Specs for procurement of NASA Spur Pig Test Gears, from J Coats

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LEWIS RESEARCH CENTER

21000 BROOKPARK ROAD

CLEVELAND, OH 44135

SPECIFICATIONS FOR

TEST GEARS

SPECIFICATION NO: 3-548642

DATED: FEBRUARY 9, 1983

SPECIFICATIONS FOR TEST GEARS

SPECIFICATIONS

1. The following documents, the latest versions of which are in effect on the date of issuance of this Solicitation shall be made a part of this Specification and are incorporated herein by reference and made a part hereof:

Specification	Description
a. Federal Test Method Standard No. 151	Test Methods
b. MIL-I-6868	Magnetic Particle Inspection
c. AMS 2251	Alloy Steel Bars
d. AMS 2300	Inspection
e. ASTM-E45-63	Inspection
f. MIL-S-6090	Process For Steel
g. MIL-H-6875	Process Heat Treating
h. MIL-S-7393	Steel SAE 3310
i. MIL-S-7493	Steel SAE 4620
j. MIL-S-6090	Steel SAE 8620
k. AMS-6260	Steel SAE 9310
l. AMS-6265 C	Steel SAE 9310 VAR

PART I

(1). SCOPE

(a). This specification covers the requirements of SAE 9310 steel bars, forgings and forging stock made by the consumable electrode vacuum arc remelt process.

(b). This steel is for use in the manufacture of critical carburized parts requiring uniformly high hardenability, core strength and cleanliness.

(2). REFERENCES

The following references shall form a part of this specification:

(a). Federal Test Method Standard No. 151, Metals, Test Methods.

(b). MIL-I-6868. Inspection Process, Magnetic Particle

(c). AMS 2251. Tolerances, Alloy Steel Bars

(d). AMS 2300. Premium Aircraft Quality Steel Cleanliness, Magnetic Particle Inspection Procedure

(e). ASTM-E45-63. Determination of Inclusion Content of Steel

(3). FORM

Bar, forgings and forging stock.

(4). CONDITION

(a). Material shall be tarnished hot rolled or forged and in the normalized condition. The material shall have a hardness of not more than BHN264 (Rockwell C-27).

(b). Material shall be furnished in either the pickled or blast cleaned condition.

(5). TOLERANCE

Tolerances shall conform to the requirements of AMS 2251.

(6). REQUIREMENTS

(a). Manufacturing Process

The steel shall be multiple melted using the vacuum consumable electrode process during the remelt cycle.

(b). Workmanship

Steel shall be uniform and clean, sound, smooth, and free of pipes, bursts, porosity, foreign materials, carbide or other segregation, banding ingot pattern, alloy depletion and from internal and external defects detrimental to fabrication or performance of the parts.

(c). Chemical Composition

The chemical composition shall be as follows:

Element	Analysis %	Check Analysis Under Min.	Check Analysis Over Max.
Carbon	0.07-0.13	0.01	0.01
Manganese	0.40-0.70	0.03	0.03
Silicon	0.20-0.35	0.02	0.02
Phosphorus	0.010 max.	----	0.005
Sulphur	0.010 max.	----	0.005
Chromium	1.00-1.40	0.05	0.05
Nickel	3.00-3.50	0.07	0.07
Molybdenum	0.08-0.18	0.01	0.01
Copper	0.35 max.	----	0.02

(d). Hardenability

The hardenability shall be J40-1 maximum and J32-8 minimum.

(e). Grain Size

The grain size shall be predominantly 5 or finer, with occasional grains as large as 3 permissible.

(f). Magnetic Inspection

Not more than 4 rateable (1/64-inch minimum length) indications and not more than 1/8 inch aggregate length of all rateable indications shall be allowed per specimen as prepared per AMS 2300.

(g). Micro-inclusion Test

When rated per Method D of ASTM E45-63, the worst field ratings shall not exceed the following:

A		B		C		D	
T	H	T	H	T	H	T	H
1.5	0	1.5	0	1.5	0	2.0	1.0

A rateable field is defined as one which has Type A, B, C or D inclusion ratings of at least 1.0.

(h) Macroscopic Cleanliness

Macroscopic cleanliness shall conform to Section (6), (b) "Workmanship".

(i) Parts shall be case carburized according to Part II. After finish machining inspection and marking, corrosion protect disks with black oxide per AMS 2485.

(7) QUALITY ASSURANCE

(a) Chemical Composition

1. Sampling - A complete chemical analysis shall be performed on material representing each vacuum arc remelt ingot of steel.

2. Test Method - Federal Test Method Standard 151, Method 111 or 112.

(b). Hardenability

1. Sampling - Hardenability tests shall be performed on vacuum arc remelt material representing the first, middle and last ingot of each air melt heat.

2. Test Method - Federal Test Method Standard 151, Method 711.

(c). Grain Size

1. Sampling - Grain size tests shall be performed on vacuum arc remelt material representing the first, middle and last ingot of each air melt heat.

2. Test Method - Federal Test Method Standard 151, Method 311.

(d). Magnetic Inspection

1. Sampling - Magnetic inspection shall be performed on vacuum arc remelt material representing the top and bottom of the first, middle and last ingot of each air melt heat.

