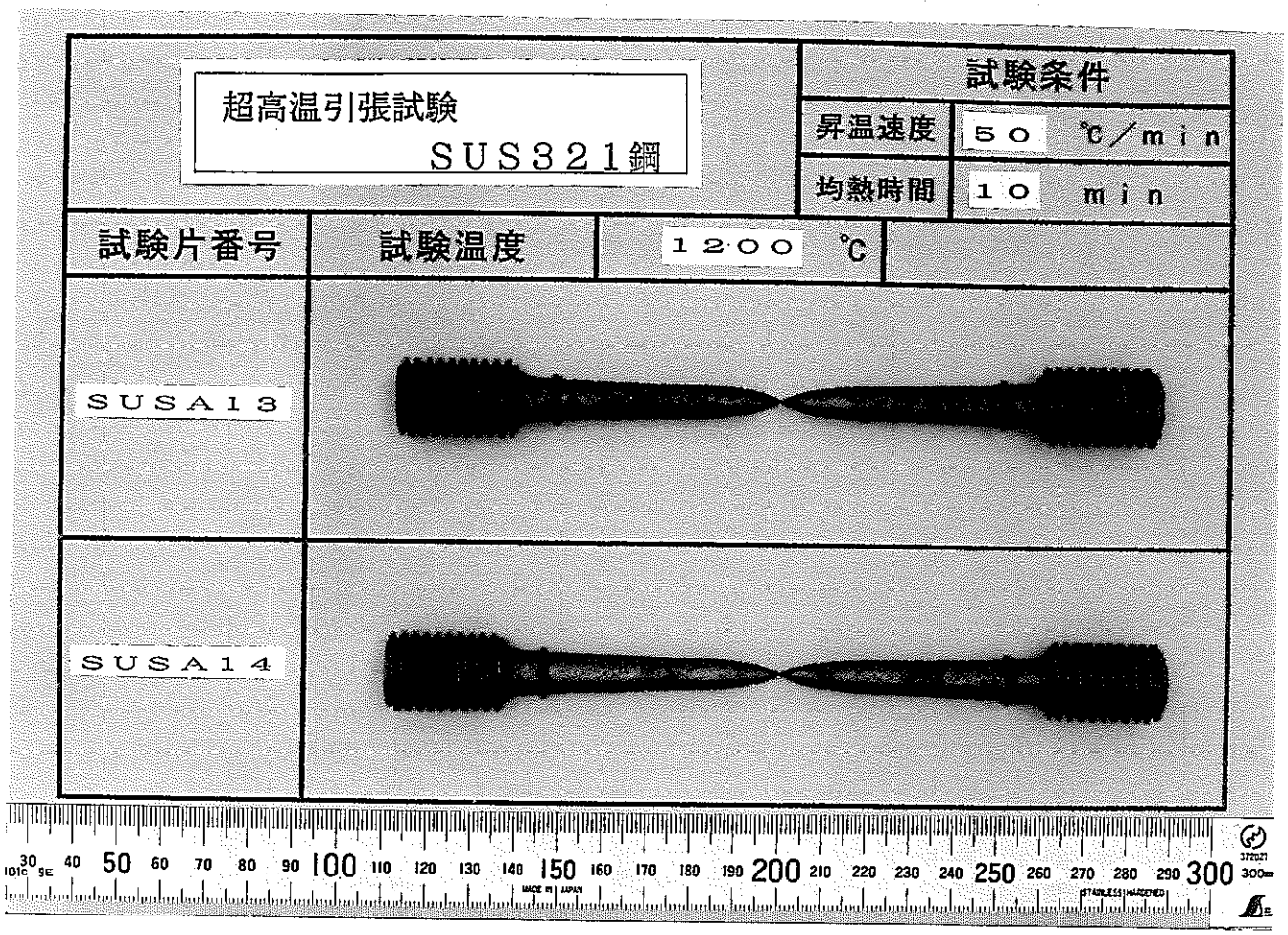


Photo.12 Appearance of SUS321 Stainless Steel After Tensile Test at 1200℃.

Appendix a　応力－ひずみ関係一覧

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA01											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)			
1	0.0	0.0	46	6.543	9.911	91	46.105	2.604			
2	0.221	6.103	47	7.430	9.740	92	46.438	2.496			
3	0.244	6.234	48	8.315	9.554	93	46.771	2.404			
4	0.269	6.374	49	9.201	9.383	94	47.105	2.295			
5	0.269	6.514	50	10.087	9.213	95	47.438	2.187			
6	0.244	6.653	51	10.948	9.058	96	47.771	2.093			
7	0.269	6.793	52	11.834	8.903	97	48.105	1.985			
8	0.293	6.916	53	12.720	8.748	98	48.438	1.875			
9	0.293	7.056	54	13.605	8.608	99	48.771	1.767			
10	0.293	7.180	55	14.492	8.468	100	49.105	1.658			
11	0.293	7.305	56	15.353	8.329	101	49.438	1.550			
12	0.317	7.429	57	16.239	8.189	102	54.225	0.0			
13	0.317	7.537	58	17.125	8.064	103					
14	0.342	7.647	59	17.986	7.925	104					
15	0.366	7.755	60	18.872	7.802	105					
16	0.366	7.862	61	19.734	7.677	106					
17	0.366	7.956	62	20.619	7.553	107					
18	0.392	8.064	63	21.505	7.429	108					
19	0.392	8.142	64	22.366	7.290	109					
20	0.416	8.236	65	23.252	7.180	110					
21	0.441	8.313	66	24.113	7.056	111					
22	0.441	8.406	67	25.000	6.933	112					
23	0.441	8.484	68	25.861	6.808	113					
24	0.416	8.561	69	26.771	6.684	114					
25	0.489	8.623	70	27.632	6.544	115					
26	0.515	8.701	71	28.519	6.404	116					
27	0.515	8.763	72	29.380	6.281	117					
28	0.539	8.825	73	30.266	6.142	118					
29	1.499	10.159	74	31.151	6.002	119					
30	2.483	10.391	75	32.038	5.862	120					
31	2.729	10.391	76	32.898	5.707	121					
32	2.754	10.391	77	33.785	5.552	122					
33	2.778	10.406	78	34.670	5.397	123					
34	2.803	10.391	79	35.556	5.226	124					
35	2.803	10.391	80	36.442	5.071	125					
36	2.828	10.391	81	37.304	4.885	126					
37	2.852	10.391	82	38.189	4.714	127					
38	2.877	10.391	83	39.075	4.529	128					
39	2.901	10.391	84	39.936	4.327	129					
40	2.901	10.406	85	40.823	4.125	130					
41	2.901	10.406	86	41.708	3.923	131					
42	2.926	10.391	87	42.570	3.706	132					
43	3.861	10.346	88	43.455	3.473	133					
44	4.747	10.221	89	44.342	3.225	134					
45	5.632	10.066	90	45.771	2.698	135					

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA02											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	6.030	10.155	91	45.148	2.970			
2	0.205	5.508	47	6.915	9.968	92	45.482	2.877			
3	0.228	5.647	48	7.800	9.790	93	45.815	2.785			
4	0.228	5.802	49	8.686	9.604	94	46.148	2.691			
5	0.228	5.950	50	9.546	9.441	95	46.482	2.598			
6	0.228	6.089	51	10.407	9.271	96	46.815	2.497			
7	0.253	6.237	52	11.291	9.108	97	47.148	2.396			
8	0.277	6.369	53	12.152	8.961	98	47.482	2.295			
9	0.277	6.509	54	13.013	8.812	99	47.815	2.195			
10	0.277	6.641	55	13.848	8.665	100	48.148	2.086			
11	0.301	6.772	56	14.734	8.542	101	48.482	1.985			
12	0.301	6.904	57	15.593	8.402	102	48.815	1.876			
13	0.301	7.028	58	16.454	8.262	103	49.148	1.776			
14	0.326	7.145	59	17.314	8.137	104	49.482	1.666			
15	0.326	7.268	60	18.175	8.014	105	49.815	1.558			
16	0.351	7.378	61	19.036	7.890	106	50.148	1.458			
17	0.351	7.486	62	19.896	7.765	107	50.482	1.349			
18	0.376	7.595	63	20.757	7.650	108	50.815	1.241			
19	0.376	7.695	64	21.617	7.525	109	51.148	1.139			
20	0.400	7.797	65	22.478	7.393	110	51.482	1.031			
21	0.425	7.897	66	23.339	7.285	111	51.815	0.930			
22	0.425	7.982	67	24.223	7.160	112	52.148	0.829			
23	0.449	8.075	68	25.059	7.028	113	52.482	0.736			
24	0.449	8.153	69	25.919	6.919	114	54.541	0.0			
25	0.449	8.247	70	26.780	6.788	115					
26	0.498	8.324	71	27.640	6.671	116					
27	0.498	8.402	72	28.526	6.539	117					
28	0.498	8.472	73	29.386	6.399	118					
29	0.523	8.542	74	30.246	6.284	119					
30	1.433	10.046	75	31.107	6.152	120					
31	2.342	10.458	76	31.993	6.012	121					
32	3.154	10.535	77	32.852	5.872	122					
33	3.178	10.535	78	33.713	5.732	123					
34	3.178	10.535	79	34.573	5.593	124					
35	3.203	10.535	80	35.459	5.438	125					
36	3.227	10.535	81	36.320	5.290	126					
37	3.227	10.543	82	37.179	5.143	127					
38	3.252	10.543	83	38.040	4.973	128					
39	3.276	10.535	84	38.900	4.810	129					
40	3.276	10.535	85	39.761	4.646	130					
41	3.301	10.535	86	40.622	4.468	131					
42	3.326	10.535	87	41.482	4.274	132					
43	3.350	10.535	88	42.343	4.088	133					
44	4.260	10.465	89	43.203	3.886	134					
45	5.145	10.325	90	44.088	3.669	135					

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA03											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	12.447	9.501	91	46.252	7.312
2	0.150	6.006	47	13.186	9.486	92	47.585	7.210
3	0.172	6.171	48	13.924	9.462	93	48.919	7.110
4	0.172	6.350	49	14.686	9.431	94	50.252	7.017
5	0.172	6.520	50	15.400	9.409	95	51.585	6.923
6	0.196	6.675	51	16.163	9.377	96	52.919	6.823
7	0.196	6.823	52	16.876	9.346	97	54.252	6.722
8	0.221	6.955	53	17.614	9.322	98	55.585	6.621
9	0.221	7.072	54	18.353	9.284	99	56.919	6.520
10	0.221	7.188	55	19.115	9.252	100	58.252	6.411
11	0.270	7.280	56	19.853	9.214	101	59.585	6.310
12	0.270	7.367	57	20.566	9.182	102	60.919	6.202
13	0.270	7.444	58	21.305	9.137	103	62.252	6.093
14	0.295	7.514	59	22.042	9.105	104	63.585	5.985
15	0.295	7.575	60	22.805	9.051	105	64.919	5.876
16	0.344	7.630	61	23.542	9.020	106	66.252	5.768
17	0.368	7.677	62	24.281	8.974	107	67.585	5.643
18	0.368	7.715	63	24.995	8.919	108	68.919	5.518
19	0.394	7.755	64	25.732	8.880	109	70.252	5.395
20	1.255	8.453	65	26.470	8.826	110	71.585	5.270
21	2.067	8.795	66	27.233	8.787	111	72.919	5.138
22	2.853	9.012	67	27.971	8.732	112	74.252	5.006
23	3.616	9.152	68	28.709	8.686	113	75.585	4.874
24	4.354	9.261	69	29.422	8.639	114	76.919	4.726
25	5.141	9.354	70	30.161	8.585	115	78.252	4.579
26	5.854	9.409	71	30.923	8.531	116	79.585	4.424
27	6.593	9.447	72	31.661	8.469	117	80.919	4.269
28	7.331	9.486	73	32.400	8.422	118	82.252	4.106
29	8.069	9.517	74	33.162	8.367	119	83.585	3.934
30	8.807	9.517	75	33.875	8.305	120	84.919	3.749
31	9.545	9.524	76	34.613	8.267	121	86.252	3.554
32	10.061	9.524	77	35.229	8.329	122	87.585	3.344
33	10.086	9.517	78	36.040	8.220	123	88.919	3.119
34	10.086	9.517	79	36.803	8.135	124	90.252	2.871
35	10.111	9.524	80	37.591	8.057	125	91.585	2.607
36	10.111	9.524	81	38.304	8.003	126	92.919	2.327
37	10.135	9.532	82	39.066	7.940	127	94.252	2.009
38	10.160	9.532	83	39.804	7.887	128	95.585	1.676
39	10.160	9.532	84	40.517	7.832	129	96.919	1.319
40	10.184	9.524	85	41.256	7.777	130	98.252	0.945
41	10.210	9.524	86	42.018	7.723	131	101.170	0.0
42	10.234	9.524	87	42.732	7.677	132		
43	10.258	9.524	88	43.495	7.622	133		
44	10.972	9.524	89	44.208	7.568	134		
45	11.710	9.517	90	44.946	7.530	135		

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA04								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	13.285	9.555	91	47.605	7.289
2	0.149	6.033	47	13.999	9.539	92	48.938	7.187
3	0.166	6.178	48	14.738	9.508	93	50.271	7.094
4	0.166	6.387	49	15.476	9.493	94	51.605	6.992
5	0.190	6.582	50	16.215	9.453	95	52.938	6.900
6	0.190	6.760	51	16.953	9.431	96	54.271	6.807
7	0.190	6.922	52	17.691	9.408	97	55.605	6.706
8	0.215	7.079	53	18.430	9.368	98	56.938	6.605
9	0.239	7.210	54	19.169	9.330	99	58.271	6.504
10	0.264	7.334	55	19.907	9.291	100	59.605	6.403
11	0.264	7.444	56	20.645	9.251	101	60.938	6.302
12	0.289	7.536	57	21.384	9.213	102	62.271	6.202
13	0.289	7.622	58	22.122	9.174	103	63.605	6.092
14	0.313	7.684	59	22.861	9.120	104	64.938	5.992
15	0.338	7.746	60	23.599	9.089	105	66.271	5.883
16	0.362	7.801	61	24.337	9.043	106	67.605	5.775
17	0.387	7.839	62	25.052	9.003	107	68.938	5.665
18	0.387	7.886	63	25.789	8.956	108	70.271	5.565
19	0.411	7.917	64	26.528	8.903	109	71.605	5.448
20	1.322	8.576	65	27.291	8.856	110	72.938	5.340
21	2.135	8.895	66	28.005	8.809	111	74.271	5.223
22	2.898	9.081	67	28.743	8.756	112	75.605	5.115
23	3.636	9.228	68	29.507	8.708	113	76.938	4.998
24	4.399	9.338	69	30.220	8.654	114	78.271	4.881
25	5.138	9.408	70	30.959	8.608	115	79.605	4.765
26	5.876	9.485	71	31.722	8.546	116	80.938	4.633
27	6.615	9.531	72	32.435	8.506	117	82.271	4.508
28	7.353	9.555	73	33.174	8.452	118	83.605	4.385
29	8.091	9.570	74	33.937	8.391	119	84.938	4.253
30	8.830	9.586	75	34.651	8.336	120	86.271	4.113
31	9.470	9.703	76	35.390	8.289	121	87.605	3.973
32	10.282	9.648	77	36.128	8.227	122	88.938	3.833
33	10.849	9.616	78	36.867	8.181	123	90.271	3.678
34	10.873	9.616	79	37.605	8.126	124	91.605	3.516
35	10.898	9.616	80	38.344	8.064	125	92.938	3.344
36	10.898	9.616	81	39.107	8.009	126	94.271	3.166
37	10.922	9.616	82	39.820	7.964	127	95.605	2.972
38	10.972	9.616	83	40.559	7.917	128	96.938	2.762
39	10.972	9.616	84	41.298	7.869	129	98.271	2.529
40	10.996	9.616	85	42.011	7.816	130	99.605	2.274
41	11.021	9.616	86	42.774	7.769	131	100.930	2.002
42	11.021	9.616	87	43.488	7.714	132	102.270	1.699
43	11.045	9.616	88	44.226	7.661	133	103.600	1.372
44	11.784	9.593	89	44.965	7.622	134	104.930	1.024
45	12.523	9.578	90	46.271	7.381	135	108.690	0.0

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA05											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	9.756	6.043	91	52.910	3.847
2	0.121	3.919	47	10.643	6.012	92	54.244	3.769
3	0.138	3.994	48	11.553	5.982	93	55.577	3.716
4	0.138	4.119	49	12.438	5.942	94	56.910	3.646
5	0.138	4.236	50	13.349	5.912	95	58.244	3.567
6	0.138	4.344	51	14.258	5.880	96	59.577	3.499
7	0.162	4.453	52	15.145	5.842	97	60.910	3.420
8	0.162	4.546	53	16.030	5.810	98	62.244	3.351
9	0.162	4.639	54	16.941	5.772	99	63.577	3.282
10	0.187	4.716	55	17.826	5.740	100	64.910	3.212
11	0.187	4.794	56	18.736	5.702	101	66.244	3.134
12	0.211	4.848	57	19.622	5.670	102	67.577	3.072
13	0.211	4.910	58	20.532	5.625	103	68.910	3.002
14	0.236	4.957	59	21.418	5.593	104	70.244	2.932
15	0.260	5.003	60	22.304	5.555	105	71.577	2.862
16	0.260	5.050	61	23.213	5.515	106	72.910	2.792
17	0.285	5.088	62	24.124	5.477	107	74.244	2.722
18	0.285	5.120	63	25.010	5.430	108	75.577	2.645
19	0.310	5.143	64	25.896	5.392	109	76.910	2.567
20	0.310	5.175	65	26.806	5.345	110	78.244	2.490
21	0.334	5.198	66	27.691	5.298	111	79.577	2.405
22	0.359	5.213	67	28.577	5.252	112	80.910	2.311
23	0.359	5.243	68	29.487	5.205	113	82.244	2.210
24	0.408	5.252	69	30.398	5.158	114	83.577	2.109
25	1.294	5.717	70	31.308	5.112	115	84.910	1.993
26	2.179	5.912	71	32.193	5.065	116	86.244	1.869
27	3.114	6.004	72	33.079	5.011	117	87.577	1.729
28	4.000	6.051	73	33.989	4.965	118	88.910	1.589
29	4.911	6.082	74	34.900	4.918	119	90.244	1.419
30	5.820	6.097	75	35.810	4.871	120	91.577	1.241
31	5.968	6.090	76	36.720	4.818	121	92.910	1.046
32	5.992	6.090	77	37.606	4.763	122	94.244	0.829
33	5.992	6.090	78	38.516	4.716	123	98.591	0.0
34	6.018	6.090	79	39.402	4.670	124		
35	6.042	6.097	80	40.287	4.623	125		
36	6.042	6.105	81	41.198	4.576	126		
37	6.067	6.097	82	42.083	4.531	127		
38	6.091	6.090	83	43.018	4.484	128		
39	6.115	6.090	84	43.879	4.436	129		
40	6.115	6.090	85	44.765	4.391	130		
41	6.140	6.097	86	46.244	4.212	131		
42	6.165	6.090	87	47.577	4.142	132		
43	7.075	6.082	88	48.910	4.072	133		
44	7.960	6.067	89	50.244	3.994	134		
45	8.847	6.059	90	51.577	3.917	135		

