DEPARTMENT OF HEALTH & HUMAN SERVICES
Public Health Service

Food and Drug Administration
1390 Piccard Drive
Rockville MD 20850

SEP 6 1994

Carol A. Weideman, Ph.D.
Manager, New Product Applications
Linvatec Corporation
11311 Concept Boulevard
Largo, Florida 34643

Re: K941691
Revo™ Rotator Cuff Repair System
Regulatory Class: II
Product Code: HRX
Dated: April 6, 1994
Received: April 6, 1994

Dear Dr. Weideman:

We have reviewed your Section 510(k) notification of intent to market the device referenced above and we have determined the device is substantially equivalent to devices marketed in interstate commerce prior to May 28, 1976, the enactment date of the Medical Device Amendments, or to devices that have been reclassified in accordance with the provisions of the Federal Food, Drug, and Cosmetic Act (Act). You may, therefore, market the device, subject to the general controls provisions of the Act. The general controls provisions of the Act include requirements for annual registration, listing of devices, good manufacturing practice, labeling, and prohibitions against misbranding and adulteration.

If your device is classified (see above) into either class II (Special Controls) or class III (Premarket Approval) it may be subject to such additional controls. Existing major regulations affecting your device can be found in the Code of Federal Regulations, Title 21, Parts 800 to 895. A substantially equivalent determination assumes compliance with the Good Manufacturing Practice for Medical Devices: General (GMP) regulation (21 CFR Part 820) and that, through periodic GMP inspections, the Food and Drug Administration (FDA) will verify such assumptions. Failure to comply with the GMP regulation may result in regulatory action. In addition, FDA may publish further announcements concerning your device in the Federal Register. Please note: this response to your premarket notification submission does not affect any obligation you might have under sections 531 through 542 of the Act for devices under the Electronic Product Radiation Control provisions, or other Federal Laws or Regulations.

This letter immediately will allow you to begin marketing your device as described in your 510(k) premarket notification. An FDA finding of substantial equivalence of your device to a legally marketed predicate device results in a classification for your device and permits your device to proceed to the market, but it does not mean that FDA approves your device. Therefore, you may not promote or in any way represent your device or its labeling as being approved by FDA. If you desire specific advice for your device on our labeling regulation (21 CFR Part 801 and additionally 809.10 for in vitro diagnostic devices), promotion, or advertising please contact the Office of Compliance, Promotion and Advertising Policy Staff (HFZ-300) at (301) 594-4639. Other general information on your responsibilities under the Act may be obtained from the Division of Small Manufacturers Assistance at their toll free number (800) 638-2041 or at (301) 443-6597.

Sincerely yours,

Paul R. Beninger, M.D.
Director
Division of General and
Restorative Devices
Office of Device Evaluation
Center for Devices and
Radiological Health

Memorandum

Date 8/31/94

From REVIEWER(S) - NAME(S) Eric Kaiser

K941691

Subject 510(k) NOTIFICATION

To THE RECORD

It is my recommendation that the subject 510(k) Notification:

__✓__ (A) Is substantially equivalent to marketed devices.

_____ (B) Requires premarket approval. NOT substantially equivalent to marketed devices.

_____ (C) Requires more data.

_____ (D) Other (e.g., exempt by regulation, not a device, duplicate, etc.)

Additional Comments:

Is this device subject to Postmarket Surveillance? Yes ☐ No ☑

This 510(k) contains: (check appropriate box(es))

☐ A 510(k) summary of safety and effectiveness, or

☑ A 510(k) statement that safety and effectiveness information will be made available

☐ The required certification and summary for class III devices

The submitter requests under 21 CFR 807.95:*

__✓__ No Confidentiality

_____ Confidentiality for 90 days

_____ Continued Confidentiality exceeding 90 days

Predicate Product Code w/panel and class:

87 HRX Class II

Additional Product Code(s) w/Panel (optional):