2. Test Method - Prepare specimens per AMS 2300 and Inspect per MIL-I-6868.

(e). Micro-Inclusion

1. Sampling - Micro-inclusion tests shall be performed on material representing the top and bottom of each vacuum arc remelt ingot.

2. Test Method - ASTM E45-63.

(f). Macroscopic Cleanliness

1. Sampling - Macroscopic cleanliness tests shall be performed on material representing the top and bottom of the first, middle and last billet of each vacuum arc remelt ingot.

2. Test Method - Grind or belt sand 1/2 inch thick slabs on one face to a finish of 63 micro inches maximum. Deep acid etch the slabs by immersing in 1 to 1 hydrochloric acid - water solution at 150° to 170°F for one hour. Support the specimens in the etchant so that the finish face is uniformly etched. Inspect per Paragraph (6),(b) - "Workmanship".

(8). IDENTIFICATION

Individual pieces or bundles shall have a metal tag attached stamped with the purchase order number, manufacturer's identification or trademark, material specification and SAE alloy number and nominal size, or shall be boxed and the box marked with the same information. In addition to the above, all bar and forging stock shall have the heat number stamped on one end. In the event that forgings are supplied, they shall be identified as shown on the applicable drawing.

(9). REJECTION

All material procured to this specification is subject to final inspection upon receipt and prior to acceptance by the Government. Material not meeting all the requirements of this specification shall be rejected and returned to the vendor.

(10). REPORTS

The material supplier shall furnish with each shipment 3 copies of a notarized report of the results of tests for chemical composition, magnetic particle inspection rating and inclusion rating, deep acid etch, and hardenability of each heat in the shipment. This report shall include:

(a). Purchase Order number

(b). Heat number

(c). Material Specification number

(d). Size

(e). Quantity from heat

(f). If forgings are supplied:

1. Part number

2. Size of stock used to make forgings

(11). PREPARATION FOR DELIVERY

(a). Preservation

All products furnished to this specification shall be protected using standard commercial practices to assure that the material does not corrode during shipment.

(b). Packing

Packaging of bars or forging stock shall not be required provided the product is protected against corrosion and mechanical damage during shipment.

PART II

(1). SCOPE

(a). This specification covers the requirements for gas carburizing and hardening alloy steel parts used.

(b). This specification is applicable to the gas carburizing of the following steels:

SAE 9310	SAE 4620
SAE 3310	SAE 8620

(2). REFERENCES

(a). Federal Test Method Standard No. 151	Metals; Test Methods
(b). MIL-S-6090	Process for steels used in aircraft carburizing and nitriding
(c). MIL-H-6875	Process for heat treatment of aircraft steels
(d). MIL-S-7393	Steel Alloy, carburizing, bars, nickel chromium (SAE 3310)
(e). MIL-S-7493	Steel bars, alloy, carburizing, aircraft quality (SAE 4620)
(f). MIL-S-8690	Steel bars, chrome, nickel-molybdenum, aircraft quality (SAE 8620)
(g). AMS 6260	Steel, bar (SAE 9310)
(h). AMS 6265C	Consumable electrode vacuum arc remelted AMS-6260 steel (SAE 9310)

(3). EQUIPMENT

(a). Furnace shall be for the gas carburizing of steel parts. The maximum temperature variation within the working zone of the furnace shall not exceed ± 25°F of the control setting. All furnaces shall have means for circulating the carburizing atmosphere.

(b). A furnace temperature uniformity survey shall be conducted on new furnaces before placing in operation and at least semiannually thereafter. Additional temperature uniformity surveys shall be in accordance with MIL-H-6875.

(c). Pyrometers shall be automatic controlling and recording, of the potentiometer type. Thermocouples shall extend into the working zone of the furnace and be protected by tubes from contamination by the furnace atmosphere.

(d). The accuracy of all temperature recording and controlling instruments shall be checked at least one every week by a comparison test with a standardized potentiometer-type instrument of known accuracy and a calibrated standard thermocouple. The test thermocouple shall be located not more than 3 inches from the furnace thermocouple and the furnace shall have a production charge in the chamber.

(e). Quenching tanks and presses shall be of sufficient capacity with circulation to handle the production charges being quenched. Temperature control of the oil quench medium shall be provided to maintain the temperature of the oil within the range of 75° to 140°F.

(f). The sub-zero chamber shall be of the dry type, capable of maintaining temperatures within the range of -100°F to -120°F.

(g). Jigs, fixtures and handling equipment shall be provided during heating and quenching. The parts shall be racked in such a way that circulation of the carburizing atmosphere is obtained around all surfaces to be carburized. Where intermeshing of gear teeth is possible, parts shall be wrapped with one turn of iron wire on the O.D.

(4). PROCESS CONTROL

(a). Surfaces that are not to be case hardened shall be protected by the application of copper plating or by leaving these surfaces oversize prior to carburizing.

(b). Parts to be carburized shall be clean and free of foreign material.

(c). Test samples as shown in Figure 1, or sections of representative scrap gears shall be included in each carburizing load of gears. A cylindrical bar with approximately the same dimensions without the notch, may be used as test samples for carburizing loads not involving gears.