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA06											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	9.635	6.146	91	42.848	4.603
2	0.170	4.279	47	10.374	6.122	92	43.611	4.576
3	0.181	4.113	48	11.113	6.100	93	44.326	4.532
4	0.181	4.324	49	11.851	6.068	94	45.040	4.498
5	0.205	4.427	50	12.589	6.050	95	46.322	4.334
6	0.205	4.526	51	13.328	6.022	96	47.989	4.246
7	0.205	4.620	52	14.067	6.000	97	49.656	4.158
8	0.231	4.703	53	14.806	5.967	98	51.322	4.061
9	0.231	4.784	54	15.545	5.935	99	52.989	3.971
10	0.231	4.855	55	16.282	5.907	100	54.656	3.874
11	0.255	4.917	56	17.021	5.883	101	56.322	3.784
12	0.255	4.976	57	17.760	5.855	102	57.989	3.695
13	0.279	5.027	58	18.499	5.823	103	59.656	3.605
14	0.304	5.079	59	19.237	5.799	104	61.322	3.517
15	0.304	5.126	60	19.976	5.767	105	62.989	3.425
16	0.328	5.160	61	20.714	5.746	106	64.656	3.344
17	0.354	5.199	62	21.453	5.709	107	66.322	3.254
18	0.354	5.234	63	22.167	5.674	108	67.989	3.173
19	0.354	5.262	64	22.930	5.640	109	69.656	3.089
20	0.403	5.289	65	23.669	5.610	110	71.322	3.009
21	0.403	5.317	66	24.383	5.582	111	72.989	2.925
22	0.403	5.339	67	25.121	5.541	112	74.656	2.835
23	0.427	5.361	68	25.860	5.507	113	76.322	2.749
24	1.190	5.823	69	26.599	5.470	114	77.989	2.652
25	1.978	6.003	70	27.338	5.432	115	79.656	2.553
26	2.766	6.094	71	28.101	5.399	116	81.322	2.448
27	3.530	6.143	72	28.814	5.361	117	82.989	2.332
28	4.268	6.171	73	29.553	5.324	118	84.656	2.209
29	5.032	6.189	74	30.292	5.287	119	86.322	2.069
30	5.769	6.195	75	31.055	5.246	120	87.989	1.917
31	6.484	6.195	76	31.769	5.209	121	89.656	1.740
32	6.508	6.193	77	32.533	5.165	122	91.322	1.544
33	6.508	6.193	78	33.271	5.126	123	92.989	1.321
34	6.533	6.195	79	34.010	5.091	124	94.656	1.076
35	6.558	6.193	80	34.748	5.044	125	96.322	0.806
36	6.558	6.195	81	35.487	5.007	126	97.989	0.514
37	6.583	6.195	82	36.250	4.967	127	100.620	0.0
38	6.583	6.195	83	36.964	4.924	128		
39	6.607	6.195	84	37.727	4.883	129		
40	6.631	6.199	85	38.466	4.846	130		
41	6.656	6.195	86	39.180	4.805	131		
42	6.681	6.195	87	39.918	4.765	132		
43	7.419	6.184	88	40.657	4.730	133		
44	8.158	6.171	89	41.420	4.681	134		
45	8.897	6.158	90	42.135	4.648	135		

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA07											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	12.781	3.386	91	46.847	2.046
2	0.159	2.647	47	13.543	3.364	92	47.514	2.002
3	0.176	2.697	48	14.280	3.342	93	48.180	1.959
4	0.176	2.765	49	15.042	3.321	94	48.847	1.915
5	0.200	2.824	50	15.779	3.293	95	49.514	1.872
6	0.200	2.874	51	16.541	3.265	96	50.180	1.823
7	0.200	2.917	52	17.303	3.233	97	50.847	1.776
8	0.225	2.958	53	18.040	3.196	98	51.514	1.729
9	0.225	2.992	54	18.802	3.156	99	52.180	1.679
10	0.249	3.022	55	19.539	3.115	100	52.847	1.627
11	0.273	3.048	56	20.276	3.076	101	53.514	1.571
12	0.298	3.072	57	21.063	3.022	102	54.180	1.512
13	0.323	3.091	58	21.800	2.970	103	54.847	1.453
14	0.323	3.109	59	22.562	2.923	104	55.514	1.388
15	0.348	3.125	60	23.299	2.876	105	56.180	1.322
16	0.348	3.143	61	24.061	2.831	106	56.847	1.258
17	0.372	3.156	62	24.823	2.786	107	57.514	1.189
18	0.397	3.169	63	25.560	2.756	108	58.180	1.118
19	1.183	3.407	64	26.297	2.730	109	58.847	1.044
20	1.969	3.469	65	27.034	2.709	110	59.514	0.969
21	2.731	3.485	66	27.796	2.694	111	60.180	0.895
22	3.518	3.491	67	28.558	2.675	112	60.847	0.817
23	4.254	3.491	68	29.295	2.666	113	61.514	0.744
24	4.378	3.491	69	30.032	2.653	114	62.180	0.666
25	4.426	3.491	70	30.794	2.644	115	62.847	0.591
26	4.426	3.491	71	31.556	2.629	116	63.514	0.514
27	4.451	3.494	72	32.318	2.616	117	64.180	0.439
28	4.451	3.494	73	33.055	2.607	118	64.847	0.365
29	4.451	3.491	74	33.841	2.595	119	65.514	0.290
30	4.475	3.494	75	34.578	2.579	120	67.641	0.0
31	4.501	3.491	76	35.316	2.564	121		
32	4.525	3.494	77	36.053	2.545	122		
33	4.525	3.487	78	36.815	2.530	123		
34	4.550	3.487	79	37.552	2.511	124		
35	4.598	3.487	80	38.314	2.489	125		
36	5.336	3.487	81	39.051	2.474	126		
37	6.049	3.485	82	39.837	2.442	127		
38	6.810	3.476	83	40.574	2.421	128		
39	7.548	3.476	84	41.312	2.390	129		
40	8.309	3.459	85	42.073	2.365	130		
41	9.047	3.454	86	42.811	2.328	131		
42	9.783	3.441	87	43.548	2.294	132		
43	10.546	3.431	88	44.284	2.253	133		
44	11.307	3.420	89	45.047	2.214	134		
45	12.045	3.401	90	46.180	2.092	135		

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA08									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	7.173	3.453	91	40.157	2.521
2	0.134	2.537	47	7.862	3.449	92	40.870	2.508
3	0.157	2.496	48	8.625	3.447	93	41.584	2.493
4	0.157	2.573	49	9.364	3.443	94	42.347	2.471
5	0.157	2.611	50	10.102	3.431	95	43.036	2.456
6	0.183	2.648	51	10.840	3.421	96	43.775	2.433
7	0.183	2.682	52	11.555	3.412	97	44.513	2.418
8	0.183	2.713	53	12.292	3.397	98	45.253	2.297
9	0.207	2.741	54	13.031	3.387	99	46.253	2.263
10	0.207	2.773	55	13.770	3.369	100	47.253	2.226
11	0.207	2.794	56	14.508	3.347	101	48.253	2.185
12	0.232	2.812	57	15.222	3.328	102	49.253	2.142
13	0.232	2.835	58	15.961	3.309	103	50.253	2.099
14	0.256	2.857	59	16.699	3.285	104	51.253	2.052
15	0.256	2.874	60	17.437	3.264	105	52.253	2.005
16	0.280	2.891	61	18.151	3.232	106	53.253	1.961
17	0.280	2.906	62	18.890	3.204	107	54.253	1.921
18	0.306	2.924	63	19.628	3.164	108	55.253	1.881
19	0.306	2.937	64	20.366	3.130	109	56.253	1.841
20	0.330	2.949	65	21.080	3.089	110	57.253	1.806
21	0.330	2.962	66	21.818	3.049	111	58.253	1.772
22	0.330	2.975	67	22.557	3.005	112	59.253	1.735
23	0.355	2.984	68	23.320	2.962	113	60.253	1.701
24	0.355	2.993	69	24.034	2.915	114	61.253	1.666
25	0.379	3.008	70	24.772	2.878	115	62.253	1.630
26	0.995	3.264	71	25.487	2.840	116	63.253	1.598
27	1.659	3.363	72	26.224	2.807	117	64.253	1.561
28	2.373	3.415	73	26.939	2.779	118	65.253	1.524
29	3.087	3.436	74	27.701	2.754	119	66.253	1.483
30	3.800	3.449	75	28.415	2.735	120	67.253	1.447
31	4.539	3.468	76	29.154	2.719	121	68.253	1.403
32	5.253	3.464	77	29.892	2.698	122	69.253	1.359
33	5.524	3.462	78	30.606	2.691	123	70.253	1.309
34	5.549	3.459	79	31.344	2.676	124	71.253	1.257
35	5.549	3.462	80	32.083	2.657	125	72.253	1.195
36	5.573	3.462	81	32.797	2.651	126	73.253	1.126
37	5.597	3.464	82	33.559	2.639	127	74.253	1.046
38	5.597	3.464	83	34.274	2.626	128	75.253	0.956
39	5.622	3.464	84	35.012	2.620	129	76.253	0.859
40	5.646	3.462	85	35.750	2.601	130	77.253	0.756
41	5.672	3.462	86	36.489	2.590	131	78.253	0.651
42	5.672	3.464	87	37.227	2.577	132	79.253	0.545
43	5.696	3.462	88	37.941	2.568	133	80.253	0.443
44	5.696	3.459	89	38.68	2.549	134	81.253	0.334
45	6.435	3.462	90	39.418	2.536	135	84.164	0.0

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA09									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	11.945	3.595	91	44.354	2.536
2	0.091	2.257	47	11.969	3.597	92	45.115	2.514
3	0.102	2.294	48	11.969	3.597	93	46.199	2.428
4	0.102	2.378	49	12.731	3.588	94	47.199	2.390
5	0.102	2.452	50	13.493	3.586	95	48.199	2.350
6	0.127	2.517	51	14.230	3.586	96	49.199	2.309
7	0.127	2.573	52	14.992	3.573	97	50.199	2.266
8	0.127	2.620	53	15.754	3.564	98	51.199	2.226
9	0.151	2.657	54	16.515	3.552	99	52.199	2.182
10	0.176	2.688	55	17.252	3.545	100	53.199	2.138
11	0.200	2.719	56	18.038	3.530	101	54.199	2.095
12	0.200	2.744	57	18.775	3.511	102	55.199	2.051
13	0.200	2.766	58	19.537	3.487	103	56.199	2.008
14	0.200	2.787	59	20.274	3.470	104	57.199	1.961
15	0.225	2.809	60	21.012	3.455	105	58.199	1.915
16	0.249	2.824	61	21.773	3.427	106	59.199	1.871
17	0.249	2.843	62	22.535	3.399	107	60.199	1.828
18	0.274	2.859	63	23.272	3.375	108	61.199	1.778
19	0.299	2.871	64	24.033	3.347	109	62.199	1.731
20	0.299	2.890	65	24.796	3.315	110	63.199	1.685
21	0.323	2.906	66	25.532	3.285	111	64.199	1.636
22	1.060	3.231	67	26.295	3.246	112	65.199	1.586
23	1.798	3.347	68	27.056	3.218	113	66.199	1.536
24	2.559	3.408	69	27.793	3.185	114	67.199	1.483
25	3.320	3.446	70	28.555	3.147	115	68.199	1.427
26	4.082	3.476	71	29.316	3.117	116	69.199	1.375
27	4.844	3.498	72	30.078	3.085	117	70.199	1.319
28	5.581	3.524	73	30.839	3.054	118	71.199	1.263
29	6.318	3.545	74	31.577	3.020	119	72.199	1.203
30	7.080	3.558	75	32.338	2.986	120	73.199	1.147
31	7.817	3.569	76	33.101	2.955	121	74.199	1.083
32	8.578	3.576	77	33.837	2.921	122	75.199	1.018
33	9.316	3.586	78	34.599	2.890	123	76.199	0.952
34	10.077	3.588	79	35.361	2.859	124	77.199	0.884
35	10.840	3.592	80	36.122	2.828	125	78.199	0.812
36	11.576	3.595	81	36.884	2.800	126	79.199	0.738
37	11.797	3.588	82	37.645	2.768	127	80.199	0.661
38	11.823	3.588	83	38.383	2.747	128	81.199	0.579
39	11.823	3.588	84	39.120	2.719	129	82.199	0.495
40	11.847	3.592	85	39.882	2.691	130	83.199	0.411
41	11.872	3.597	86	40.643	2.663	131	84.199	0.322
42	11.872	3.597	87	41.405	2.639	132	87.917	0.0
43	11.896	3.597	88	42.118	2.613	133		
44	11.920	3.597	89	42.879	2.589	134		
45	11.945	3.595	90	43.641	2.564	135		

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA10								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	14.739	4.086	91	44.567	2.919
2	0.084	2.559	47	14.763	4.088	92	45.306	2.887
3	0.095	2.589	48	14.763	4.088	93	46.292	2.794
4	0.095	2.648	49	14.787	4.092	94	46.959	2.766
5	0.095	2.704	50	14.813	4.092	95	47.625	2.734
6	0.095	2.757	51	14.813	4.092	96	48.292	2.704
7	0.119	2.803	52	15.551	4.086	97	48.959	2.673
8	0.119	2.846	53	16.289	4.080	98	49.625	2.635
9	0.144	2.881	54	17.027	4.077	99	50.292	2.601
10	0.144	2.912	55	17.766	4.060	100	50.959	2.564
11	0.168	2.940	56	18.529	4.039	101	51.625	2.527
12	0.144	2.968	57	19.291	4.027	102	52.292	2.484
13	0.168	2.990	58	20.030	4.011	103	52.959	2.443
14	0.194	3.012	59	20.768	3.987	104	53.625	2.400
15	0.194	3.033	60	21.507	3.965	105	54.292	2.355
16	0.243	3.057	61	22.270	3.943	106	54.959	2.303
17	0.243	3.076	62	23.008	3.918	107	55.625	2.256
18	0.267	3.098	63	23.746	3.894	108	56.292	2.204
19	0.267	3.120	64	24.484	3.868	109	56.959	2.144
20	0.291	3.141	65	25.223	3.849	110	57.625	2.088
21	0.317	3.160	66	25.986	3.813	111	58.292	2.030
22	1.129	3.608	67	26.724	3.787	112	58.959	1.965
23	1.941	3.720	68	27.463	3.754	113	59.625	1.896
24	2.729	3.782	69	28.226	3.716	114	60.292	1.828
25	3.491	3.834	70	28.964	3.682	115	60.959	1.759
26	4.254	3.871	71	29.703	3.651	116	61.625	1.685
27	4.993	3.905	72	30.440	3.614	117	62.292	1.614
28	5.731	3.940	73	31.179	3.580	118	62.959	1.539
29	6.469	3.968	74	31.941	3.537	119	63.625	1.464
30	7.233	3.989	75	32.680	3.498	120	64.292	1.387
31	7.946	4.004	76	33.443	3.459	121	64.959	1.309
32	8.709	4.027	77	34.181	3.418	122	65.625	1.232
33	9.447	4.039	78	34.944	3.380	123	66.292	1.154
34	10.186	4.049	79	35.683	3.341	124	66.959	1.074
35	10.923	4.064	80	36.421	3.298	125	67.625	0.992
36	11.662	4.064	81	37.184	3.263	126	68.292	0.912
37	12.401	4.071	82	37.897	3.223	127	68.959	0.835
38	13.139	4.077	83	38.661	3.182	128	69.625	0.753
39	13.852	4.086	84	39.399	3.148	129	70.292	0.673
40	14.591	4.088	85	40.137	3.111	130	70.959	0.598
41	14.640	4.092	86	40.900	3.076	131	71.625	0.521
42	14.665	4.088	87	41.614	3.046	132	72.292	0.443
43	14.714	4.088	88	42.352	3.008	133	72.959	0.362
44	14.690	4.088	89	43.090	2.977	134	73.625	0.260
45	14.714	4.086	90	43.853	2.947	135	75.560	0.0

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA11											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	11.254	3.573	91	44.908	2.355
2	0.090	2.355	47	11.992	3.576	92	46.213	2.254
3	0.102	2.402	48	12.729	3.573	93	46.880	2.217
4	0.102	2.484	49	13.466	3.565	94	47.547	2.179
5	0.127	2.549	50	14.227	3.554	95	48.213	2.142
6	0.127	2.607	51	14.964	3.546	96	48.880	2.099
7	0.127	2.661	52	15.701	3.530	97	49.547	2.055
8	0.127	2.704	53	16.463	3.515	98	50.213	2.008
9	0.176	2.745	54	17.200	3.502	99	50.880	1.961
10	0.152	2.775	55	17.961	3.483	100	51.547	1.912
11	0.176	2.807	56	18.698	3.462	101	52.213	1.860
12	0.201	2.831	57	19.460	3.434	102	52.880	1.806
13	0.225	2.853	58	20.197	3.415	103	53.547	1.750
14	0.201	2.872	59	20.958	3.387	104	54.213	1.688
15	0.225	2.887	60	21.695	3.354	105	54.880	1.629
16	0.250	2.902	61	22.457	3.319	106	55.547	1.565
17	0.250	2.921	62	23.193	3.287	107	56.213	1.502
18	0.274	2.936	63	23.955	3.244	108	56.880	1.434
19	0.299	2.949	64	24.716	3.207	109	57.547	1.369
20	0.324	2.964	65	25.428	3.169	110	58.213	1.300
21	1.012	3.279	66	26.190	3.130	111	58.880	1.229
22	1.749	3.375	67	26.952	3.085	112	59.547	1.160
23	2.510	3.425	68	27.688	3.042	113	60.213	1.085
24	3.271	3.459	69	28.425	3.005	114	60.880	1.014
25	4.008	3.481	70	29.187	2.964	115	61.547	0.943
26	4.746	3.502	71	29.949	2.930	116	62.213	0.872
27	5.531	3.520	72	30.685	2.891	117	62.880	0.797
28	6.268	3.537	73	31.447	2.856	118	63.547	0.723
29	7.005	3.546	74	32.183	2.822	119	64.213	0.650
30	7.767	3.558	75	32.946	2.790	120	64.880	0.579
31	8.504	3.565	76	33.682	2.762	121	65.547	0.508
32	9.265	3.570	77	34.444	2.734	122	66.213	0.437
33	9.977	3.570	78	35.205	2.704	123	66.880	0.366
34	10.740	3.573	79	35.943	2.678	124	67.547	0.297
35	11.058	3.573	80	36.704	2.654	125	70.155	0.0
36	11.082	3.570	81	37.465	2.626	126		
37	11.082	3.570	82	38.202	2.601	127		
38	11.132	3.573	83	38.940	2.579	128		
39	11.132	3.573	84	39.701	2.551	129		
40	11.132	3.573	85	40.438	2.527	130		
41	11.157	3.570	86	41.174	2.499	131		
42	11.181	3.573	87	41.911	2.471	132		
43	11.181	3.573	88	42.673	2.443	133		
44	11.206	3.570	89	43.435	2.415	134		
45	11.230	3.573	90	44.147	2.383	135		