At least three samples shall be uniformly distributed throughout each carburizing load so that they are representative of various zones within the furnace chambers. The samples shall be of the same grade of material as the parts they represent. These test samples shall be permanently identified with a carburizing lot number, heat treat lot number and the position in the carburizing furnace.

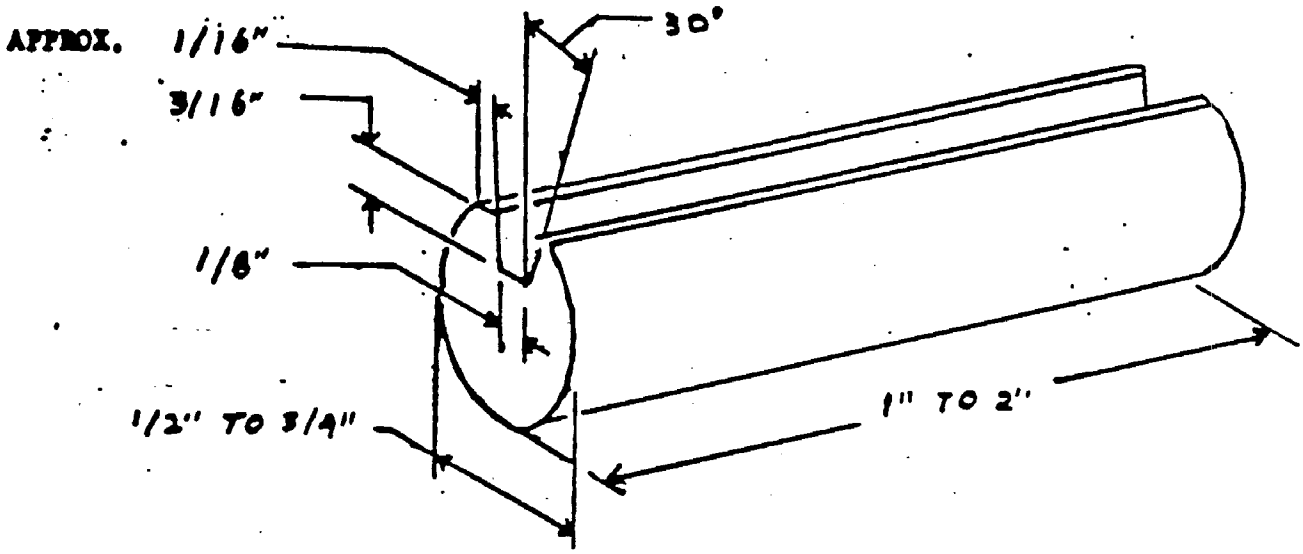


FIGURE 1 - CARBURIZING TEST SAMPLE FOR GEARS

NOTE: All dimensions are approximate and may be varied to simulate actual gear teeth being carburized.

(d). All carburizing loads and subsequent heat treating loads shall be given an identifying number or letter code designation. All test samples shall be stamped with this identifying designation.

(e). The parts shall be charged into the furnace and heated in a carburizing atmosphere within the temperature range of 1600° to 1700°F. The time of the carburizing cycle shall be such as to yield the specified effective case depth plus machining allowance. The carbon potential of the atmosphere shall be controlled to give a carbon content in the outer layer of the case in the range of 0.75% to 0.85% carbon.

(f). When necessary to control the carbon concentration gradient, the carburizing cycle shall include a period of diffusion during the last of the cycle.

(g). After carburizing, the parts shall be transferred to a separate cooling chamber. The initial cooling rate should be rapid enough to preclude the formation of excess carbides and the final cooling rate should be slow enough to prevent the formation of structures with high residual stress patterns.

(h). After cooling to room temperature, the parts shall be copper plated all over and heated to a temperature within the range of 1100°F to 1250°F for a minimum time of two (2) hours.

(i). After cooling to room temperature, the parts may be austenitized and hardened. If machining operations are performed at this time, the parts shall be stripped of all copper and plated all over prior to austenitizing and quenching.

(j). Two of the test samples may be used to determine the optimum heat treating temperature as determined by hardness. Carbide formation and retained austenite. At least one of the test samples shall be heat treated with the parts and used as a control specimen for the test required in Section (5) entitled "Quality Control". The carburized parts shall be hardened by oil quenching from within the temperature range shown in Table I.

TABLE I HEAT TREAT TEMPERATURE RANGES

Steel	Temperature Range °F
3310	1475 - 1550
4620	1475 - 1625
8620	1475 - 1575
9310	1475 - 1575

(k). The temperature may be adjusted up within the range to dissolve excess carbides or down within the range to eliminate excess retained austenite. The final hardening temperature should be based on obtaining the most favorable balance of these two constituents. The parts shall be held at the austenitizing temperature for a minimum of 2 hours prior to quenching.

(l). After completion of the quenching operation, hardness tests shall be made on the parts. The number of parts to be tested shall be determined by the lot size in accordance with the following:

TABLE II SAMPLING FOR HARDNESS TESTS

Lot Size	Sample Size
1 - 3	1
4 - 8	2
9 - 15	3
16 - 25	5
26 - 50	7
51 and over	10

1. If all the parts tested have a hardness of R_c58 or more, they shall be placed in the sub-zero chamber at -100°F to -120°F within 30 minutes after completion of the quenching operation. The parts shall be held in the sub-zero chamber for a minimum of three (3) hours.

"For the first piece of a hardening lot used as a quench press set up piece, the time in the sub-zero chamber may be reduced to 1-1/2 hours minimum provided the chamber is not opened during this period."

2. Parts which have a hardness below R_c58 shall not be put in the sub-zero chamber, but shall be referred to the NASA-Lewis Research Center Contracting Officer for disposition.

(m). After sub-zero treatment, all parts shall be tempered at 300°F minimum for two (2) hours. After cooling to room temperature, the parts shall be tempered a second time at 300°F minimum for two (2) hours.

(n). After finish grinding, all parts shall be stress relieved at the same temperature as the tempering temperature for two (2) hours minimum, or as specified on the applicable drawing.

(o). Recarburizing: In the event that carburized parts do not meet the case depth requirements, one (1) recarburizing cycle will be permitted. Specimens representing the initial carburizing cycle shall be processed with the parts to show the cumulative results of the recarburizing cycle and data entered on the heat treat record.

(p). Reheat treatment: In the event that carburized and/or recarburized parts do not meet the hardness requirements; one (1) reheat treat cycle will be permitted.

CAUTION: Prior to reheat treatment, parts must be stress relieved at 1000°F - 1200°F for one (1) hour minimum at temperature. Specimens representing the initial heat treat cycle shall be processed with the parts to show the results of the reheat treat cycle, and data entered on the heat treat record.

(q). All other process and inspection controls shall be applicable for recarburizing or reheat treatment as required.

(r). Parts that have been recarburized and/or reheat treated (one time over the initial cycle) and still do not meet the drawing or specification requirements, shall be subject to approval of the Contracting Officer prior to release for any subsequent processing.

(s). When a diffusion cycle is necessary to be used because of higher than specification case carbon content, individual approval shall be obtained from the Contracting Officer prior to employing the cycle. Specimens representing the initial carburizing cycle shall be processed with the parts to show the cumulative results of the additional diffusion cycle and data entered on the heat treat record.

Stop off paints, such as No-Carb (Park Chemical Company, Cornwells Heights, PA) and Sel-Car (National Copper Paint Company, Chicago, IL) may be used to supplement copper plating in those areas where adequacy of plating coverage is difficult and/or questionable. Examples of areas where stop off paints may be used to advantage are bore areas of spiral bevel pinion gears and I.D. surfaces of shafts.

Stop off paint is not to be used as a substitute for copper plating, but rather as a supplement to the plating. Auxiliary anodes shall be used as needed to plate internal surfaces. These surfaces may be subsequently coated with stop off paint to provide additional assurance against case hardening the areas.

(5). QUALITY CONTROL

(a). The test sample which was heat treated with the parts shall be used for determining the effective case depth, and rating the carbides and retained austenite. The effective case depth for gears shall be determined in the root area of the carburizing test sample. The effective case depth for other parts, such as bearing races and bearing lands, shall be determined on the outer diameter (O.D.) of the carburizing test sample.

(b). The effective case depth is the perpendicular distance from the surface of the case on a finished ground part to a point where the hardness is equivalent to VHN 513 (approximately R_c50). When the effective case depth to R_c58 is specifically called out on the drawing, measurements shall be made to a point where the hardness is VHN 653.

The effective case depth is measured using light indenter loads on a transverse section of the test sample polished to a microfinish. A Vickers hardness machine with a 5 Kg. load will be acceptable. The perpendicular distance from the surface of the case to the center of the impression is measured using a microscope (50 - 200X) with a filar micrometer eyepiece. The hardness data can be plotted and the effective case depth obtained from the curve as shown in Figure 2. As an alternate to graphical plotting, readings may be taken to establish the depth at which time the equivalent hardness to R_c50 is obtained. Since the test sample is used to determine the effective case depth, the amount allowed for final grinding shall be clearly indicated in the records furnished to the Government.

(c). When accepting a carburized lot of gears based on the effective case depth determined in the root of the carburized test sample (Figure 1) allowances shall be made for the inherently deeper case found on the test sample as compared to the part. Acceptance of a carburized lot of gears based on the effective case depth in the root of the carburized test sample (Figure 1) shall be in accordance with Table III. When a facsimile of the gear tooth is used as a carburizing test sample, the effective case depth in the root of the sample may not exceed the effective case depth as specified on the drawing by more than the grinding stock allowance.