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA12								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	9.597	3.505	91	39.491	2.353
2	0.106	2.258	47	9.597	3.505	92	40.230	2.310
3	0.116	2.152	48	9.621	3.505	93	40.969	2.269
4	0.116	2.288	49	9.646	3.505	94	41.708	2.219
5	0.116	2.348	50	9.646	3.507	95	42.446	2.174
6	0.116	2.404	51	9.646	3.511	96	43.210	2.124
7	0.116	2.449	52	10.434	3.505	97	43.924	2.064
8	0.140	2.484	53	11.148	3.507	98	44.663	2.012
9	0.140	2.518	54	11.887	3.501	99	45.401	1.953
10	0.140	2.552	55	12.601	3.494	100	46.315	1.832
11	0.165	2.580	56	13.364	3.492	101	46.648	1.804
12	0.165	2.608	57	14.127	3.483	102	46.981	1.776
13	0.190	2.632	58	14.842	3.470	103	47.315	1.748
14	0.165	2.654	59	15.581	3.460	104	47.648	1.720
15	0.190	2.670	60	16.319	3.445	105	47.981	1.690
16	0.190	2.688	61	17.083	3.430	106	48.315	1.662
17	0.215	2.703	62	17.821	3.408	107	48.648	1.630
18	0.215	2.720	63	18.560	3.387	108	48.981	1.606
19	0.239	2.731	64	19.299	3.361	109	49.315	1.578
20	0.239	2.748	65	20.062	3.333	110	49.648	1.546
21	0.264	2.759	66	20.801	3.303	111	49.981	1.518
22	0.264	2.772	67	21.540	3.271	112	50.315	1.488
23	0.288	2.785	68	22.303	3.238	113	50.648	1.460
24	0.288	2.793	69	23.042	3.200	114	50.981	1.429
25	0.313	2.806	70	23.780	3.154	115	51.315	1.395
26	0.313	2.812	71	24.544	3.110	116	51.648	1.367
27	0.338	2.821	72	25.282	3.070	117	51.981	1.336
28	0.929	3.122	73	26.021	3.021	118	52.315	1.305
29	1.618	3.253	74	26.785	2.974	119	52.648	1.271
30	2.332	3.333	75	27.523	2.931	120	52.981	1.243
31	3.047	3.376	76	28.262	2.890	121	53.315	1.209
32	3.786	3.411	77	29.026	2.847	122	53.648	1.174
33	4.524	3.442	78	29.765	2.804	123	53.981	1.144
34	5.263	3.467	79	30.528	2.766	124	54.315	1.109
35	6.002	3.473	80	31.267	2.731	125	54.648	1.075
36	6.741	3.492	81	32.030	2.694	126	54.981	1.045
37	7.478	3.492	82	32.769	2.664	127	55.315	1.010
38	8.243	3.505	83	33.508	2.626	128	55.648	0.976
39	8.956	3.505	84	34.246	2.593	129	55.981	0.942
40	9.474	3.507	85	35.010	2.565	130	56.315	0.911
41	9.498	3.507	86	35.773	2.531	131	56.648	0.873
42	9.523	3.507	87	36.487	2.496	132	56.981	0.843
43	9.523	3.505	88	37.250	2.462	133	57.315	0.806
44	9.547	3.505	89	37.989	2.428	134	57.648	0.774
45	9.547	3.505	90	38.752	2.391	135	57.981	0.737

Table A2 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA12					
Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)
136 58.315	0.703	181		226	
137 58.648	0.669	182		227	
138 58.981	0.634	183		228	
139 59.315	0.598	184		229	
140 59.648	0.563	185		230	
141 59.981	0.529	186		231	
142 60.315	0.495	187		232	
143 60.648	0.460	188		233	
144 60.981	0.427	189		234	
145 61.315	0.393	190		235	
146 61.648	0.359	191		236	
147 61.981	0.325	192		237	
148 62.315	0.290	193		238	
149 65.053	0.0	194		239	
150		195		240	
151		196		241	
152		197		242	
153		198		243	
154		199		244	
155		200		245	
156		201		246	
157		202		247	
158		203		248	
159		204		249	
160		205		250	
161		206		251	
162		207		252	
163		208		253	
164		209		254	
165		210		255	
166		211		256	
167		212		257	
168		213		258	
169		214		259	
170		215		260	
171		216		261	
172		217		262	
173		218		263	
174		219		264	
175		220		265	
176		221		266	
177		222		267	
178		223		268	
179		224		269	
180		225		270	

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA13								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	14.814	2.246	91	47.336	1.232
2	0.082	1.491	47	14.838	2.245	92	48.336	1.214
3	0.101	1.448	48	14.838	2.246	93	49.336	1.193
4	0.101	1.509	49	14.864	2.248	94	50.336	1.173
5	0.101	1.523	50	15.628	2.239	95	51.336	1.152
6	0.126	1.533	51	16.367	2.234	96	52.336	1.130
7	0.126	1.541	52	17.131	2.224	97	53.336	1.107
8	0.150	1.551	53	17.895	2.205	98	54.336	1.082
9	0.175	1.557	54	18.634	2.184	99	55.336	1.060
10	0.175	1.565	55	19.398	2.149	100	56.336	1.035
11	0.175	1.574	56	20.162	2.105	101	57.336	1.011
12	0.199	1.581	57	20.926	2.048	102	58.336	0.989
13	0.199	1.589	58	21.665	1.982	103	59.336	0.968
14	0.225	1.600	59	22.454	1.910	104	60.336	0.944
15	0.249	1.609	60	23.194	1.847	105	61.336	0.919
16	0.249	1.621	61	23.957	1.786	106	62.336	0.894
17	0.273	1.630	62	24.721	1.746	107	63.336	0.870
18	0.298	1.641	63	25.461	1.715	108	64.336	0.844
19	1.013	1.834	64	26.200	1.697	109	65.336	0.820
20	1.776	1.901	65	26.964	1.686	110	66.336	0.794
21	2.565	1.950	66	27.704	1.677	111	67.336	0.766
22	3.329	1.993	67	28.468	1.666	112	68.336	0.738
23	4.069	2.027	68	29.207	1.665	113	69.336	0.710
24	4.808	2.059	69	29.971	1.658	114	70.336	0.682
25	5.548	2.095	70	30.735	1.650	115	71.336	0.653
26	6.312	2.123	71	31.474	1.647	116	72.336	0.621
27	7.076	2.142	72	32.238	1.638	117	73.336	0.590
28	7.839	2.164	73	33.002	1.635	118	74.336	0.561
29	8.579	2.185	74	33.741	1.622	119	75.336	0.527
30	9.343	2.199	75	34.505	1.611	120	76.336	0.494
31	10.106	2.210	76	35.245	1.600	121	77.336	0.459
32	10.846	2.224	77	36.008	1.585	122	78.336	0.425
33	11.586	2.233	78	36.772	1.567	123	79.336	0.388
34	12.349	2.238	79	37.537	1.550	124	80.336	0.350
35	13.113	2.241	80	38.276	1.525	125	81.336	0.312
36	13.853	2.245	81	39.040	1.499	126	82.336	0.274
37	14.592	2.242	82	39.779	1.473	127	83.336	0.233
38	14.691	2.246	83	40.544	1.448	128	84.336	0.193
39	14.691	2.245	84	41.282	1.425	129	85.336	0.151
40	14.715	2.246	85	42.022	1.396	130	88.990	0.0
41	14.741	2.246	86	42.786	1.374	131		
42	14.765	2.246	87	43.525	1.350	132		
43	14.765	2.248	88	44.289	1.328	133		
44	14.789	2.248	89	45.029	1.313	134		
45	14.789	2.247	90	46.336	1.257	135		

Table A1 Relation Between Stress and Strain Value of Mod.9Cr-1Mo Steel

Specimen No. : HCRA30									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	13.830	2.251	91	44.882	1.262
2	0.079	1.451	47	13.854	2.248	92	46.263	1.195
3	0.099	1.478	48	13.879	2.248	93	47.263	1.170
4	0.099	1.495	49	13.879	2.250	94	48.263	1.143
5	0.099	1.506	50	13.904	2.251	95	49.263	1.118
6	0.124	1.510	51	14.666	2.248	96	50.263	1.090
7	0.124	1.515	52	15.405	2.243	97	51.263	1.067
8	0.149	1.515	53	16.167	2.236	98	52.263	1.039
9	0.173	1.521	54	16.930	2.227	99	53.263	1.014
10	0.173	1.528	55	17.693	2.209	100	54.263	0.991
11	0.198	1.535	56	18.456	2.181	101	55.263	0.967
12	0.198	1.542	57	19.194	2.153	102	56.263	0.940
13	0.222	1.549	58	19.957	2.110	103	57.263	0.913
14	0.222	1.559	59	20.744	2.053	104	58.263	0.884
15	0.248	1.567	60	21.507	1.982	105	59.263	0.852
16	0.248	1.573	61	22.245	1.908	106	60.263	0.823
17	0.272	1.583	62	23.032	1.839	107	61.263	0.793
18	0.272	1.595	63	23.771	1.780	108	62.263	0.761
19	0.272	1.613	64	24.533	1.738	109	63.263	0.728
20	0.296	1.625	65	25.272	1.707	110	64.263	0.691
21	0.937	1.811	66	26.034	1.690	111	65.263	0.656
22	1.650	1.888	67	26.797	1.677	112	66.263	0.619
23	2.388	1.944	68	27.535	1.670	113	67.263	0.580
24	3.126	1.985	69	28.298	1.663	114	68.263	0.540
25	3.889	2.020	70	29.036	1.656	115	69.263	0.501
26	4.627	2.053	71	29.824	1.653	116	70.263	0.458
27	5.390	2.085	72	30.561	1.643	117	71.263	0.415
28	6.128	2.115	73	31.325	1.641	118	72.263	0.366
29	6.866	2.139	74	32.062	1.629	119	73.263	0.319
30	7.629	2.162	75	32.826	1.618	120	74.263	0.271
31	8.367	2.182	76	33.589	1.608	121	75.263	0.224
32	9.130	2.199	77	34.351	1.594	122	76.263	0.176
33	9.868	2.214	78	35.090	1.580	123	79.784	0.0
34	10.631	2.229	79	35.852	1.559	124		
35	11.369	2.236	80	36.615	1.542	125		
36	12.132	2.240	81	37.377	1.516	126		
37	12.895	2.250	82	38.116	1.492	127		
38	13.658	2.252	83	38.878	1.462	128		
39	13.707	2.248	84	39.642	1.436	129		
40	13.731	2.250	85	40.379	1.404	130		
41	13.755	2.250	86	41.118	1.375	131		
42	13.781	2.250	87	41.880	1.350	132		
43	13.781	2.252	88	42.644	1.322	133		
44	13.805	2.251	89	43.381	1.303	134		
45	13.854	2.248	90	44.145	1.279	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA01									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	12.786	19.035	91	46.211	14.583
2	0.205	13.075	47	13.524	19.019	92	46.544	14.504
3	0.230	13.350	48	14.261	18.989	93	46.878	14.395
4	0.230	13.629	49	15.023	18.942	94	47.211	14.289
5	0.254	13.892	50	15.735	18.910	95	47.544	14.195
6	0.254	14.141	51	16.473	18.864	96	47.878	14.085
7	0.278	14.366	52	17.234	18.819	97	48.211	13.961
8	0.278	14.583	53	17.972	18.770	98	48.544	13.836
9	0.278	14.776	54	18.709	18.725	99	48.878	13.714
10	0.303	14.955	55	19.447	18.664	100	49.211	13.590
11	0.327	15.110	56	20.184	18.600	101	49.544	13.450
12	0.352	15.237	57	20.921	18.554	102	49.878	13.310
13	0.352	15.365	58	21.658	18.491	103	50.211	13.155
14	0.352	15.498	59	22.395	18.415	104	50.544	13.000
15	0.376	15.607	60	23.133	18.351	105	50.878	12.830
16	0.402	15.699	61	23.894	18.275	106	51.211	12.657
17	0.402	15.777	62	24.632	18.214	107	51.544	12.472
18	0.426	15.854	63	25.344	18.135	108	51.878	12.286
19	0.475	15.932	64	26.106	18.056	109	52.211	12.083
20	1.409	17.452	65	26.843	17.980	110	52.544	11.882
21	2.245	18.135	66	27.581	17.901	111	52.878	11.667
22	3.056	18.491	67	28.318	17.810	112	53.211	11.433
23	3.817	18.725	68	29.080	17.731	113	53.544	11.184
24	4.579	18.864	69	29.817	17.640	114	53.878	10.937
25	5.340	18.958	70	30.554	17.546	115	54.211	10.673
26	6.102	19.004	71	31.291	17.452	116	54.544	10.394
27	6.865	19.050	72	32.029	17.360	117	54.878	10.114
28	7.601	19.080	73	32.790	17.251	118	55.211	9.804
29	8.364	19.113	74	33.528	17.157	119	55.544	9.461
30	9.100	19.113	75	34.265	17.033	120	55.878	9.121
31	9.838	19.098	76	34.977	16.941	121	56.211	8.750
32	10.379	19.098	77	35.764	16.817	122	56.544	8.329
33	10.403	19.098	78	36.501	16.706	123	56.878	7.848
34	10.427	19.098	79	37.263	16.598	124	57.211	5.490
35	10.427	19.098	80	38.000	16.476	125	57.330	2.987
36	10.452	19.098	81	38.737	16.352	126		
37	10.476	19.113	82	39.449	16.212	127		
38	10.502	19.098	83	40.187	16.087	128		
39	10.502	19.113	84	40.948	15.948	129		
40	10.526	19.113	85	41.686	15.808	130		
41	10.551	19.098	86	42.399	15.668	131		
42	10.575	19.113	87	43.161	15.513	132		
43	10.575	19.113	88	43.922	15.358	133		
44	11.337	19.065	89	44.635	15.188	134		
45	12.050	19.065	90	45.348	15.000	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA02											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	12.841	19.045	91	46.230	14.6097
2	0.165	12.603	47	13.578	19.015	92	46.563	14.5323
3	0.180	11.833	48	14.316	18.998	93	46.896	14.4243
4	0.180	12.779	49	15.053	18.968	94	47.230	14.3303
5	0.180	13.089	50	15.791	18.937	95	47.563	14.2224
6	0.204	13.369	51	16.529	18.890	96	47.896	14.1297
7	0.204	13.633	52	17.266	18.843	97	48.230	14.0052
8	0.204	13.880	53	17.979	18.798	98	48.563	13.9125
9	0.229	14.113	54	18.717	18.766	99	48.896	13.7881
10	0.253	14.330	55	19.454	18.688	100	49.230	13.6636
11	0.277	14.532	56	20.192	18.643	101	49.563	13.5392
12	0.277	14.719	57	20.929	18.580	102	49.896	13.4007
13	0.303	14.889	58	21.667	18.518	103	50.230	13.261
14	0.327	15.028	59	22.404	18.456	104	50.563	13.1213
15	0.327	15.153	60	23.142	18.379	105	50.896	12.9816
16	0.352	15.261	61	23.879	18.316	106	51.230	12.8267
17	0.376	15.370	62	24.617	18.239	107	51.563	12.6718
18	0.401	15.463	63	25.330	18.161	108	51.896	12.4851
19	0.425	15.555	64	26.067	18.084	109	52.230	12.3149
20	1.409	17.215	65	26.805	17.991	110	52.563	12.1282
21	2.269	17.929	66	27.543	17.929	111	52.896	11.9263
22	3.081	18.316	67	28.280	17.835	112	53.230	11.7256
23	3.868	18.564	68	29.017	17.758	113	53.563	11.5237
24	4.604	18.704	69	29.755	17.665	114	53.896	11.2913
25	5.392	18.828	70	30.493	17.572	115	54.230	11.0576
26	6.129	18.906	71	31.205	17.479	116	54.563	10.81
27	6.867	18.968	72	31.943	17.385	117	54.896	10.5458
28	7.604	18.998	73	32.705	17.277	118	55.230	10.283
29	8.342	19.045	74	33.419	17.168	119	55.563	9.98832
30	9.079	19.076	75	34.181	17.060	120	55.896	9.69368
31	9.817	19.076	76	34.918	16.968	121	56.230	9.3673
32	10.555	19.076	77	35.655	16.843	122	56.563	9.04219
33	11.194	19.076	78	36.369	16.734	123	56.896	8.67009
34	11.218	19.076	79	37.131	16.626	124	57.230	8.28148
35	11.218	19.076	80	37.843	16.502	125	57.563	7.83191
36	11.242	19.076	81	38.581	16.377	126	57.896	6.23428
37	11.242	19.076	82	39.319	16.239	127	58.230	1.98496
38	11.268	19.076	83	40.056	16.114	128		
39	11.292	19.076	84	40.793	15.990	129		
40	11.317	19.076	85	41.531	15.850	130		
41	11.317	19.076	86	42.245	15.710	131		
42	11.341	19.076	87	42.981	15.555	132		
43	11.366	19.076	88	43.719	15.400	133		
44	11.366	19.076	89	44.433	15.230	134		
45	12.128	19.061	90	45.170	15.059	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA03									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	11.465	11.078	91	44.803	9.265
2	0.129	8.015	47	12.130	11.063	92	45.541	9.233
3	0.132	7.530	48	12.941	11.047	93	46.208	9.079
4	0.132	8.041	49	13.679	11.016	94	47.208	8.986
5	0.156	8.288	50	14.441	11.001	95	48.208	8.909
6	0.156	8.537	51	15.178	10.986	96	49.208	8.831
7	0.156	8.784	52	15.915	10.954	97	50.208	8.739
8	0.156	9.016	53	16.653	10.923	98	51.208	8.661
9	0.205	9.250	54	17.391	10.907	99	52.208	8.567
10	0.181	9.450	55	18.128	10.861	100	53.208	8.475
11	0.205	9.652	56	18.866	10.846	101	54.208	8.382
12	0.230	9.839	57	19.603	10.814	102	55.208	8.288
13	0.255	9.993	58	20.341	10.769	103	56.208	8.165
14	0.230	10.133	59	21.103	10.737	104	57.208	8.071
15	0.255	10.257	60	21.841	10.706	105	58.208	7.948
16	0.279	10.365	61	22.553	10.675	106	59.208	7.824
17	0.304	10.458	62	23.316	10.644	107	60.208	7.684
18	0.304	10.535	63	24.053	10.613	108	61.208	7.545
19	0.328	10.597	64	24.791	10.567	109	62.208	7.390
20	0.353	10.660	65	25.528	10.520	110	63.208	7.220
21	0.377	10.706	66	26.266	10.505	111	64.208	7.033
22	1.361	11.280	67	27.004	10.443	112	65.208	6.816
23	1.361	11.280	68	27.741	10.412	113	66.208	6.569
24	1.410	11.280	69	28.504	10.365	114	67.208	6.305
25	1.434	11.280	70	29.240	10.318	115	68.208	6.011
26	1.459	11.280	71	29.978	10.273	116	69.208	5.670
27	1.459	11.280	72	30.716	10.226	117	70.208	5.283
28	1.509	11.280	73	31.478	10.179	118	71.208	4.833
29	1.509	11.280	74	32.216	10.133	119	72.208	4.353
30	1.533	11.263	75	32.954	10.086	120	73.208	3.826
31	1.558	11.280	76	33.690	10.040	121	74.208	3.253
32	1.582	11.280	77	34.453	9.993	122	75.208	2.664
33	1.606	11.280	78	35.215	9.946	123	76.208	2.075
34	2.443	11.248	79	35.928	9.901	124	77.208	1.517
35	3.254	11.201	80	36.666	9.839	125	79.636	0.0
36	4.041	11.186	81	37.403	9.792	126		
37	4.778	11.156	82	38.165	9.730	127		
38	5.541	11.140	83	38.903	9.684	128		
39	6.278	11.140	84	39.640	9.637	129		
40	7.015	11.140	85	40.378	9.590	130		
41	7.753	11.140	86	41.115	9.528	131		
42	8.515	11.140	87	41.877	9.482	132		
43	9.253	11.124	88	42.615	9.435	133		
44	10.015	11.109	89	43.328	9.373	134		
45	10.729	11.093	90	44.066	9.327	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA04											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)			
1	0.0	0.0	46	9.180	11.036	91	42.274	9.391			
2	0.146	7.454	47	9.893	11.021	92	43.036	9.338			
3	0.164	7.623	48	10.655	11.013	93	43.748	9.283			
4	0.164	7.856	49	11.391	11.006	94	44.461	9.229			
5	0.164	8.080	50	12.129	10.989	95	45.222	9.191			
6	0.164	8.307	51	12.842	10.959	96	46.209	9.012			
7	0.188	8.531	52	13.578	10.951	97	47.209	8.934			
8	0.188	8.749	53	14.315	10.928	98	48.209	8.849			
9	0.213	8.958	54	15.053	10.904	99	49.209	8.771			
10	0.213	9.151	55	15.765	10.874	100	50.209	8.686			
11	0.238	9.338	56	16.526	10.850	101	51.209	8.601			
12	0.238	9.501	57	17.263	10.819	102	52.209	8.507			
13	0.238	9.656	58	18.001	10.804	103	53.209	8.415			
14	0.262	9.795	59	18.713	10.764	104	54.209	8.322			
15	0.262	9.920	60	19.450	10.742	105	55.209	8.213			
16	0.287	10.035	61	20.187	10.711	106	56.209	8.120			
17	0.311	10.145	62	20.925	10.679	107	57.209	8.003			
18	0.311	10.237	63	21.662	10.649	108	58.209	7.895			
19	0.336	10.307	64	22.398	10.617	109	59.209	7.778			
20	0.360	10.369	65	23.135	10.579	110	60.209	7.655			
21	0.385	10.432	66	23.873	10.547	111	61.209	7.523			
22	0.385	10.477	67	24.610	10.509	112	62.209	7.398			
23	0.410	10.524	68	25.346	10.470	113	63.209	7.251			
24	1.319	11.091	69	26.059	10.432	114	64.209	7.096			
25	1.466	11.106	70	26.797	10.408	115	65.209	6.941			
26	1.491	11.106	71	27.509	10.385	116	66.209	6.770			
27	1.515	11.099	72	28.270	10.322	117	67.209	6.584			
28	1.540	11.106	73	29.032	10.253	118	68.209	6.390			
29	1.564	11.099	74	29.745	10.214	119	69.209	6.180			
30	1.564	11.106	75	30.481	10.175	120	70.209	5.940			
31	1.588	11.099	76	31.218	10.137	121	71.209	5.693			
32	1.614	11.099	77	31.980	10.090	122	72.209	5.413			
33	1.638	11.099	78	32.693	10.043	123	73.209	5.094			
34	1.663	11.099	79	33.454	9.990	124	74.209	4.754			
35	1.663	11.099	80	34.192	9.950	125	75.209	4.365			
36	1.687	11.099	81	34.929	9.896	126	76.209	3.947			
37	2.523	11.076	82	35.665	9.850	127	77.209	3.481			
38	3.284	11.059	83	36.353	9.810	128	78.209	2.986			
39	4.021	11.044	84	37.114	9.765	129	79.209	2.465			
40	4.783	11.036	85	37.877	9.703	130	80.209	1.945			
41	5.520	11.044	86	38.613	9.640	131	81.209	1.441			
42	6.256	11.044	87	39.350	9.593	132	82.209	0.969			
43	6.970	11.044	88	40.088	9.548	133	83.983	0.0			
44	7.707	11.044	89	40.800	9.493	134					
45	8.443	11.036	90	41.537	9.446	135					