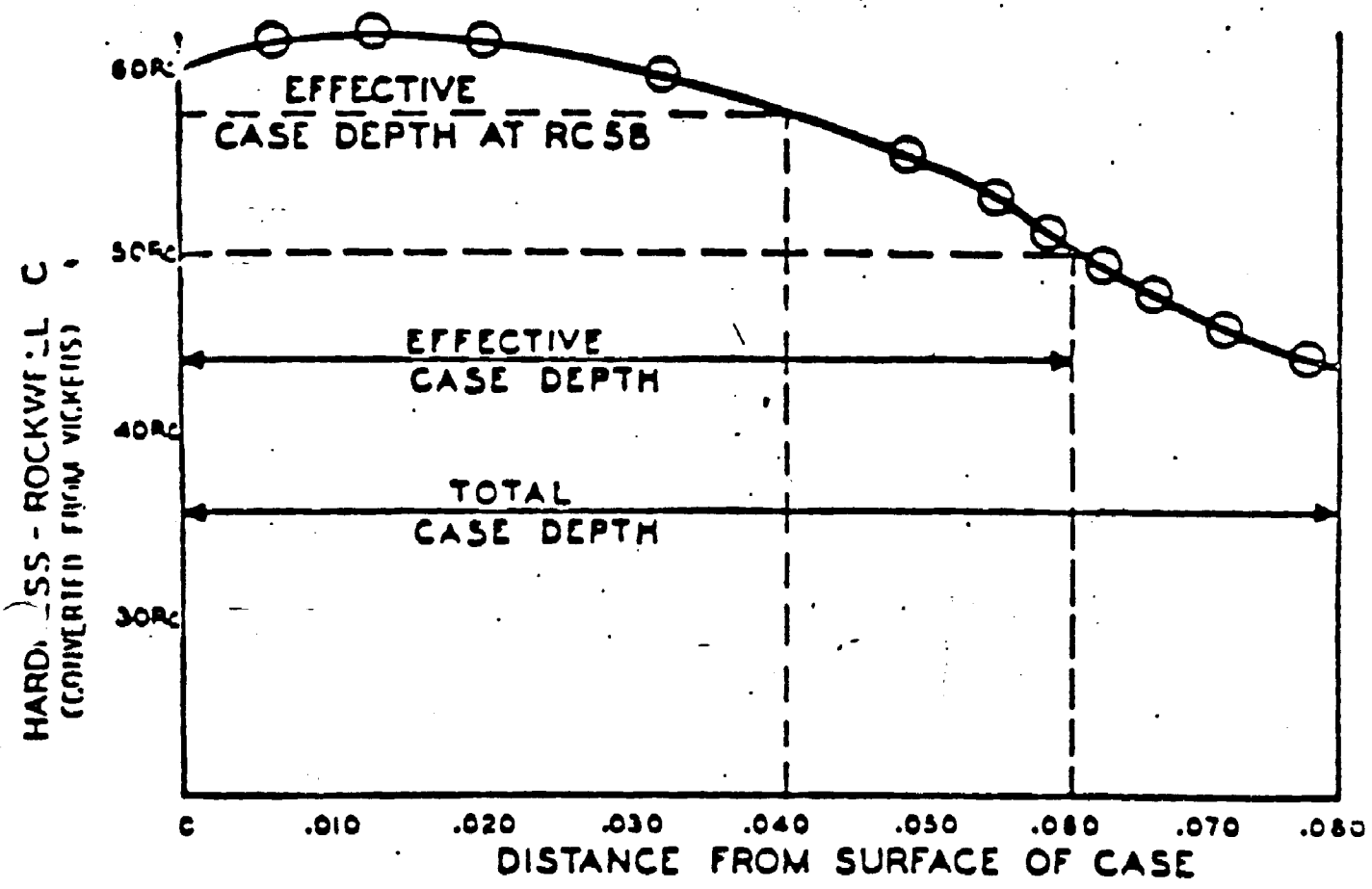


FIG. 2 METHOD OF MEASURING EFFECTIVE CASE DEPTH

TABLE III

Maximum Effective Case Depth from Drawing	Effective Case Depth Allowance Over Maximum for Acceptance of Test Sample Including Grinding Stock
0.015 to 0.025	0.008
0.026 and over	0.010

(d). The test sample shall be etched and examined for free carbides in accordance with Figure 3. The reagent used to reveal carbides shall have the following composition:

2 grams picric acid
25 grams sodium hydroxide
100 ml. water

The specimen is made the anode and 6 volts DC is applied for 60 seconds.

(e). The test sample shall be etched and examined for retained austenite. The maximum amount of uniformly distributed visual retained austenite that will be acceptable is 10%. Localized areas with a higher amount of visual retained austenite will be acceptable provided the overall average is 10% or less. The following recommendations are made:

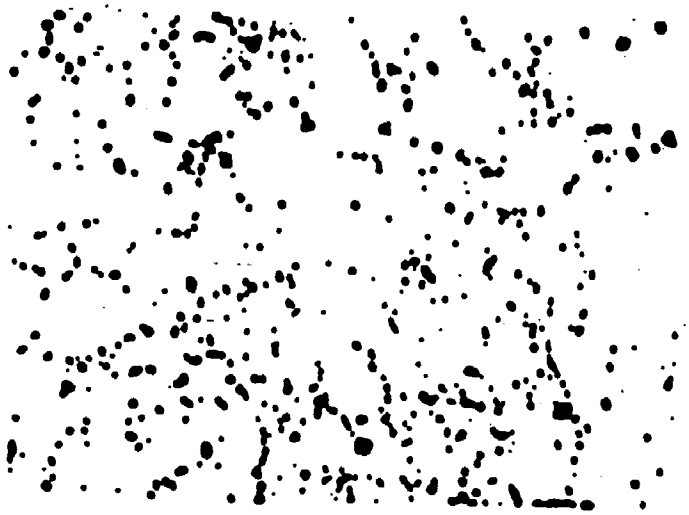
1. The use of low austenitizing temperatures within the range shown in Paragraph (4),(j) will minimize retained austenite.