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA05									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	9.413	7.286	91	42.711	5.703
2	0.127	4.985	47	10.149	7.270	92	43.448	5.664
3	0.148	5.129	48	10.887	7.255	93	44.160	5.618
4	0.148	5.291	49	11.599	7.255	94	44.898	5.571
5	0.148	5.454	50	12.362	7.217	95	46.203	5.401
6	0.148	5.609	51	13.098	7.200	96	47.203	5.338
7	0.148	5.765	52	13.836	7.170	97	48.203	5.268
8	0.172	5.913	53	14.597	7.147	98	49.203	5.198
9	0.172	6.052	54	15.311	7.122	99	50.203	5.129
10	0.198	6.183	55	16.072	7.100	100	51.203	5.059
11	0.198	6.300	56	16.810	7.084	101	52.203	4.996
12	0.222	6.417	57	17.547	7.053	102	53.203	4.919
13	0.247	6.525	58	18.259	7.022	103	54.203	4.849
14	0.247	6.626	59	19.021	6.990	104	55.203	4.771
15	0.271	6.720	60	19.758	6.967	105	56.203	4.702
16	0.271	6.797	61	20.496	6.937	106	57.203	4.624
17	0.295	6.867	62	21.232	6.905	107	58.203	4.547
18	0.295	6.929	63	21.970	6.875	108	59.203	4.461
19	0.320	6.983	64	22.707	6.843	109	60.203	4.384
20	0.344	7.030	65	23.445	6.805	110	61.203	4.297
21	0.344	7.069	66	24.182	6.773	111	62.203	4.212
22	0.370	7.107	67	24.944	6.735	112	63.203	4.127
23	0.394	7.138	68	25.656	6.704	113	64.203	4.034
24	0.861	7.379	69	26.393	6.657	114	65.203	3.942
25	0.935	7.379	70	27.131	6.618	115	66.203	3.848
26	0.959	7.372	71	27.892	6.587	116	67.203	3.747
27	0.983	7.379	72	28.630	6.548	117	68.203	3.630
28	0.983	7.379	73	29.366	6.502	118	69.203	3.522
29	1.008	7.379	74	30.104	6.471	119	70.203	3.398
30	1.033	7.379	75	30.865	6.425	120	71.203	3.273
31	1.058	7.379	76	31.603	6.378	121	72.203	3.142
32	1.082	7.379	77	32.316	6.340	122	73.203	3.002
33	1.107	7.379	78	33.078	6.293	123	74.203	2.847
34	1.107	7.379	79	33.815	6.253	124	75.203	2.683
35	1.131	7.379	80	34.551	6.207	125	76.203	2.506
36	1.966	7.347	81	35.314	6.160	126	77.203	2.326
37	2.729	7.325	82	36.050	6.113	127	78.203	2.126
38	3.514	7.325	83	36.788	6.068	128	79.203	1.924
39	4.252	7.317	84	37.525	6.021	129	80.203	1.706
40	5.014	7.309	85	38.263	5.975	130	81.203	1.489
41	5.751	7.317	86	38.999	5.936	131	82.203	1.272
42	6.488	7.309	87	39.737	5.896	132	83.203	1.054
43	7.226	7.309	88	40.498	5.843	133	84.203	0.837
44	7.938	7.302	89	41.211	5.796	134	87.929	0.0
45	8.700	7.286	90	41.973	5.749	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA06									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	8.248	7.275	91	41.567	5.756
2	0.121	4.891	47	8.985	7.267	92	42.305	5.716
3	0.140	4.995	48	9.723	7.252	93	43.042	5.669
4	0.140	5.127	49	10.460	7.237	94	43.778	5.616
5	0.140	5.259	50	11.198	7.222	95	44.492	5.569
6	0.140	5.375	51	11.959	7.205	96	45.253	5.522
7	0.140	5.491	52	12.696	7.190	97	46.215	5.382
8	0.164	5.607	53	13.433	7.167	98	47.215	5.305
9	0.164	5.724	54	14.170	7.152	99	48.215	5.235
10	0.189	5.833	55	14.908	7.128	100	49.215	5.157
11	0.189	5.941	56	15.645	7.105	101	50.215	5.080
12	0.214	6.042	57	16.381	7.082	102	51.215	5.002
13	0.214	6.143	58	17.119	7.050	103	52.215	4.925
14	0.214	6.236	59	17.856	7.020	104	53.215	4.840
15	0.214	6.329	60	18.618	6.997	105	54.215	4.762
16	0.239	6.415	61	19.331	6.965	106	55.215	4.677
17	0.263	6.500	62	20.092	6.942	107	56.215	4.592
18	0.263	6.578	63	20.830	6.911	108	57.215	4.506
19	0.287	6.655	64	21.591	6.850	109	58.215	4.413
20	0.287	6.717	65	22.328	6.833	110	59.215	4.320
21	0.312	6.780	66	23.041	6.810	111	60.215	4.227
22	0.312	6.833	67	23.802	6.780	112	61.215	4.126
23	0.336	6.880	68	24.514	6.756	113	62.215	4.025
24	0.361	6.927	69	25.252	6.717	114	63.215	3.924
25	0.386	6.965	70	26.013	6.678	115	64.215	3.816
26	1.221	7.322	71	26.751	6.640	116	65.215	3.699
27	1.221	7.322	72	27.488	6.601	117	66.215	3.591
28	1.271	7.315	73	28.225	6.578	118	67.215	3.466
29	1.295	7.322	74	28.963	6.531	119	68.215	3.342
30	1.295	7.315	75	29.699	6.493	120	69.215	3.219
31	1.319	7.315	76	30.462	6.446	121	70.215	3.079
32	1.368	7.315	77	31.174	6.406	122	71.215	2.939
33	1.368	7.315	78	31.935	6.360	123	72.215	2.792
34	1.368	7.315	79	32.673	6.321	124	73.215	2.637
35	1.393	7.315	80	33.410	6.275	125	74.215	2.473
36	1.418	7.322	81	34.146	6.228	126	75.215	2.295
37	1.442	7.322	82	34.909	6.181	127	76.215	2.117
38	2.278	7.307	83	35.621	6.136	128	77.215	1.931
39	3.039	7.299	84	36.383	6.089	129	78.215	1.736
40	3.777	7.299	85	37.120	6.050	130	79.215	1.519
41	4.563	7.299	86	37.882	5.996	131	80.215	1.318
42	5.300	7.299	87	38.595	5.949	132	81.215	1.101
43	6.037	7.292	88	39.356	5.903	133	82.215	0.899
44	6.774	7.284	89	40.094	5.856	134	86.556	0.0
45	7.512	7.284	90	40.830	5.801	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA07									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	12.124	3.961	91	40.295	2.698
2	0.100	2.535	47	12.124	3.961	92	41.106	2.686
3	0.112	2.307	48	12.148	3.957	93	41.843	2.670
4	0.112	2.381	49	12.173	3.961	94	42.580	2.658
5	0.112	2.453	50	12.173	3.961	95	43.317	2.651
6	0.138	2.580	51	12.197	3.961	96	44.054	2.636
7	0.112	2.636	52	12.221	3.961	97	44.790	2.630
8	0.138	2.688	53	12.246	3.957	98	45.503	2.615
9	0.138	2.742	54	12.984	3.961	99	46.170	2.555
10	0.138	2.791	55	13.720	3.954	100	47.836	2.512
11	0.162	2.841	56	14.457	3.951	101	49.503	2.456
12	0.162	2.888	57	15.194	3.942	102	51.170	2.400
13	0.162	2.927	58	15.931	3.942	103	52.836	2.338
14	0.187	2.965	59	16.668	3.920	104	54.503	2.267
15	0.187	2.998	60	17.404	3.911	105	56.170	2.202
16	0.211	3.032	61	18.141	3.899	106	57.836	2.140
17	0.236	3.064	62	18.878	3.883	107	59.503	2.077
18	0.236	3.095	63	19.639	3.864	108	61.170	2.019
19	0.236	3.120	64	20.376	3.843	109	62.836	1.966
20	0.260	3.148	65	21.113	3.821	110	64.503	1.910
21	0.260	3.170	66	21.849	3.796	111	66.170	1.858
22	0.284	3.187	67	22.587	3.761	112	67.836	1.804
23	0.310	3.206	68	23.324	3.731	113	69.503	1.748
24	0.310	3.225	69	24.061	3.697	114	71.170	1.693
25	0.310	3.241	70	24.798	3.650	115	72.836	1.640
26	0.334	3.256	71	25.534	3.610	116	74.503	1.581
27	1.021	3.526	72	26.296	3.548	117	76.170	1.522
28	1.783	3.628	73	27.032	3.479	118	77.836	1.466
29	2.545	3.684	74	27.769	3.408	119	79.503	1.404
30	3.281	3.740	75	28.506	3.327	120	81.170	1.342
31	4.018	3.778	76	29.267	3.250	121	82.836	1.280
32	4.779	3.817	77	30.005	3.172	122	84.503	1.224
33	5.516	3.849	78	30.766	3.101	123	86.170	1.165
34	6.253	3.877	79	31.478	3.032	124	87.836	1.103
35	6.990	3.901	80	32.215	2.974	125	89.503	1.041
36	7.727	3.918	81	32.976	2.921	126	91.170	0.976
37	8.489	3.933	82	33.713	2.877	127	92.836	0.908
38	9.226	3.942	83	34.450	2.843	128	94.503	0.836
39	9.962	3.948	84	35.187	2.806	129	96.170	0.762
40	10.699	3.954	85	35.948	2.785	130	97.836	0.678
41	11.436	3.957	86	36.685	2.759	131	99.503	0.591
42	12.050	3.954	87	37.397	2.744	132	101.170	0.495
43	12.075	3.957	88	38.159	2.726	133	102.830	0.389
44	12.075	3.957	89	38.822	2.738	134	108.970	0.0
45	12.099	3.957	90	39.608	2.716	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA08									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	11.224	3.908	91	36.272	2.714
2	0.086	2.176	47	11.986	3.904	92	37.033	2.696
3	0.100	2.213	48	12.305	3.908	93	37.794	2.686
4	0.100	2.278	49	12.305	3.908	94	38.531	2.673
5	0.100	2.336	50	12.354	3.904	95	39.268	2.665
6	0.100	2.392	51	12.354	3.908	96	40.005	2.658
7	0.100	2.451	52	12.378	3.911	97	40.766	2.643
8	0.100	2.501	53	12.378	3.908	98	41.503	2.634
9	0.125	2.550	54	12.403	3.908	99	42.214	2.624
10	0.125	2.594	55	12.427	3.911	100	42.951	2.618
11	0.125	2.630	56	12.427	3.908	101	43.688	2.609
12	0.149	2.671	57	12.453	3.911	102	44.424	2.600
13	0.149	2.708	58	12.477	3.911	103	45.161	2.587
14	0.174	2.742	59	12.477	3.915	104	46.049	2.529
15	0.149	2.776	60	13.238	3.915	105	47.715	2.484
16	0.174	2.811	61	13.975	3.902	106	49.382	2.439
17	0.199	2.838	62	14.687	3.898	107	51.049	2.379
18	0.199	2.863	63	15.448	3.898	108	52.715	2.314
19	0.199	2.888	64	16.185	3.883	109	54.382	2.243
20	0.224	2.913	65	16.921	3.874	110	56.049	2.175
21	0.224	2.935	66	17.682	3.861	111	57.715	2.110
22	0.248	2.956	67	18.419	3.852	112	59.382	2.048
23	0.248	2.978	68	19.156	3.827	113	61.049	1.992
24	0.248	3.000	69	19.893	3.803	114	62.715	1.940
25	0.272	3.019	70	20.630	3.790	115	64.382	1.893
26	0.272	3.036	71	21.391	3.769	116	66.049	1.843
27	0.297	3.049	72	22.128	3.734	117	67.715	1.790
28	0.297	3.068	73	22.889	3.700	118	69.382	1.734
29	0.297	3.083	74	23.601	3.666	119	71.049	1.676
30	0.321	3.102	75	24.362	3.623	120	72.715	1.620
31	0.346	3.114	76	25.099	3.563	121	74.382	1.555
32	0.985	3.393	77	25.860	3.505	122	76.049	1.489
33	1.697	3.514	78	26.597	3.436	123	77.715	1.425
34	2.409	3.597	79	27.333	3.359	124	79.382	1.356
35	3.121	3.660	80	28.045	3.292	125	81.049	1.285
36	3.858	3.713	81	28.806	3.204	126	82.715	1.208
37	4.570	3.756	82	29.592	3.114	127	84.382	1.124
38	5.282	3.793	83	30.353	3.036	128	86.049	1.034
39	6.068	3.825	84	31.090	2.965	129	87.715	0.941
40	6.805	3.840	85	31.827	2.907	130	89.382	0.838 4
41	7.542	3.864	86	32.564	2.854	131	91.049	0.728 4
42	8.277	3.883	87	33.325	2.817	132	92.715	0.610 9
43	9.014	3.892	88	34.086	2.780	133	94.382	0.483 1
44	9.751	3.898	89	34.823	2.755	134	96.049	0.355 3
45	10.512	3.904	90	35.560	2.733	135	100.160	0.0