2. The more efficient the quenching operation, the less retained austenite will be found in the hardened part.

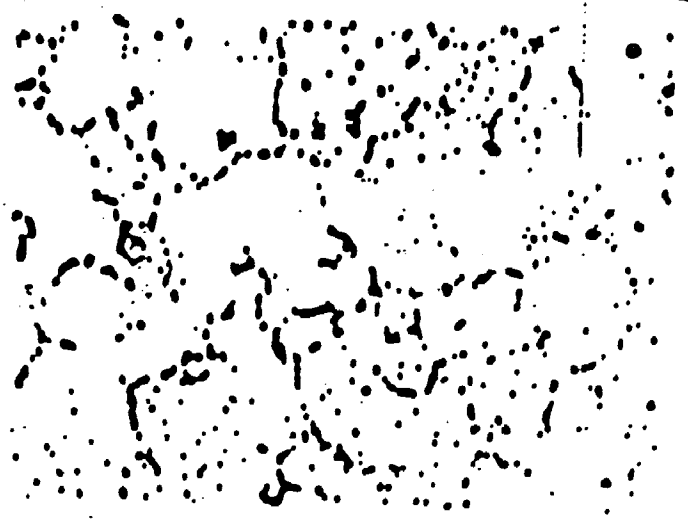
3. Cooling from the austenitizing temperature should be continuous down to ambient temperature or preferably 70°F. Any interruption in the cooling cycle will tend to stabilize austenite against further transformation to martensite.

4. The control of the carbon content of the case to lower composition levels such as 0.75% to 0.85% will minimize the amount of retained ausenite when compared with a carbon content of 0.95%.

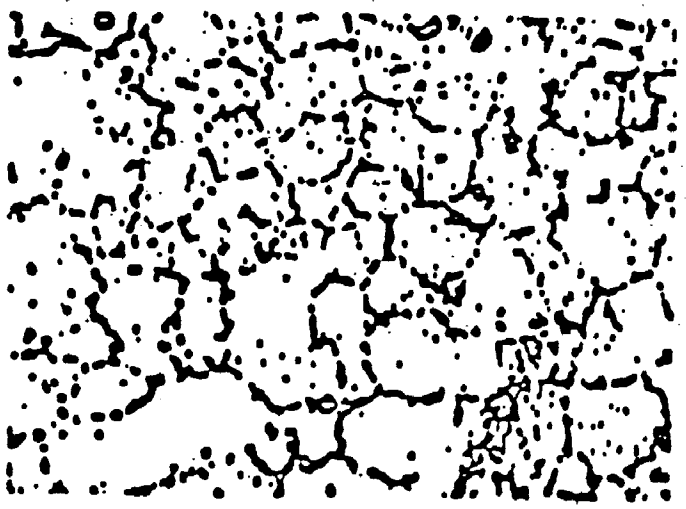
STANDARDS OF ACCEPTANCE FOR CARBIDE NETWORKS



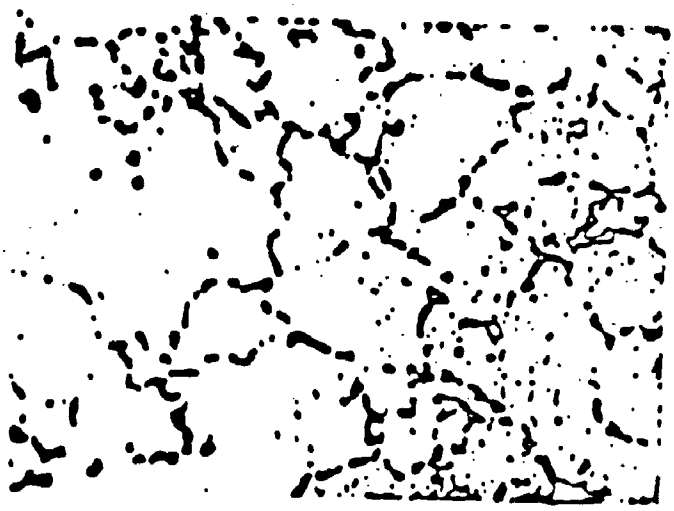
CLASS A - ACCEPTABLE
LIGHT DISCONTINUOUS NETWORK



CLASS B - ACCEPTABLE
HEAVY PARTIALLY CONTINUOUS NETWORK



CLASS C - NOT ACCEPTABLE
HEAVY CONTINUOUS NETWORK



CLASS D - NOT ACCEPTABLE
VERY HEAVY CONTINUOUS NETWORK

ALKALINE SODIUM PICRATE ELECTROLYTIC ETCH

ALL PHOTOMICROGRAPHS AT 500 DIAMETERS

FIGURE 3

(f). Carbon control bars, conforming to Figure 4, shall be run along with the first ten production runs of parts for a new configuration. Thereafter, a carbon control bar shall be run with every consecutive tenth heat number, shall be forwarded to the NASA Contracting Officer.