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA09											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	12.978	3.885	91	47.808	2.536
2	0.107	2.662	47	13.714	3.878	92	49.475	2.492
3	0.131	2.713	48	14.451	3.878	93	51.142	2.446
4	0.131	2.762	49	15.189	3.876	94	52.808	2.393
5	0.155	2.805	50	15.950	3.869	95	54.475	2.331
6	0.155	2.846	51	16.711	3.857	96	56.142	2.266
7	0.155	2.883	52	17.473	3.842	97	57.808	2.201
8	0.180	2.915	53	18.209	3.833	98	59.475	2.141
9	0.205	2.943	54	18.947	3.820	99	61.142	2.096
10	0.205	2.967	55	19.708	3.801	100	62.808	2.046
11	0.230	2.988	56	20.445	3.788	101	64.475	1.993
12	0.230	3.010	57	21.182	3.760	102	66.142	1.950
13	0.230	3.032	58	21.943	3.732	103	67.808	1.907
14	0.254	3.051	59	22.680	3.702	104	69.475	1.860
15	0.278	3.070	60	23.442	3.674	105	71.142	1.813
16	0.303	3.085	61	24.203	3.631	106	72.808	1.767
17	0.303	3.100	62	24.940	3.581	107	74.475	1.717
18	0.327	3.113	63	25.677	3.519	108	76.142	1.668
19	1.040	3.388	64	26.414	3.459	109	77.808	1.615
20	1.802	3.500	65	27.176	3.382	110	79.475	1.562
21	2.563	3.565	66	27.937	3.298	111	81.142	1.507
22	3.324	3.618	67	28.674	3.214	112	82.808	1.451
23	4.061	3.665	68	29.435	3.128	113	84.475	1.395
24	4.822	3.708	69	30.197	3.048	114	86.142	1.329
25	5.560	3.743	70	30.934	2.973	115	87.808	1.264
26	6.321	3.770	71	31.671	2.911	116	89.475	1.199
27	7.058	3.801	72	32.432	2.855	117	91.142	1.124
28	7.795	3.820	73	33.193	2.814	118	92.808	1.044
29	8.556	3.842	74	33.930	2.781	119	94.475	0.961
30	9.293	3.854	75	34.692	2.747	120	96.142	0.871
31	10.055	3.866	76	35.429	2.726	121	97.808	0.771
32	10.792	3.876	77	36.190	2.706	122	99.475	0.669
33	11.529	3.878	78	36.903	2.698	123	101.140	0.554
34	12.290	3.885	79	37.639	2.687	124	102.800	0.430
35	12.781	3.878	80	38.426	2.679	125	104.470	0.303
36	12.781	3.878	81	39.187	2.666	126	108.230	0.0
37	12.806	3.882	82	39.924	2.659	127		
38	12.830	3.882	83	40.661	2.651	128		
39	12.830	3.885	84	41.398	2.647	129		
40	12.855	3.885	85	42.160	2.642	130		
41	12.880	3.882	86	42.897	2.632	131		
42	12.904	3.885	87	43.633	2.632	132		
43	12.904	3.885	88	44.395	2.623	133		
44	12.929	3.889	89	45.131	2.614	134		
45	12.953	3.885	90	46.142	2.567	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA10											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	13.039	3.883	91	43.275	2.624			
2	0.093	2.385	47	13.064	3.887	92	44.037	2.618			
3	0.105	2.280	48	13.064	3.887	93	44.748	2.609			
4	0.129	2.445	49	13.088	3.887	94	46.152	2.551			
5	0.105	2.516	50	13.039	3.887	95	47.818	2.512			
6	0.129	2.581	51	13.113	3.887	96	49.485	2.473			
7	0.129	2.637	52	13.873	3.883	97	51.152	2.424			
8	0.129	2.690	53	14.634	3.874	98	52.818	2.364			
9	0.129	2.736	54	15.395	3.871	99	54.485	2.302			
10	0.154	2.770	55	16.131	3.868	100	56.152	2.240			
11	0.178	2.811	56	16.892	3.859	101	57.818	2.175			
12	0.178	2.841	57	17.628	3.843	102	59.485	2.110			
13	0.178	2.873	58	18.389	3.831	103	61.152	2.057			
14	0.178	2.903	59	19.151	3.815	104	62.818	2.005			
15	0.203	2.925	60	19.911	3.799	105	64.485	1.958			
16	0.227	2.950	61	20.648	3.780	106	66.152	1.917			
17	0.227	2.972	62	21.408	3.752	107	67.818	1.868			
18	0.227	2.987	63	22.169	3.728	108	69.485	1.825			
19	0.253	3.009	64	22.930	3.694	109	71.152	1.779			
20	0.277	3.028	65	23.666	3.660	110	72.818	1.728			
21	0.301	3.043	66	24.452	3.617	111	74.485	1.674			
22	0.301	3.056	67	25.187	3.561	112	76.152	1.620			
23	0.326	3.075	68	25.949	3.499	113	77.818	1.567			
24	1.037	3.372	69	26.684	3.430	114	79.485	1.506			
25	1.774	3.483	70	27.446	3.348	115	81.152	1.446			
26	2.560	3.554	71	28.207	3.264	116	82.818	1.382			
27	3.295	3.617	72	28.967	3.174	117	84.485	1.313			
28	4.057	3.664	73	29.728	3.090	118	86.152	1.242			
29	4.817	3.709	74	30.464	3.006	119	87.818	1.165			
30	5.578	3.737	75	31.250	2.938	120	89.485	1.081			
31	6.339	3.769	76	32.035	2.875	121	91.152	0.991			
32	7.075	3.799	77	32.747	2.826	122	92.818	0.894			
33	7.861	3.818	78	33.508	2.783	123	94.485	0.793			
34	8.596	3.840	79	34.244	2.752	124	96.152	0.681			
35	9.333	3.853	80	35.005	2.724	125	97.818	0.560			
36	10.119	3.864	81	35.766	2.712	126	99.485	0.432			
37	10.855	3.874	82	36.502	2.697	127	101.150	0.303			
38	11.591	3.887	83	37.263	2.680	128	105.620	0.0			
39	12.352	3.887	84	38.023	2.671	129					
40	12.941	3.890	85	38.784	2.662	130					
41	12.941	3.890	86	39.521	2.652	131					
42	12.965	3.887	87	40.257	2.646	132					
43	12.990	3.887	88	41.043	2.641	133					
44	13.014	3.887	89	41.778	2.637	134					
45	13.014	3.887	90	42.515	2.628	135					

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA11									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	12.229	3.946	91	40.192	2.697
2	0.103	2.428	47	12.254	3.946	92	40.952	2.687
3	0.126	2.489	48	12.254	3.949	93	41.689	2.680
4	0.126	2.545	49	12.278	3.949	94	42.450	2.669
5	0.126	2.597	50	12.278	3.946	95	43.187	2.659
6	0.126	2.650	51	12.304	3.946	96	43.922	2.650
7	0.152	2.702	52	12.328	3.949	97	44.659	2.644
8	0.152	2.749	53	12.353	3.949	98	45.420	2.635
9	0.176	2.792	54	12.353	3.949	99	46.161	2.588
10	0.176	2.833	55	13.089	3.942	100	47.828	2.551
11	0.176	2.867	56	13.850	3.940	101	49.494	2.501
12	0.176	2.904	57	14.586	3.931	102	51.161	2.452
13	0.201	2.938	58	15.348	3.927	103	52.828	2.390
14	0.225	2.970	59	16.109	3.916	104	54.494	2.324
15	0.201	2.997	60	16.845	3.903	105	56.161	2.256
16	0.225	3.024	61	17.630	3.890	106	57.828	2.188
17	0.225	3.050	62	18.367	3.875	107	59.494	2.126
18	0.250	3.078	63	19.128	3.860	108	61.161	2.074
19	0.250	3.099	64	19.865	3.837	109	62.828	2.018
20	0.250	3.125	65	20.625	3.813	110	64.494	1.973
21	0.274	3.153	66	21.362	3.794	111	66.161	1.928
22	0.274	3.170	67	22.123	3.759	112	67.828	1.885
23	0.298	3.192	68	22.884	3.732	113	69.494	1.838
24	0.298	3.209	69	23.646	3.688	114	71.161	1.794
25	0.323	3.226	70	24.381	3.645	115	72.828	1.739
26	0.323	3.242	71	25.143	3.587	116	74.494	1.692
27	0.348	3.258	72	25.904	3.531	117	76.161	1.640
28	1.035	3.533	73	26.641	3.459	118	77.828	1.584
29	1.796	3.636	74	27.401	3.379	119	79.494	1.528
30	2.558	3.699	75	28.162	3.297	120	81.161	1.468
31	3.318	3.744	76	28.923	3.211	121	82.828	1.410
32	4.055	3.791	77	29.660	3.134	122	84.494	1.348
33	4.816	3.822	78	30.421	3.059	123	86.161	1.279
34	5.577	3.850	79	31.181	2.988	124	87.828	1.208
35	6.338	3.871	80	31.918	2.932	125	89.494	1.137
36	7.098	3.893	81	32.679	2.886	126	91.161	1.059
37	7.835	3.912	82	33.441	2.848	127	92.828	0.976
38	8.572	3.916	83	34.176	2.814	128	94.494	0.886
39	9.333	3.927	84	34.962	2.792	129	96.161	0.789
40	10.069	3.940	85	35.699	2.768	130	97.828	0.684
41	10.830	3.949	86	36.436	2.746	131	99.494	0.569
42	11.567	3.949	87	37.197	2.736	132	101.160	0.449
43	12.156	3.946	88	37.933	2.725	133	102.820	0.324
44	12.205	3.942	89	38.669	2.715	134	106.920	0.0
45	12.205	3.946	90	39.430	2.699	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA12								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	12.414	3.934	91	41.656	2.682
2	0.094	2.555	47	12.464	3.934	92	42.393	2.674
3	0.113	2.484	48	12.464	3.934	93	43.104	2.665
4	0.113	2.596	49	12.488	3.936	94	43.866	2.655
5	0.113	2.646	50	12.488	3.940	95	44.602	2.652
6	0.113	2.699	51	12.513	3.936	96	45.315	2.643
7	0.138	2.749	52	12.537	3.940	97	46.153	2.596
8	0.138	2.792	53	13.274	3.934	98	48.153	2.555
9	0.138	2.835	54	14.035	3.930	99	50.153	2.503
10	0.162	2.872	55	14.796	3.921	100	52.153	2.441
11	0.162	2.912	56	15.508	3.915	101	54.153	2.366
12	0.162	2.944	57	16.269	3.906	102	56.153	2.286
13	0.212	2.977	58	17.006	3.896	103	58.153	2.209
14	0.212	3.005	59	17.742	3.880	104	60.153	2.134
15	0.212	3.033	60	18.504	3.868	105	62.153	2.065
16	0.212	3.061	61	19.240	3.850	106	64.153	2.007
17	0.237	3.089	62	19.976	3.837	107	66.153	1.953
18	0.237	3.111	63	20.737	3.809	108	68.153	1.901
19	0.261	3.130	64	21.474	3.788	109	70.153	1.852
20	0.285	3.149	65	22.235	3.762	110	72.153	1.796
21	0.285	3.167	66	22.972	3.725	111	74.153	1.736
22	0.310	3.183	67	23.708	3.689	112	76.153	1.675
23	0.310	3.201	68	24.469	3.642	113	78.153	1.613
24	0.334	3.216	69	25.206	3.590	114	80.153	1.547
25	1.022	3.502	70	25.967	3.527	115	82.153	1.482
26	1.783	3.598	71	26.704	3.471	116	84.153	1.417
27	2.545	3.676	72	27.465	3.384	117	86.153	1.346
28	3.280	3.723	73	28.202	3.304	118	88.153	1.274
29	4.042	3.766	74	28.962	3.220	119	90.153	1.203
30	4.778	3.797	75	29.723	3.139	120	92.153	1.123
31	5.540	3.831	76	30.460	3.061	121	94.153	1.041
32	6.276	3.859	77	31.221	2.996	122	96.153	0.951
33	7.038	3.878	78	31.958	2.934	123	98.153	0.856
34	7.774	3.900	79	32.719	2.884	124	100.150	0.744
35	8.510	3.908	80	33.431	2.844	125	102.150	0.628
36	9.271	3.924	81	34.192	2.813	126	104.150	0.499
37	10.008	3.927	82	34.929	2.783	127	106.150	0.355
38	10.745	3.934	83	35.690	2.760	128	110.690	0.0
39	11.482	3.934	84	36.451	2.751	129		
40	12.243	3.940	85	37.163	2.732	130		
41	12.365	3.934	86	37.925	2.721	131		
42	12.365	3.934	87	38.660	2.710	132		
43	12.389	3.936	88	39.421	2.704	133		
44	12.414	3.936	89	40.158	2.693	134		
45	12.414	3.936	90	40.895	2.689	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA13								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	13.663	2.300	91	41.391	1.511
2	0.089	1.362	47	13.663	2.301	92	42.102	1.491
3	0.106	1.382	48	13.663	2.304	93	42.864	1.468
4	0.106	1.403	49	13.687	2.301	94	43.625	1.448
5	0.131	1.423	50	13.712	2.296	95	44.362	1.431
6	0.131	1.439	51	13.737	2.295	96	45.074	1.418
7	0.155	1.454	52	13.737	2.295	97	46.208	1.365
8	0.155	1.465	53	13.761	2.296	98	47.541	1.342
9	0.155	1.477	54	13.761	2.297	99	48.874	1.323
10	0.180	1.491	55	14.523	2.295	100	50.208	1.305
11	0.180	1.504	56	15.259	2.292	101	51.541	1.290
12	0.180	1.517	57	15.996	2.283	102	52.874	1.274
13	0.204	1.529	58	16.733	2.273	103	54.208	1.257
14	0.204	1.543	59	17.470	2.250	104	55.541	1.241
15	0.254	1.552	60	18.231	2.224	105	56.874	1.218
16	0.229	1.563	61	18.968	2.182	106	58.208	1.200
17	0.254	1.571	62	19.704	2.135	107	59.541	1.180
18	0.254	1.578	63	20.466	2.073	108	60.874	1.154
19	0.254	1.587	64	21.227	2.007	109	62.208	1.133
20	0.278	1.600	65	21.964	1.933	110	63.541	1.110
21	0.278	1.606	66	22.725	1.874	111	64.874	1.083
22	0.303	1.617	67	23.487	1.822	112	66.208	1.056
23	0.303	1.624	68	24.224	1.784	113	67.541	1.027
24	0.327	1.629	69	24.961	1.755	114	68.874	0.999
25	0.965	1.784	70	25.697	1.741	115	70.208	0.970
26	1.653	1.862	71	26.459	1.732	116	71.541	0.940
27	2.415	1.915	72	27.195	1.727	117	72.874	0.905
28	3.151	1.970	73	27.957	1.722	118	74.208	0.870
29	3.888	2.015	74	28.693	1.719	119	75.541	0.829
30	4.576	2.062	75	29.430	1.721	120	76.874	0.787
31	5.313	2.101	76	30.191	1.719	121	78.208	0.740
32	6.050	2.139	77	30.953	1.719	122	79.541	0.688
33	6.786	2.174	78	31.689	1.711	123	80.874	0.635
34	7.499	2.197	79	32.451	1.705	124	82.208	0.576
35	8.235	2.224	80	33.163	1.704	125	83.541	0.517
36	8.972	2.245	81	33.924	1.693	126	84.874	0.453
37	9.709	2.259	82	34.661	1.684	127	86.208	0.389
38	10.446	2.273	83	35.422	1.672	128	87.541	0.323
39	11.158	2.286	84	36.209	1.658	129	88.874	0.256
40	11.895	2.292	85	36.896	1.645	130	90.208	0.190
41	12.632	2.295	86	37.657	1.623	131	94.037	0.0
42	13.369	2.297	87	38.394	1.601	132		
43	13.589	2.297	88	39.155	1.582	133		
44	13.614	2.296	89	39.892	1.559	134		
45	13.638	2.297	90	40.628	1.535	135		

Table A1 Relation Between Stress and Strain Value of SUS321 Stainless steel

Specimen No. : SUSA14											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	13.911	2.301	91	44.036	1.473
2	0.097	1.427	47	13.935	2.300	92	44.772	1.457
3	0.112	1.443	48	13.935	2.302	93	45.818	1.396
4	0.112	1.462	49	13.984	2.302	94	46.151	1.391
5	0.112	1.475	50	13.984	2.306	95	47.485	1.363
6	0.137	1.487	51	13.984	2.306	96	48.818	1.339
7	0.137	1.500	52	14.745	2.300	97	50.151	1.320
8	0.162	1.510	53	15.482	2.295	98	51.485	1.301
9	0.187	1.524	54	16.243	2.288	99	52.818	1.287
10	0.187	1.538	55	17.005	2.277	100	54.151	1.270
11	0.187	1.548	56	17.741	2.258	101	55.485	1.255
12	0.211	1.558	57	18.502	2.230	102	56.818	1.237
13	0.236	1.570	58	19.263	2.196	103	58.151	1.221
14	0.236	1.580	59	20.024	2.151	104	59.485	1.203
15	0.236	1.593	60	20.785	2.092	105	60.818	1.185
16	0.260	1.604	61	21.546	2.029	106	62.151	1.165
17	0.284	1.612	62	22.308	1.963	107	63.485	1.147
18	0.284	1.619	63	23.069	1.900	108	64.818	1.128
19	0.284	1.627	64	23.830	1.844	109	66.151	1.104
20	0.309	1.632	65	24.591	1.801	110	67.485	1.084
21	0.333	1.637	66	25.303	1.770	111	68.818	1.065
22	0.972	1.783	67	26.064	1.749	112	70.151	1.042
23	1.684	1.863	68	26.801	1.740	113	71.485	1.018
24	2.445	1.920	69	27.562	1.729	114	72.818	0.997
25	3.182	1.974	70	28.299	1.725	115	74.151	0.974
26	3.919	2.021	71	29.084	1.723	116	75.485	0.953
27	4.680	2.064	72	29.796	1.718	117	76.818	0.926
28	5.441	2.107	73	30.557	1.718	118	78.151	0.900
29	6.177	2.141	74	31.293	1.713	119	79.485	0.869
30	6.913	2.175	75	32.055	1.709	120	80.818	0.841
31	7.650	2.203	76	32.791	1.707	121	82.151	0.809
32	8.411	2.231	77	33.553	1.699	122	83.485	0.774
33	9.148	2.250	78	34.288	1.690	123	84.818	0.736
34	9.908	2.266	79	35.050	1.683	124	86.151	0.695
35	10.645	2.278	80	35.811	1.671	125	87.485	0.647
36	11.406	2.287	81	36.548	1.661	126	88.818	0.600
37	12.168	2.295	82	37.309	1.646	127	90.151	0.549
38	12.929	2.302	83	38.046	1.632	128	91.485	0.495
39	13.666	2.302	84	38.781	1.614	129	103.930	0.0
40	13.812	2.302	85	39.543	1.595	130		
41	13.838	2.302	86	40.279	1.577	131		
42	13.838	2.305	87	41.041	1.553	132		
43	13.862	2.302	88	41.802	1.536	133		
44	13.886	2.302	89	42.539	1.514	134		
45	13.886	2.301	90	43.299	1.492	135		

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA01											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)			
1	0.0	0.0	46	40.185	4.969	91					
2	0.103	4.569	47	42.323	4.865	92					
3	0.108	4.692	48	45.278	4.757	93					
4	0.124	5.032	49	45.883	4.664	94					
5	0.136	5.339	50	47.269	4.609	95					
6	0.148	5.565	51	49.157	4.520	96					
7	0.156	5.792	52	51.507	4.446	97					
8	0.219	5.987	53	53.838	4.322	98					
9	0.229	6.181	54	55.686	4.234	99					
10	0.283	6.310	55	57.454	4.161	100					
11	0.339	6.439	56	59.503	4.071	101					
12	0.397	6.552	57	61.592	3.981	102					
13	0.401	6.633	58	63.721	3.843	103					
14	0.454	6.714	59	65.911	3.768	104					
15	0.508	6.746	60	68.523	3.660	105					
16	0.560	6.794	61	71.174	3.536	106					
17	0.610	6.810	62	73.364	3.445	107					
18	0.715	6.842	63	75.755	3.305	108					
19	0.769	6.858	64	77.743	3.184	109					
20	0.870	6.858	65	79.933	3.061	110					
21	1.074	6.857	66	82.183	2.938	111					
22	1.277	6.840	67	84.011	2.833	112					
23	1.478	6.807	68	85.839	2.728	113					
24	1.886	6.773	69	87.527	2.592	114					
25	2.447	6.722	70	89.094	2.472	115					
26	2.903	6.705	71	90.721	2.351	116					
27	3.515	6.670	72	92.408	2.198	117					
28	4.534	6.634	73	94.397	2.028	118					
29	5.452	6.615	74	95.964	1.844	119					
30	6.470	6.563	75	97.290	1.692	120					
31	7.744	6.526	76	98.817	1.492	121					
32	9.172	6.472	77	100.500	1.291	122					
33	10.956	6.401	78	102.170	1.009	123					
34	12.583	6.330	79	103.310	0.794	124					
35	13.759	6.294	80	103.940	0.663	125					
36	15.998	6.189	81	104.340	0.563	126					
37	18.138	6.084	82	104.540	0.482	127					
38	20.175	5.979	83	104.740	0.320	128					
39	22.515	5.841	84	105.080	0.011	129					
40	24.607	5.770	85			130					
41	27.047	5.631	86			131					
42	29.442	5.525	87			132					
43	31.734	5.404	88			133					
44	33.871	5.283	89			134					
45	37.027	5.126	90			135					

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA02											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	10.662	6.381	91	43.925	4.783
2	0.125	4.821	47	11.397	6.358	92	44.637	4.760
3	0.138	4.915	48	12.133	6.326	93	45.397	4.728
4	0.138	5.085	49	12.869	6.295	94	46.137	4.590
5	0.138	5.257	50	13.629	6.265	95	47.804	4.520
6	0.162	5.412	51	14.341	6.218	96	49.471	4.443
7	0.162	5.567	52	15.102	6.203	97	51.137	4.364
8	0.187	5.706	53	15.838	6.163	98	52.804	4.294
9	0.187	5.831	54	16.573	6.141	99	54.471	4.209
10	0.211	5.939	55	17.309	6.094	100	56.137	4.139
11	0.211	6.039	56	18.045	6.055	101	57.804	4.054
12	0.236	6.133	57	18.781	6.031	102	59.471	3.977
13	0.260	6.210	58	19.517	5.993	103	61.137	3.907
14	0.260	6.280	59	20.253	5.961	104	62.804	3.822
15	0.284	6.342	60	20.989	5.931	105	64.471	3.744
16	0.284	6.396	61	21.749	5.884	106	66.137	3.659
17	0.333	6.450	62	22.461	5.854	107	67.804	3.574
18	0.333	6.497	63	23.221	5.814	108	69.471	3.480
19	0.358	6.528	64	23.958	5.784	109	71.137	3.387
20	0.358	6.567	65	24.693	5.753	110	72.804	3.295
21	0.383	6.598	66	25.429	5.706	111	74.471	3.201
22	0.628	6.777	67	26.165	5.667	112	76.137	3.100
23	0.653	6.777	68	26.901	5.644	113	77.804	2.993
24	0.677	6.777	69	27.661	5.597	114	79.471	2.883
25	0.677	6.784	70	28.372	5.567	115	81.137	2.768
26	0.702	6.792	71	29.133	5.520	116	82.804	2.643
27	0.726	6.792	72	29.869	5.481	117	84.471	2.511
28	0.751	6.792	73	30.605	5.457	118	86.137	2.364
29	0.775	6.800	74	31.341	5.404	119	87.804	2.209
30	0.775	6.800	75	32.101	5.372	120	89.471	2.039
31	0.799	6.800	76	32.838	5.334	121	91.137	1.852
32	0.824	6.800	77	33.574	5.295	122	92.804	1.650
33	0.849	6.800	78	34.309	5.257	123	94.471	1.426
34	1.683	6.737	79	35.070	5.225	124	96.137	1.186
35	2.493	6.668	80	35.756	5.217	125	97.804	0.899
36	3.253	6.621	81	36.517	5.155	126	102.750	0.0
37	4.013	6.598	82	37.278	5.102	127		
38	4.749	6.575	83	38.014	5.062	128		
39	5.485	6.560	84	38.749	5.024	129		
40	6.246	6.535	85	39.485	4.985	130		
41	6.982	6.513	86	40.221	4.954	131		
42	7.718	6.490	87	40.981	4.915	132		
43	8.453	6.466	88	41.693	4.885	133		
44	9.189	6.435	89	42.429	4.853	134		
45	9.925	6.412	90	43.190	4.815	135		

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA03								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	18.718	7.816	91	43.561	6.784
2	0.113	3.458	47	19.454	7.827	92	44.297	6.714
3	0.129	3.525	48	20.214	7.827	93	45.032	6.644
4	0.129	3.615	49	20.926	7.827	94	46.091	6.443
5	0.129	3.695	50	21.661	7.833	95	47.091	6.341
6	0.154	3.776	51	21.955	7.827	96	48.091	6.224
7	0.154	3.850	52	21.980	7.827	97	49.091	6.115
8	0.154	3.923	53	21.980	7.827	98	50.091	6.002
9	0.178	3.984	54	22.004	7.827	99	51.091	5.884
10	0.178	4.043	55	22.029	7.827	100	52.091	5.760
11	0.203	4.093	56	22.029	7.827	101	53.091	5.642
12	0.227	4.145	57	22.053	7.827	102	54.091	5.527
13	0.227	4.190	58	22.078	7.827	103	55.091	5.409
14	0.227	4.233	59	22.078	7.827	104	56.091	5.302
15	0.251	4.274	60	22.102	7.827	105	57.091	5.184
16	0.276	4.310	61	22.126	7.827	106	58.091	5.076
17	0.276	4.345	62	22.151	7.827	107	59.091	4.959
18	0.300	4.382	63	22.862	7.816	108	60.091	4.860
19	0.326	4.412	64	23.598	7.816	109	61.091	4.749
20	0.326	4.444	65	24.334	7.801	110	62.091	4.656
21	0.350	4.474	66	25.070	7.795	111	63.091	4.555
22	1.061	5.416	67	25.756	7.810	112	64.091	4.457
23	1.796	5.934	68	26.517	7.772	113	65.091	4.361
24	2.557	6.279	69	27.277	7.740	114	66.091	4.260
25	3.268	6.496	70	28.037	7.715	115	67.091	4.160
26	4.004	6.685	71	28.773	7.687	116	68.091	4.059
27	4.739	6.837	72	29.509	7.655	117	69.091	3.957
28	5.475	6.971	73	30.269	7.632	118	70.091	3.855
29	6.211	7.073	74	31.005	7.591	119	71.091	3.741
30	6.947	7.165	75	31.740	7.562	120	72.091	3.624
31	7.683	7.251	76	32.476	7.530	121	73.091	3.499
32	8.418	7.327	77	33.236	7.492	122	74.091	3.359
33	9.179	7.397	78	33.972	7.451	123	75.091	3.204
34	9.890	7.460	79	34.707	7.413	124	76.091	3.035
35	10.626	7.515	80	35.467	7.369	125	77.091	2.838
36	11.361	7.562	81	36.179	7.320	126	78.091	2.615
37	12.096	7.607	82	36.939	7.282	127	79.091	2.357
38	12.832	7.645	83	37.650	7.229	128	80.091	1.824
39	13.568	7.677	84	38.410	7.181	129	81.155	0.0
40	14.304	7.708	85	39.146	7.134	130		
41	15.039	7.731	86	39.906	7.073	131		
42	15.775	7.757	87	40.618	7.019	132		
43	16.511	7.785	88	41.353	6.964	133		
44	17.222	7.795	89	42.114	6.907	134		
45	17.982	7.810	90	42.825	6.847	135		

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA04								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	15.107	7.750	91	40.919	6.974
2	0.100	3.173	47	15.843	7.766	92	41.680	6.919
3	0.116	3.242	48	16.604	7.789	93	42.391	6.866
4	0.116	3.343	49	17.364	7.797	94	43.127	6.796
5	0.116	3.444	50	18.100	7.805	95	43.888	6.734
6	0.116	3.529	51	18.837	7.820	96	44.599	6.664
7	0.140	3.614	52	19.573	7.828	97	45.359	6.602
8	0.140	3.684	53	20.333	7.828	98	46.100	6.407
9	0.140	3.754	54	20.578	7.828	99	47.100	6.307
10	0.140	3.824	55	20.604	7.828	100	48.100	6.199
11	0.165	3.886	56	20.628	7.836	101	49.100	6.082
12	0.165	3.941	57	20.652	7.828	102	50.100	5.974
13	0.189	3.994	58	20.652	7.828	103	51.100	5.857
14	0.189	4.049	59	20.677	7.828	104	52.100	5.748
15	0.214	4.096	60	20.701	7.828	105	53.100	5.632
16	0.238	4.134	61	20.701	7.828	106	54.100	5.515
17	0.238	4.174	62	20.726	7.828	107	55.100	5.407
18	0.262	4.212	63	20.750	7.828	108	56.100	5.290
19	0.262	4.251	64	20.775	7.828	109	57.100	5.182
20	0.262	4.289	65	21.511	7.828	110	58.100	5.081
21	0.287	4.329	66	22.272	7.820	111	59.100	4.980
22	0.312	4.359	67	23.007	7.813	112	60.100	4.879
23	0.312	4.391	68	23.744	7.797	113	61.100	4.786
24	0.337	4.421	69	24.504	7.781	114	62.100	4.693
25	0.337	4.446	70	25.240	7.773	115	63.100	4.601
26	0.361	4.476	71	25.977	7.758	116	64.100	4.514
27	1.073	5.368	72	26.713	7.735	117	65.100	4.421
28	1.808	5.895	73	27.473	7.719	118	66.100	4.344
29	2.520	6.229	74	28.210	7.696	119	67.100	4.251
30	3.281	6.477	75	28.970	7.665	120	68.100	4.166
31	4.041	6.664	76	29.706	7.641	121	69.100	4.081
32	4.778	6.819	77	30.467	7.611	122	70.100	3.994
33	5.514	6.944	78	31.203	7.571	123	71.100	3.902
34	6.274	7.052	79	31.963	7.541	124	72.100	3.809
35	7.011	7.153	80	32.700	7.510	125	73.100	3.707
36	7.722	7.238	81	33.435	7.471	126	74.100	3.607
37	8.482	7.316	82	34.196	7.424	127	75.100	3.499
38	9.218	7.386	83	34.932	7.386	128	76.100	3.367
39	9.979	7.440	84	35.693	7.339	129	77.100	3.227
40	10.715	7.501	85	36.428	7.301	130	78.100	3.072
41	11.452	7.548	86	37.190	7.246	131	79.100	2.893
42	12.187	7.595	87	37.950	7.191	132	80.100	2.675
43	12.923	7.634	88	38.687	7.146	133	81.100	2.396
44	13.684	7.665	89	39.422	7.091	134	82.100	1.606
45	14.420	7.703	90	40.158	7.044	135	83.084	0.0

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA05											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	26.554	4.643	91		
2	0.032	2.217	47	27.264	4.528	92		
3	0.044	2.493	48	28.280	4.394	93		
4	0.100	2.655	49	29.397	4.197	94		
5	0.160	2.849	50	30.772	3.998	95		
6	0.269	2.995	51	31.991	3.833	96		
7	0.324	3.140	52	33.366	3.698	97		
8	0.430	3.237	53	35.100	3.580	98		
9	0.537	3.349	54	36.632	3.542	99		
10	0.694	3.446	55	38.163	3.504	100		
11	0.851	3.559	56	39.902	3.483	101		
12	1.060	3.656	57	41.691	3.477	102		
13	1.320	3.769	58	43.679	3.454	103		
14	1.630	3.865	59	45.316	3.401	104		
15	1.939	3.929	60	45.803	3.360	105		
16	2.197	4.008	61	46.708	3.372	106		
17	2.507	4.041	62	47.694	3.351	107		
18	2.867	4.087	63	48.821	3.315	108		
19	3.276	4.119	64	49.988	3.293	109		
20	3.636	4.166	65	51.256	3.224	110		
21	3.994	4.214	66	52.544	3.137	111		
22	4.407	4.260	67	53.973	3.034	112		
23	4.970	4.307	68	55.603	2.931	113		
24	5.586	4.370	69	57.133	2.826	114		
25	6.355	4.433	70	58.602	2.739	115		
26	7.124	4.479	71	60.332	2.619	116		
27	7.739	4.525	72	61.962	2.515	117		
28	8.456	4.556	73	63.492	2.395	118		
29	9.120	4.602	74	64.981	2.276	119		
30	10.096	4.680	75	66.450	2.124	120		
31	11.070	4.709	76	67.778	1.973	121		
32	11.837	4.755	77	68.885	1.839	122		
33	13.014	4.800	78	69.751	1.674	123		
34	14.296	4.861	79	70.777	1.540	124		
35	15.727	4.889	80	71.683	1.359	125		
36	16.956	4.916	81	72.387	1.210	126		
37	17.721	4.882	82	72.950	1.046	127		
38	18.641	4.879	83	73.252	0.948	128		
39	19.458	4.892	84	73.494	0.817	129		
40	20.736	4.873	85	73.695	0.639	130		
41	21.605	4.853	86	73.836	0.380	131		
42	22.728	4.834	87	74.379	0.0	132		
43	23.698	4.798	88			133		
44	24.817	4.729	89			134		
45	25.837	4.678	90			135		

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA06								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	15.794	4.935	91	40.653	3.533
2	0.069	2.253	47	16.530	4.946	92	41.389	3.529
3	0.087	2.310	48	17.291	4.950	93	42.150	3.516
4	0.087	2.381	49	18.051	4.953	94	42.862	3.520
5	0.087	2.443	50	18.051	4.953	95	43.623	3.511
6	0.087	2.505	51	18.051	4.953	96	44.334	3.505
7	0.112	2.561	52	18.076	4.956	97	45.071	3.501
8	0.112	2.608	53	18.100	4.953	98	51.569	3.443
9	0.112	2.654	54	18.100	4.953	99	51.891	3.439
10	0.161	2.698	55	18.125	4.953	100	52.212	3.432
11	0.136	2.735	56	18.150	4.950	101	52.534	3.427
12	0.161	2.772	57	18.174	4.953	102	52.875	3.421
13	0.161	2.809	58	18.174	4.953	103	53.197	3.415
14	0.161	2.841	59	18.199	4.953	104	53.518	3.402
15	0.186	2.875	60	18.223	4.950	105	53.820	3.396
16	0.186	2.903	61	18.223	4.953	106	54.161	3.389
17	0.186	2.931	62	18.984	4.953	107	54.483	3.380
18	0.210	2.955	63	19.745	4.946	108	54.804	3.371
19	0.235	2.983	64	20.481	4.935	109	55.126	3.361
20	0.235	3.008	65	21.217	4.925	110	55.467	3.352
21	0.259	3.032	66	21.953	4.913	111	55.789	3.340
22	0.259	3.054	67	22.714	4.888	112	56.110	3.331
23	0.259	3.077	68	23.450	4.857	113	56.432	3.318
24	0.284	3.095	69	24.211	4.823	114	56.753	3.305
25	0.308	3.114	70	24.972	4.780	115	57.075	3.296
26	0.946	3.653	71	25.708	4.724	116	57.396	3.281
27	1.683	3.914	72	26.469	4.655	117	57.718	3.269
28	2.419	4.079	73	27.205	4.578	118	58.059	3.253
29	3.155	4.189	74	27.966	4.484	119	58.381	3.241
30	3.916	4.277	75	28.702	4.379	120	58.702	3.222
31	4.652	4.354	76	29.463	4.262	121	59.024	3.206
32	5.413	4.429	77	30.223	4.144	122	59.345	3.191
33	6.149	4.494	78	30.960	4.028	123	59.667	3.172
34	6.885	4.550	79	31.720	3.926	124	59.988	3.154
35	7.621	4.606	80	32.457	3.836	125	60.330	3.135
36	8.358	4.655	81	33.217	3.761	126	60.652	3.120
37	9.118	4.705	82	33.954	3.703	127	60.973	3.095
38	9.855	4.752	83	34.714	3.660	128	61.295	3.077
39	10.591	4.785	84	35.451	3.625	129	61.616	3.054
40	11.352	4.817	85	36.187	3.594	130	61.938	3.036
41	12.088	4.845	86	36.948	3.576	131	62.279	3.011
42	12.824	4.869	87	37.684	3.566	132	62.601	2.993
43	13.560	4.894	88	38.421	3.554	133	62.922	2.965
44	14.321	4.909	89	39.181	3.544	134	63.244	2.943
45	15.057	4.922	90	39.918	3.539	135	63.565	2.921

Table A2 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA06						
	Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)
136	63.867	2.896	181		226	
137	64.208	2.871	182		227	
138	64.530	2.847	183		228	
139	64.851	2.821	184		229	
140	65.173	2.800	185		230	
141	65.494	2.778	186		231	
142	65.816	2.754	187		232	
143	66.157	2.729	188		233	
144	66.459	2.707	189		234	
145	66.780	2.682	190		235	
146	67.122	2.660	191		236	
147	67.423	2.636	192		237	
148	69.272	2.449	193		238	
149	71.201	2.240	194		239	
150	73.753	1.969	195		240	
151	76.184	1.649	196		241	
152	78.756	1.300	197		242	
153	79.721	0.590	198		243	
154	80.042	0.039	199		244	
155	80.086	0.0	200		245	
156			201		246	
157			202		247	
158			203		248	
159			204		249	
160			205		250	
161			206		251	
162			207		252	
163			208		253	
164			209		254	
165			210		255	
166			211		256	
167			212		257	
168			213		258	
169			214		259	
170			215		260	
171			216		261	
172			217		262	
173			218		263	
174			219		264	
175			220		265	
176			221		266	
177			222		267	
178			223		268	
179			224		269	
180			225		270	

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA07											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)			
1	0.0	0.0	46	19.957	2.931	91					
2	0.024	1.203	47	20.567	2.892	92					
3	0.078	1.255	48	21.127	2.839	93					
4	0.138	1.306	49	21.733	2.780	94					
5	0.199	1.416	50	22.645	2.688	95					
6	0.263	1.526	51	23.249	2.622	96					
7	0.320	1.584	52	24.214	2.536	97					
8	0.376	1.649	53	25.128	2.464	98					
9	0.485	1.713	54	25.992	2.404	99					
10	0.593	1.758	55	26.855	2.345	100					
11	0.753	1.804	56	27.619	2.298	101					
12	0.807	1.842	57	28.738	2.232	102					
13	0.912	1.881	58	29.958	2.172	103					
14	1.069	1.906	59	31.537	2.092	104					
15	1.175	1.945	60	32.809	2.025	105					
16	1.385	1.971	61	34.285	1.945	106					
17	1.540	2.003	62	36.319	1.832	107					
18	1.802	2.054	63	38.202	1.719	108					
19	2.114	2.106	64	39.879	1.606	109					
20	2.476	2.150	65	41.099	1.527	110					
21	2.841	2.201	66	42.367	1.428	111					
22	3.153	2.246	67	43.686	1.322	112					
23	3.567	2.284	68	44.651	1.243	113					
24	3.980	2.335	69	45.462	1.177	114					
25	4.598	2.386	70	45.766	1.125	115					
26	5.168	2.444	71	46.471	1.059	116					
27	5.788	2.501	72	47.397	0.987	117					
28	6.461	2.558	73	48.444	0.888	118					
29	7.184	2.621	74	49.572	0.789	119					
30	7.697	2.653	75	50.679	0.678	120					
31	8.317	2.697	76	51.847	0.579	121					
32	8.883	2.735	77	53.377	0.441	122					
33	10.015	2.785	78	54.283	0.349	123					
34	11.146	2.835	79	55.552	0.238	124					
35	12.070	2.873	80	56.921	0.125	125					
36	12.995	2.904	81	58.491	0.037	126					
37	13.766	2.941	82	58.600	0.0	127					
38	14.585	2.966	83			128					
39	15.411	2.997	84			129					
40	16.281	3.002	85			130					
41	16.742	3.014	86			131					
42	17.356	3.013	87			132					
43	18.022	3.012	88			133					
44	18.584	2.992	89			134					
45	19.349	2.978	90			135					