(g). The hardness of all finished carburized parts shall be checked for conformance to drawing requirements. The surface hardness of the case shall be measured on the finished parts, using the 30N scale on a Rockwell Superficial Hardness Tester. The core hardness shall be checked on a non-carburized surface. If the part is carburized all over, the core hardness of the test sample shall be determined and so noted in the record.

(h). Records showing the carburizing and heat treating conditions for each furnace load shall be maintained. The serial numbers of each part in the load shall be kept on this record along with the results of the laboratory tests or a cross reference record shall be established.

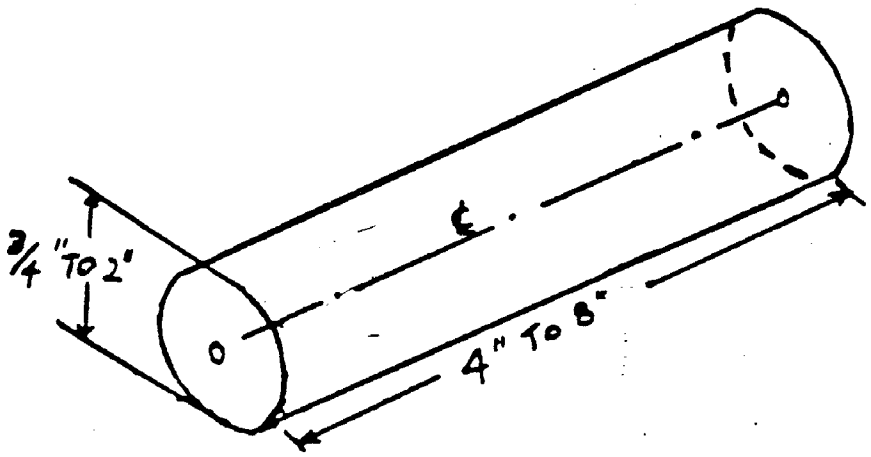


FIGURE 4 - CARBON CONTROL BAR

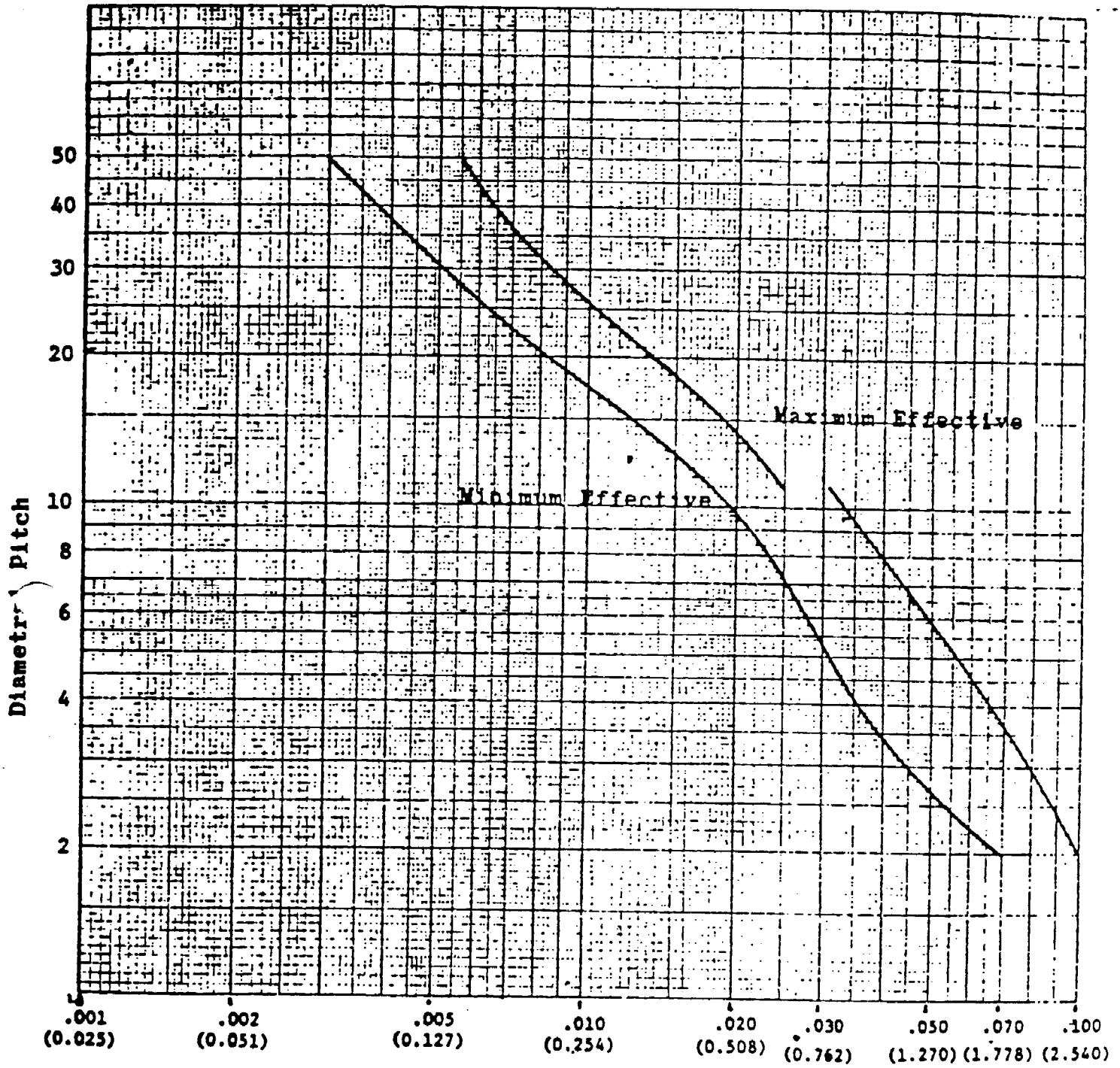
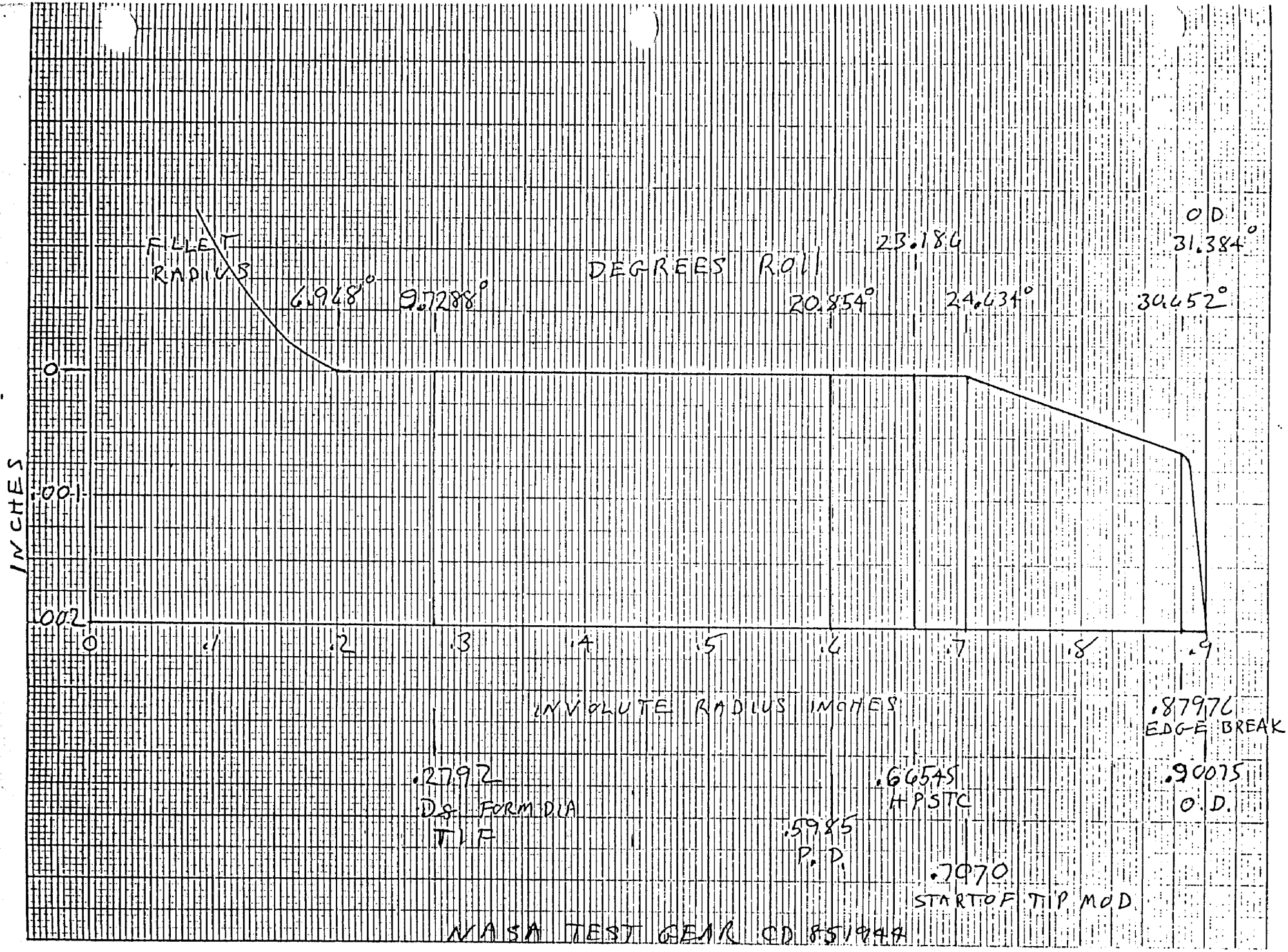


Figure 5 - Carburized Case Depth Requirements


FILLET RADIUS
6.948°
9.728°
DEGREES ROLL
20.854°
23.186
24.434°
30.452°
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INVOLUTE RADIUS INCHES
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EDGE BREAK
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