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA08								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	16.327	3.109	91	44.416	1.596
2	0.068	1.252	47	16.351	3.110	92	45.152	1.548
3	0.087	1.289	48	16.377	3.112	93	46.137	1.426
4	0.087	1.327	49	16.401	3.110	94	46.471	1.399
5	0.112	1.351	50	16.401	3.110	95	46.804	1.375
6	0.112	1.376	51	16.426	3.113	96	47.137	1.350
7	0.112	1.394	52	16.450	3.113	97	47.471	1.327
8	0.137	1.413	53	16.475	3.113	98	47.804	1.303
9	0.161	1.431	54	16.475	3.112	99	48.137	1.280
10	0.161	1.449	55	17.259	3.104	100	48.471	1.257
11	0.161	1.468	56	17.971	3.095	101	48.804	1.233
12	0.210	1.483	57	18.756	3.063	102	49.137	1.207
13	0.186	1.500	58	19.516	3.015	103	49.471	1.181
14	0.210	1.519	59	20.277	2.955	104	49.804	1.153
15	0.210	1.534	60	21.062	2.870	105	50.137	1.125
16	0.235	1.547	61	21.822	2.781	106	50.471	1.098
17	0.259	1.566	62	22.558	2.688	107	50.804	1.069
18	0.259	1.581	63	23.318	2.607	108	51.137	1.039
19	0.259	1.594	64	24.080	2.541	109	51.471	1.011
20	0.283	1.609	65	24.840	2.485	110	51.804	0.984
21	0.308	1.623	66	25.625	2.447	111	52.137	0.952
22	0.946	1.966	67	26.360	2.407	112	52.471	0.924
23	1.657	2.126	68	27.097	2.379	113	52.804	0.895
24	2.393	2.240	69	27.857	2.354	114	53.137	0.864
25	3.154	2.340	70	28.593	2.332	115	53.471	0.835
26	3.915	2.430	71	29.353	2.311	116	53.804	0.804
27	4.650	2.514	72	30.114	2.285	117	54.137	0.774
28	5.410	2.596	73	30.875	2.268	118	54.471	0.743
29	6.172	2.667	74	31.635	2.240	119	54.804	0.711
30	6.907	2.733	75	32.371	2.218	120	55.137	0.682
31	7.643	2.789	76	33.132	2.189	121	55.471	0.650
32	8.403	2.840	77	33.892	2.158	122	55.804	0.620
33	9.164	2.887	78	34.628	2.124	123	56.137	0.586
34	9.900	2.929	79	35.388	2.087	124	56.471	0.555
35	10.661	2.964	80	36.149	2.051	125	56.804	0.522
36	11.421	2.996	81	36.909	2.013	126	57.137	0.494
37	12.181	3.027	82	37.670	1.975	127	57.471	0.464
38	12.918	3.049	83	38.430	1.933	128	57.804	0.433
39	13.678	3.071	84	39.141	1.898	129	58.137	0.401
40	14.438	3.089	85	39.927	1.854	130	58.471	0.369
41	15.174	3.098	86	40.663	1.814	131	58.804	0.339
42	15.935	3.109	87	41.423	1.770	132	59.137	0.310
43	16.278	3.109	88	42.183	1.729	133	59.471	0.278
44	16.303	3.109	89	42.920	1.685	134	59.804	0.249
45	16.327	3.108	90	43.656	1.640	135	60.137	0.219

Table A2 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA08					
Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)
136 60.471	0.191	181		226	
137 60.804	0.162	182		227	
138 61.137	0.137	183		228	
139 62.621	0.0	184		229	
140		185		230	
141		186		231	
142		187		232	
143		188		233	
144		189		234	
145		190		235	
146		191		236	
147		192		237	
148		193		238	
149		194		239	
150		195		240	
151		196		241	
152		197		242	
153		198		243	
154		199		244	
155		200		245	
156		201		246	
157		202		247	
158		203		248	
159		204		249	
160		205		250	
161		206		251	
162		207		252	
163		208		253	
164		209		254	
165		210		255	
166		211		256	
167		212		257	
168		213		258	
169		214		259	
170		215		260	
171		216		261	
172		217		262	
173		218		263	
174		219		264	
175		220		265	
176		221		266	
177		222		267	
178		223		268	
179		224		269	
180		225		270	

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA09								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	16.988	3.070	91	43.186	1.644
2	0.069	1.227	47	16.988	3.068	92	43.922	1.617
3	0.087	1.261	48	17.013	3.071	93	44.658	1.587
4	0.087	1.294	49	17.038	3.070	94	45.393	1.556
5	0.087	1.322	50	17.062	3.073	95	46.134	1.484
6	0.112	1.343	51	17.062	3.075	96	46.801	1.453
7	0.112	1.365	52	17.087	3.073	97	47.468	1.425
8	0.136	1.385	53	17.087	3.073	98	48.134	1.397
9	0.136	1.403	54	17.111	3.073	99	48.801	1.369
10	0.136	1.421	55	17.111	3.071	100	49.468	1.341
11	0.161	1.436	56	17.160	3.071	101	50.134	1.315
12	0.161	1.450	57	17.920	3.062	102	50.801	1.291
13	0.186	1.468	58	18.657	3.042	103	51.468	1.264
14	0.186	1.482	59	19.417	3.010	104	52.134	1.238
15	0.211	1.498	60	20.153	2.958	105	52.801	1.215
16	0.235	1.512	61	20.913	2.892	106	53.468	1.187
17	0.235	1.528	62	21.649	2.804	107	54.134	1.158
18	0.235	1.544	63	22.409	2.716	108	54.801	1.131
19	0.259	1.556	64	23.170	2.635	109	55.468	1.102
20	0.259	1.568	65	23.906	2.567	110	56.134	1.071
21	0.259	1.581	66	24.642	2.508	111	56.801	1.043
22	0.284	1.594	67	25.378	2.463	112	57.468	1.014
23	0.308	1.606	68	26.113	2.417	113	58.134	0.986
24	0.946	1.941	69	26.849	2.381	114	58.801	0.958
25	1.633	2.106	70	27.585	2.341	115	59.468	0.929
26	2.369	2.227	71	28.345	2.304	116	60.134	0.896
27	3.129	2.325	72	29.082	2.269	117	60.801	0.865
28	3.865	2.410	73	29.818	2.232	118	61.468	0.832
29	4.601	2.486	74	30.554	2.194	119	62.134	0.797
30	5.337	2.555	75	31.314	2.154	120	62.801	0.762
31	6.097	2.622	76	32.050	2.114	121	63.468	0.724
32	6.808	2.683	77	32.785	2.079	122	64.134	0.687
33	7.569	2.736	78	33.546	2.041	123	64.801	0.647
34	8.305	2.782	79	34.281	2.004	124	65.468	0.605
35	9.065	2.825	80	35.018	1.967	125	66.134	0.563
36	9.826	2.865	81	35.778	1.938	126	66.801	0.521
37	10.537	2.906	82	36.514	1.906	127	67.468	0.477
38	11.273	2.935	83	37.274	1.877	128	68.134	0.432
39	12.009	2.965	84	38.010	1.847	129	68.801	0.387
40	12.745	2.989	85	38.746	1.820	130	69.468	0.341
41	13.481	3.014	86	39.482	1.792	131	70.134	0.297
42	14.217	3.039	87	40.218	1.763	132	70.801	0.252
43	14.953	3.049	88	40.979	1.735	133	71.468	0.207
44	15.688	3.067	89	41.690	1.700	134	72.134	0.162
45	16.449	3.071	90	42.450	1.674	135	74.791	0.0

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA10									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	17.262	3.076	91	44.626	1.630
2	0.069	1.305	47	17.286	3.079	92	45.388	1.592
3	0.091	1.329	48	17.311	3.080	93	46.202	1.491
4	0.115	1.354	49	17.311	3.081	94	46.535	1.469
5	0.115	1.375	50	17.335	3.081	95	46.869	1.447
6	0.115	1.394	51	17.360	3.080	96	47.202	1.425
7	0.140	1.410	52	17.360	3.081	97	47.535	1.405
8	0.140	1.422	53	17.385	3.083	98	47.869	1.385
9	0.140	1.438	54	17.385	3.080	99	48.202	1.366
10	0.164	1.453	55	17.409	3.080	100	48.535	1.347
11	0.164	1.469	56	18.195	3.076	101	48.869	1.326
12	0.189	1.481	57	18.932	3.060	102	49.202	1.306
13	0.189	1.497	58	19.694	3.037	103	49.535	1.284
14	0.214	1.511	59	20.431	2.995	104	49.869	1.259
15	0.214	1.526	60	21.216	2.941	105	50.202	1.237
16	0.239	1.538	61	21.953	2.865	106	50.535	1.216
17	0.239	1.555	62	22.740	2.785	107	50.869	1.190
18	0.239	1.568	63	23.501	2.705	108	51.202	1.166
19	0.263	1.582	64	24.238	2.630	109	51.535	1.141
20	0.263	1.592	65	24.999	2.563	110	51.869	1.115
21	0.287	1.602	66	25.761	2.506	111	52.202	1.094
22	0.951	1.939	67	26.522	2.456	112	52.535	1.068
23	1.663	2.100	68	27.259	2.409	113	52.869	1.043
24	2.400	2.220	69	28.021	2.368	114	53.202	1.019
25	3.161	2.317	70	28.758	2.329	115	53.535	0.991
26	3.924	2.406	71	29.519	2.293	116	53.869	0.965
27	4.660	2.484	72	30.305	2.259	117	54.202	0.937
28	5.421	2.561	73	31.067	2.227	118	54.535	0.909
29	6.183	2.626	74	31.804	2.197	119	54.869	0.884
30	6.919	2.687	75	32.565	2.171	120	55.202	0.857
31	7.682	2.744	76	33.302	2.141	121	55.535	0.829
32	8.418	2.794	77	34.064	2.112	122	55.869	0.803
33	9.204	2.842	78	34.825	2.084	123	56.202	0.773
34	9.941	2.884	79	35.587	2.058	124	56.535	0.745
35	10.679	2.922	80	36.348	2.028	125	56.869	0.718
36	11.440	2.955	81	37.110	1.996	126	57.202	0.688
37	12.201	2.982	82	37.871	1.967	127	57.535	0.659
38	12.963	3.006	83	38.608	1.930	128	57.869	0.631
39	13.724	3.030	84	39.370	1.896	129	58.202	0.599
40	14.486	3.042	85	40.131	1.856	130	58.535	0.571
41	15.247	3.061	86	40.868	1.823	131	58.869	0.542
42	16.009	3.072	87	41.605	1.786	132	59.202	0.514
43	16.770	3.081	88	42.366	1.747	133	59.535	0.484
44	17.213	3.079	89	43.128	1.711	134	59.869	0.456
45	17.237	3.075	90	43.890	1.669	135	60.202	0.428

Table A2 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA10					
Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)
136 60.535	0.400	181		226	
137 60.869	0.369	182		227	
138 61.202	0.341	183		228	
139 61.535	0.312	184		229	
140 61.869	0.285	185		230	
141 62.202	0.257	186		231	
142 62.535	0.230	187		232	
143 62.869	0.204	188		233	
144 63.202	0.177	189		234	
145 63.535	0.151	190		235	
146 65.042	0.0	191		236	
147		192		237	
148		193		238	
149		194		239	
150		195		240	
151		196		241	
152		197		242	
153		198		243	
154		199		244	
155		200		245	
156		201		246	
157		202		247	
158		203		248	
159		204		249	
160		205		250	
161		206		251	
162		207		252	
163		208		253	
164		209		254	
165		210		255	
166		211		256	
167		212		257	
168		213		258	
169		214		259	
170		215		260	
171		216		261	
172		217		262	
173		218		263	
174		219		264	
175		220		265	
176		221		266	
177		222		267	
178		223		268	
179		224		269	
180		225		270	

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA11								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	15.834	3.071	91	41.113	1.644
2	0.065	1.225	47	16.595	3.077	92	41.875	1.601
3	0.076	1.246	48	16.840	3.079	93	42.636	1.555
4	0.076	1.286	49	16.840	3.077	94	43.372	1.508
5	0.100	1.315	50	16.864	3.077	95	44.108	1.459
6	0.076	1.342	51	16.889	3.077	96	44.868	1.407
7	0.100	1.356	52	16.889	3.077	97	46.174	1.266
8	0.100	1.371	53	16.913	3.076	98	46.507	1.241
9	0.126	1.386	54	16.938	3.076	99	46.841	1.215
10	0.126	1.400	55	16.962	3.077	100	47.174	1.189
11	0.150	1.418	56	16.962	3.079	101	47.507	1.168
12	0.150	1.433	57	16.988	3.081	102	47.841	1.145
13	0.175	1.447	58	17.012	3.079	103	48.174	1.118
14	0.175	1.463	59	17.036	3.077	104	48.507	1.096
15	0.199	1.478	60	17.772	3.073	105	48.841	1.070
16	0.199	1.496	61	18.509	3.057	106	49.174	1.042
17	0.199	1.510	62	19.270	3.029	107	49.507	1.018
18	0.224	1.524	63	19.858	3.031	108	49.841	0.990
19	0.224	1.536	64	20.717	2.940	109	50.174	0.963
20	0.224	1.552	65	21.527	2.837	110	50.507	0.936
21	0.248	1.566	66	22.313	2.730	111	50.841	0.907
22	0.248	1.578	67	23.074	2.633	112	51.174	0.882
23	0.272	1.592	68	23.834	2.553	113	51.507	0.856
24	0.272	1.604	69	24.596	2.483	114	51.841	0.830
25	0.297	1.615	70	25.332	2.427	115	52.174	0.800
26	0.911	1.954	71	26.093	2.378	116	52.507	0.774
27	1.647	2.116	72	26.609	2.429	117	52.841	0.746
28	2.383	2.232	73	27.492	2.364	118	53.174	0.716
29	3.120	2.327	74	28.302	2.310	119	53.507	0.688
30	3.881	2.415	75	29.088	2.262	120	53.841	0.659
31	4.617	2.491	76	29.848	2.214	121	54.174	0.631
32	5.378	2.558	77	30.609	2.169	122	54.507	0.601
33	6.138	2.624	78	31.370	2.127	123	54.841	0.575
34	6.851	2.683	79	32.106	2.088	124	55.174	0.547
35	7.636	2.737	80	32.867	2.050	125	55.507	0.517
36	8.348	2.790	81	33.627	2.014	126	55.841	0.489
37	9.109	2.839	82	34.364	1.980	127	56.174	0.461
38	9.869	2.879	83	35.125	1.947	128	56.507	0.430
39	10.581	2.914	84	35.861	1.911	129	56.841	0.402
40	11.342	2.951	85	36.622	1.877	130	57.174	0.374
41	12.078	2.979	86	37.408	1.845	131	57.507	0.347
42	12.840	3.006	87	38.119	1.804	132	57.841	0.317
43	13.600	3.025	88	38.881	1.765	133	58.174	0.289
44	14.337	3.043	89	39.641	1.728	134	58.507	0.263
45	15.097	3.062	90	40.378	1.688	135	58.841	0.233

Table A2 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA11					
Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)	Strain (%)	Stress (kg/mm²)
136 59.174	0.207	181		226	
137 59.507	0.179	182		227	
138 59.841	0.152	183		228	
139 61.475	0.0	184		229	
140		185		230	
141		186		231	
142		187		232	
143		188		233	
144		189		234	
145		190		235	
146		191		236	
147		192		237	
148		193		238	
149		194		239	
150		195		240	
151		196		241	
152		197		242	
153		198		243	
154		199		244	
155		200		245	
156		201		246	
157		202		247	
158		203		248	
159		204		249	
160		205		250	
161		206		251	
162		207		252	
163		208		253	
164		209		254	
165		210		255	
166		211		256	
167		212		257	
168		213		258	
169		214		259	
170		215		260	
171		216		261	
172		217		262	
173		218		263	
174		219		264	
175		220		265	
176		221		266	
177		222		267	
178		223		268	
179		224		269	
180		225		270	

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA12											
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	16.282	2.979	91	42.592	1.537
2	0.090	1.294	47	16.307	2.979	92	43.377	1.497
3	0.109	1.316	48	16.332	2.980	93	44.113	1.463
4	0.109	1.338	49	16.332	2.980	94	44.800	1.427
5	0.134	1.361	50	16.356	2.977	95	46.154	1.321
6	0.134	1.378	51	16.381	2.980	96	46.821	1.281
7	0.134	1.391	52	16.405	2.979	97	47.487	1.247
8	0.134	1.399	53	16.405	2.977	98	48.154	1.215
9	0.158	1.411	54	16.430	2.977	99	48.821	1.182
10	0.158	1.425	55	16.454	2.976	100	49.487	1.149
11	0.183	1.439	56	16.454	2.976	101	50.154	1.116
12	0.183	1.453	57	17.215	2.977	102	50.821	1.078
13	0.207	1.468	58	17.951	2.961	103	51.487	1.041
14	0.233	1.483	59	18.712	2.923	104	52.154	1.001
15	0.233	1.497	60	19.473	2.871	105	52.821	0.965
16	0.233	1.513	61	20.234	2.797	106	53.487	0.928
17	0.257	1.524	62	20.970	2.719	107	54.154	0.882
18	0.281	1.538	63	21.731	2.640	108	54.821	0.846
19	0.281	1.547	64	22.492	2.569	109	55.487	0.803
20	0.281	1.560	65	23.228	2.517	110	56.154	0.761
21	0.306	1.572	66	23.965	2.470	111	56.821	0.719
22	0.306	1.584	67	24.725	2.431	112	57.487	0.675
23	0.330	1.598	68	25.462	2.387	113	58.154	0.629
24	0.944	1.909	69	26.197	2.347	114	58.821	0.586
25	1.631	2.066	70	26.959	2.305	115	59.487	0.541
26	2.342	2.178	71	27.694	2.262	116	60.154	0.495
27	3.079	2.274	72	28.456	2.214	117	60.821	0.446
28	3.815	2.354	73	29.191	2.170	118	61.487	0.400
29	4.552	2.436	74	29.952	2.124	119	62.154	0.354
30	5.287	2.502	75	30.688	2.081	120	62.821	0.306
31	6.073	2.562	76	31.449	2.042	121	63.487	0.260
32	6.784	2.620	77	32.185	2.002	122	64.154	0.213
33	7.521	2.671	78	32.946	1.965	123	64.821	0.165
34	8.257	2.715	79	33.682	1.932	124	66.891	0.0
35	8.994	2.757	80	34.443	1.897	125		
36	9.729	2.797	81	35.180	1.867	126		
37	10.466	2.832	82	35.940	1.833	127		
38	11.202	2.858	83	36.677	1.804	128		
39	11.963	2.886	84	37.389	1.769	129		
40	12.699	2.913	85	38.150	1.734	130		
41	13.436	2.935	86	38.886	1.702	131		
42	14.172	2.949	87	39.647	1.672	132		
43	14.933	2.968	88	40.383	1.635	133		
44	15.669	2.975	89	41.144	1.602	134		
45	16.258	2.980	90	41.855	1.565	135		

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA13								
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	13.951	1.867	91	42.032	0.933
2	0.090	0.739	47	13.951	1.867	92	42.793	0.913
3	0.105	0.753	48	13.951	1.864	93	43.529	0.894
4	0.105	0.768	49	14.000	1.864	94	44.266	0.873
5	0.105	0.783	50	14.024	1.863	95	45.002	0.853
6	0.105	0.798	51	14.024	1.864	96	46.185	0.787
7	0.131	0.815	52	14.048	1.864	97	46.851	0.763
8	0.131	0.825	53	14.073	1.864	98	47.518	0.739
9	0.131	0.839	54	14.073	1.864	99	48.185	0.716
10	0.155	0.853	55	14.834	1.863	100	48.851	0.690
11	0.180	0.866	56	15.571	1.849	101	49.518	0.662
12	0.180	0.877	57	16.282	1.832	102	50.185	0.634
13	0.204	0.886	58	17.043	1.785	103	50.851	0.605
14	0.204	0.899	59	17.853	1.720	104	51.518	0.573
15	0.229	0.909	60	18.639	1.652	105	52.185	0.541
16	0.229	0.920	61	19.399	1.593	106	52.851	0.507
17	0.253	0.928	62	20.161	1.542	107	53.518	0.471
18	0.253	0.938	63	20.922	1.506	108	54.185	0.438
19	0.277	0.946	64	21.683	1.475	109	54.851	0.400
20	0.277	0.955	65	22.443	1.443	110	55.518	0.361
21	0.277	0.962	66	23.180	1.422	111	56.185	0.328
22	0.302	0.971	67	23.941	1.395	112	56.851	0.291
23	0.302	0.976	68	24.702	1.371	113	57.518	0.253
24	0.327	0.984	69	25.438	1.352	114	58.185	0.216
25	0.965	1.160	70	26.199	1.329	115	58.851	0.184
26	1.677	1.260	71	26.961	1.308	116	59.518	0.148
27	2.438	1.339	72	27.696	1.285	117	62.045	0.0
28	3.175	1.413	73	28.458	1.265	118		
29	3.935	1.478	74	29.219	1.245	119		
30	4.672	1.535	75	29.980	1.226	120		
31	5.408	1.584	76	30.740	1.208	121		
32	6.169	1.631	77	31.477	1.191	122		
33	6.905	1.673	78	32.238	1.172	123		
34	7.667	1.710	79	32.998	1.153	124		
35	8.402	1.742	80	33.760	1.135	125		
36	9.164	1.770	81	34.496	1.118	126		
37	9.925	1.792	82	35.257	1.097	127		
38	10.661	1.813	83	36.018	1.081	128		
39	11.422	1.832	84	36.779	1.062	129		
40	12.159	1.844	85	37.516	1.040	130		
41	12.920	1.855	86	38.276	1.022	131		
42	13.680	1.864	87	39.037	1.004	132		
43	13.876	1.864	88	39.774	0.987	133		
44	13.901	1.863	89	40.534	0.969	134		
45	13.926	1.864	90	41.271	0.951	135		

Table A1 Relation Between Stress and Strain Value of 2¼Cr-1Mo Steel

Specimen No. : CRMA14									
	Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)		Strain (%)	Stress (kg/mm²)
1	0.0	0.0	46	13.748	1.881	91	43.354	0.968
2	0.086	0.805	47	13.772	1.881	92	44.115	0.944
3	0.099	0.816	48	13.797	1.878	93	44.852	0.920
4	0.123	0.830	49	13.797	1.878	94	46.180	0.837
5	0.123	0.845	50	13.821	1.881	95	46.847	0.811
6	0.123	0.859	51	13.846	1.882	96	47.514	0.788
7	0.148	0.868	52	13.846	1.881	97	48.180	0.762
8	0.148	0.882	53	14.631	1.875	98	48.847	0.734
9	0.148	0.894	54	15.368	1.861	99	49.514	0.705
10	0.172	0.908	55	16.154	1.829	100	50.180	0.675
11	0.172	0.920	56	16.915	1.784	101	50.847	0.641
12	0.197	0.930	57	17.676	1.721	102	51.514	0.608
13	0.197	0.941	58	18.462	1.652	103	52.180	0.578
14	0.221	0.949	59	19.222	1.589	104	52.847	0.541
15	0.221	0.958	60	19.983	1.536	105	53.514	0.508
16	0.271	0.968	61	20.744	1.496	106	54.180	0.475
17	0.246	0.977	62	21.506	1.468	107	54.847	0.439
18	0.271	0.986	63	22.267	1.449	108	55.514	0.402
19	0.271	0.996	64	23.003	1.435	109	56.180	0.367
20	0.271	1.001	65	23.764	1.422	110	56.847	0.331
21	0.295	1.010	66	24.525	1.414	111	57.514	0.296
22	0.320	1.015	67	25.262	1.406	112	58.180	0.260
23	0.958	1.189	68	26.022	1.394	113	58.847	0.227
24	1.645	1.287	69	26.759	1.383	114	59.514	0.193
25	2.382	1.366	70	27.520	1.372	115	60.180	0.158
26	3.118	1.439	71	28.281	1.358	116	63.099	0.0
27	3.854	1.506	72	29.041	1.347	117		
28	4.591	1.567	73	29.778	1.328	118		
29	5.328	1.618	74	30.539	1.309	119		
30	6.065	1.665	75	31.300	1.289	120		
31	6.825	1.709	76	32.062	1.269	121		
32	7.562	1.744	77	32.797	1.249	122		
33	8.323	1.775	78	33.559	1.229	123		
34	9.084	1.801	79	34.320	1.205	124		
35	9.844	1.821	80	35.081	1.186	125		
36	10.581	1.845	81	35.841	1.165	126		
37	11.342	1.859	82	36.578	1.146	127		
38	12.103	1.871	83	37.339	1.130	128		
39	12.865	1.875	84	38.100	1.109	129		
40	13.600	1.881	85	38.862	1.090	130		
41	13.675	1.881	86	39.597	1.069	131		
42	13.675	1.881	87	40.334	1.052	132		
43	13.699	1.881	88	41.120	1.032	133		
44	13.723	1.881	89	41.857	1.010	134		
45	13.748	1.881	90	42.592	0.990	135		

Appendix b　高温バースト評価用応力－ひずみ特性の検討

Appendix b　高温バースト評価用応力－ひずみ特性の検討

1．はじめに

高温バースト試験での破損評価を行う場合において、単純な弾性解析解としての円周応力を適用するならば、ＪＩＳ高温引張試験結果による引張強さを破損基準として評価する方法が成立する。例えば、内圧を一定にして、肉厚内一様温度の条件で温度を上昇させることを考えれば良い。これに対して、塑性解析を実施し、応力－ひずみ挙動を詳細に求めて評価するときには、ひずみ進行とともに肉厚が減少することを考慮しているため、引張試験においても断面減少を考慮した破損基準を適用しないと、評価の基盤が整合しなくなる。

このため、ここでは塑性解析を基本とする高温バースト評価のための解析用応力－ひずみ曲線と最終破損条件を検討した。

2．高温バースト評価用応力－塑性ひずみ特性の２直線近似法の検討

高温バースト評価用の応力σと塑性ひずみε_p特性を、下記の２直線で近似して非弾性解析を実施する場合を考える。

$$\sigma = \sigma_y + H' \varepsilon_p$$

ただし、σ_yは降伏点，H'は２直線近似の加工硬化係数である。上記関係を、引張試験で得られる公称応力Ｓと公称ひずみe_p関係で表すと、

$$S(1+e_p) = \sigma_y + H' \ell n(1+e_p)$$

となる。この関係式で、引張強さは$dS/de_p = 0$のときに相当することから、

$$dS/de_p = \left[-\sigma_y + H' - H' \ell n(1+e_p) \right] / (1+e_p)^2 = 0$$

より、

$$\ell n(1+e_p) = (H' - \sigma_y) / H'$$

のときのＳの値を求めることで、弾性解析解と引張強さを適用した場合と整合させてH'を定めることができる。すなわち、内圧を一定にして、肉厚内一様温度の条件で温度を上昇させた場合について塑性解析で応力を求めると、一定内圧荷重を支えきれなくなる状態（$dS/de_p < 0$）が必ず生じ、公称応力Ｓが引張強さσ_uに到達した時点に相当する。

上記条件でのσ_uとH'の関係は、

$$\sigma_u = H' \exp(\sigma_y / H' - 1)$$

と求まるため、σ_u値を与えることにより、２直線近似の加工硬化係数H'を引張試験結果と整合させて定めることができる。

以上の手順によって定めた応力－塑性ひずみ特性の２直線近似結果をTable B1(Mod.9Cr-1Mo鋼）およびTable B2(2¼Cr-1Mo鋼）に示す。

3．最終破損条件の検討

一様な温度と応力が作用する場合には、塑性ひずみの進行とともに応力が増大し、自動的に不安定破壊（肉厚減少による円周応力の増大が加速し釣合う条件がなくなる）に至る

ので、特に最終破損条件を定める必要はない。また、この条件は、上記で定めたように引張試験での引張強さに相当している。

これに対して、肉厚内で温度や応力の分布があり、局所的に不安定条件に相当する応力に達した場合は、健全な部分での応力負担（再配分）によって釣合いは維持でき、直ぐに破損に至ることはない。応力再配分の結果、最後には肉厚全体で内圧荷重を支え切れずに不安定変形に至る。

不安定破損の条件では、最終破断の判定を一定の応力（強度）あるいは変形（延性）のどちらとするかという問題は残っているが、評価上は真破断強度で評価するのが現実的である。しかし、これはあくまで最終分離の条件であり、本来の破損は不安定変形に入った段階とするのが妥当である。このため、ここでは厳密な最終破断の強度ではなく、その目安となる値（厳密な真破断強度は材料試験結果から一意的に決定しにくいことも考慮）として、引張強さσ_uの1.5倍を破断応力σ_fとして暫定する。この値の見直しは、解析結果と試験結果の比較検討を踏まえつつ実施するものとする。

Table B1(1) Bi-linear Approximation to Stress-Strain Behavior(Mod.9Cr-1Mo Steel)

	800℃	900℃	1000℃	1100℃	1200℃
σ_u	10.5kg/mm^2	9.6kg/mm^2	6.2kg/mm^2	3.5kg/mm^2	2.3kg/mm^2
σ_y	8.7kg/mm^2	7.9kg/mm^2	5.3kg/mm^2	3.1kg/mm^2	1.6kg/mm^2
H'	17kg/mm^2	16kg/mm^2	10kg/mm^2	5.5kg/mm^2	4.0kg/mm^2

Table B1(2) Parameters on Tesile Stress-Strain Equation(Mod.9Cr-1Mo Steel)

T (℃)	600≦T< 800	800≦T<1100	1100≦T<1200
H'	157− 0.175T	45− 0.035T	
σ_y	80.9−0.09T	23.3− 0.018T	
σ_f	145.1−0.16T	45.9− 0.036T	

Table B2(1) Bi-linear Approximation to Stress-Strain Behavior (2¼Cr-1Mo Steel)

	800℃	900℃	1000℃	1100℃	1200℃
σ_u	6.9kg/mm^2	7.8kg/mm^2	5.0kg/mm^2	3.1kg/mm^2	1.9kg/mm^2
σ_y	6.6kg/mm^2	4.5kg/mm^2	3.1kg/mm^2	1.6kg/mm^2	1.0kg/mm^2
H'	9kg/mm^2	16kg/mm^2	10kg/mm^2	6.5kg/mm^2	4.0kg/mm^2

Table B2(2) Parameters on Tesile Stress-Strain Equation (2¼Cr-1Mo Steel)

T (℃)	600≦T< 800	800≦T<1100	1100≦T<1200
H'	157− 0.175T	45− 0.035T	
σ_y	46.6−0.05T	20.2− 0.017T	7.0− 0.005T
σ_f	108.5− 0.12T	31.7− 0.024T	

（備考）文献データでは、800℃でσ_y=8.9kg/mm^2, σ_u=10.3kg/mm^2（H'=16kg/mm^2）という例もあり、今回の結果は異常点となっていることも配慮した。

4．真破断応力の推定

今回の引張試験では、絞りが100%あるいはそれに近い値であり、破断時の応力も0に近いことから、破断後に断面積0㎟ で破断応力0kg/㎟の条件となるため、真破断応力を一意的に決定するのは困難であった。そこで、下記の手順による真応力－真ひずみ関係を公称応力－公称ひずみの引張曲線から近似的に求めることを試みた。

〔手順－1〕

真一様伸びまでは neckingは生じていないので、真応力－真ひずみ関係は、公称ひずみ $e=(\ell-\ell_0)/\ell_0$ を用いて真ひずみ $\varepsilon=\ell n(1+e)$、公称応力 $S=P/A_0$ を用いて真応力 $\sigma=S(1+e)$ によって表される。ただし、体積一定（$A\ell\equiv A_0\ \ell_0$）を仮定している。

〔手順－2〕

真一様伸びを超えると neckingが生じる。厳密な necking開始時点の計測はできていない上に、necking時の局所断面変化も計測していない。そこで、近似的な方法として、変位 ℓ の進行とともに断面積Aが変化すると考え、$A=rA_1+(1-r)A_2$ を用いる。これ以外にも近似方法は考えられるがまずは簡便な方法を選んだ。ここで、A_1 は necking開始と推定される時点での断面積で $A/(1+e_u)$（e_u は一様伸び）、A_1 は破断時の最小断面積で $A_0(1-\phi)$（ϕ は絞り）、rは変位の進行に伴う比率であり $e=e_u$ の時点で $r=1$，$e=\delta$（δ は破断伸び）の時点で $r=0$ となることから、$r=(\delta-e)/(\delta-e_u)$ と表される。本関係を式に表せば、

$$A/A_0=\left[(\delta-e)/(1+e_u)+(e-e_u)(1-\phi)\right]/(\delta-e_u)$$

となる。この A/A_0 を用いて、$\sigma=SA_0/A$，$\varepsilon=\ell n(A_0/A)$ と算定することができる。

以上の手法による計算例をFig. B1 に示す。この例は、Mod. 9Cr-1Mo鋼の 800℃の場合の結果であるが、真破断応力 σ_f は引張強さの1.5倍となっている。この比が、他の条件でも成立するかどうかは確かめていないが、ここに示した手順をAppendics a のデータとTable 6～8の数値とを適用することで推定することができる。

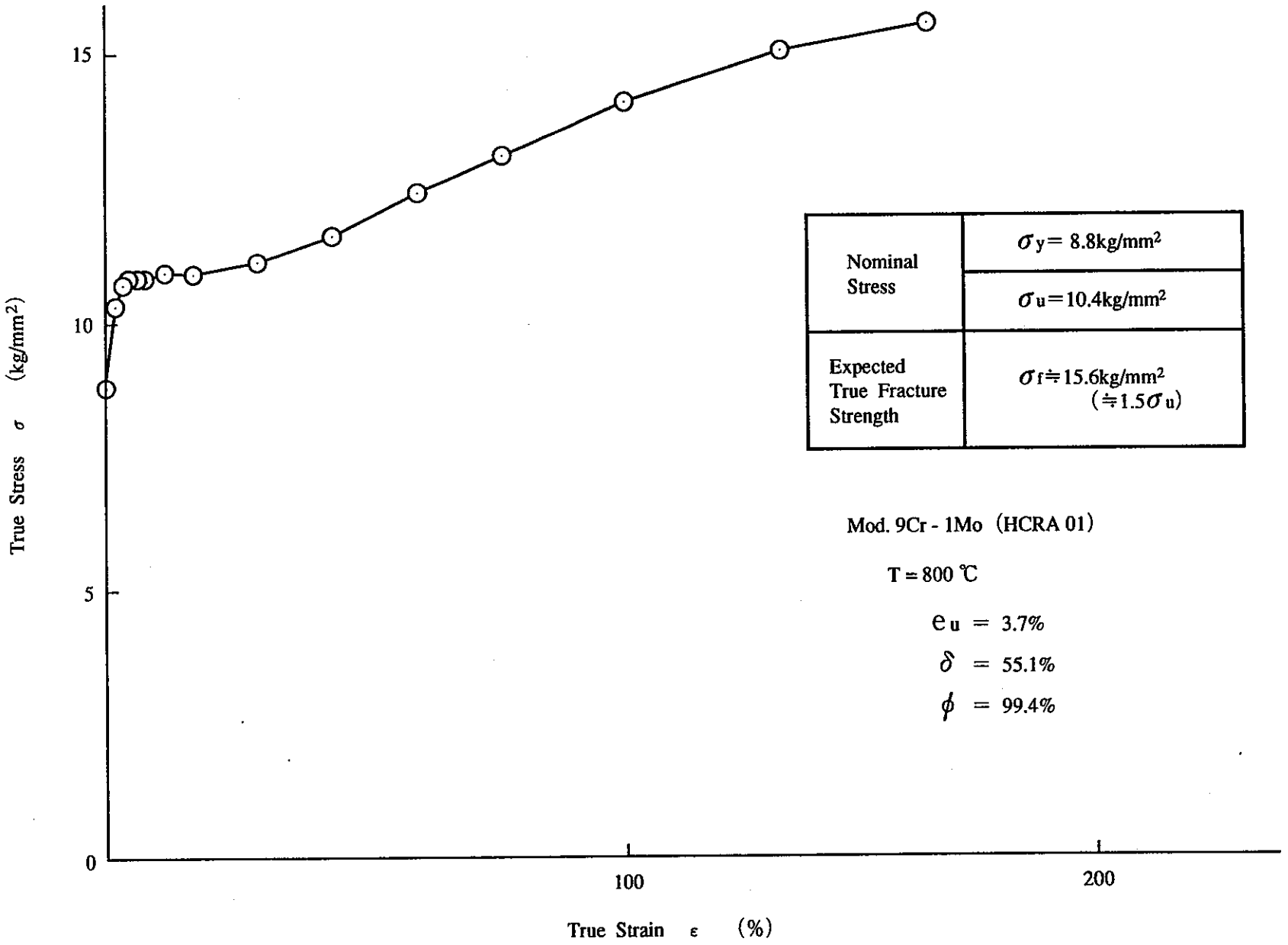


Fig. B1. Example of Expected True Stress - Strain Behavior (Mod.9Cr - 1Mo, 800℃)