_____

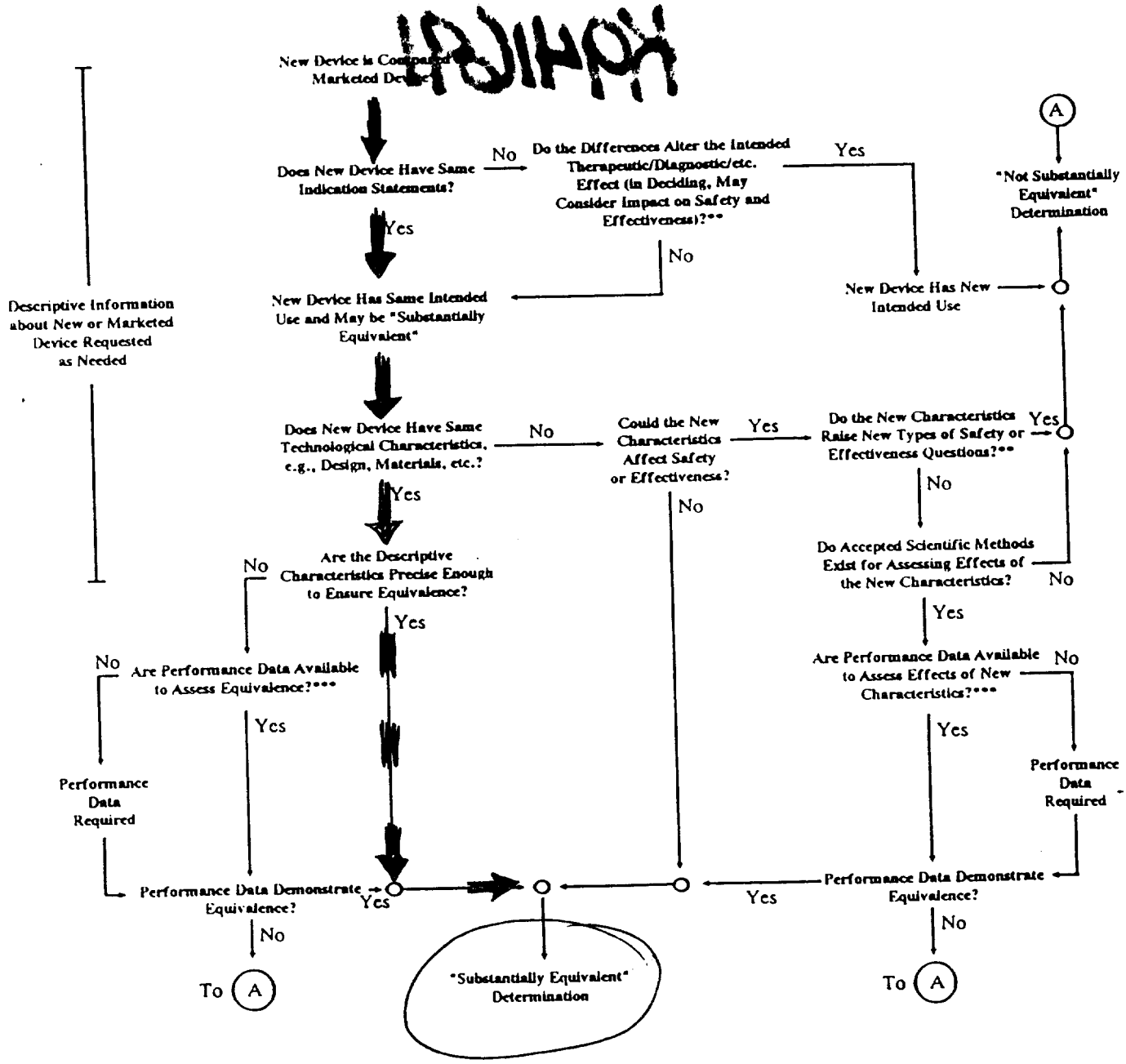
REVIEW: Daniel L. McGeary (BRANCH CHIEF) ORD (BRANCH CODE) 8/31/94 (DATE)

FINAL REVIEW: [signature] (DIVISION DIRECTOR) 9/2/94 (DATE)

*DOES NOT APPLY TO ANY "SE" DECISIONS

Revised 11/18/91

510(k) "SUBSTANTIAL EQUIVALENCE" DECISION-MAKING PROCESS (DETAILED)



- 510(k) submissions compare new devices to marketed devices. FDA requests additional information if the relationship between marketed and "predicate" (pre-Amendments or reclassified post-Amendments) devices is unclear.

** This decision is normally based on descriptive information alone, but limited testing information is sometimes required.

*** Data may be in the 510(k), other 510(k)s, the Center's classification files, or the literature.

K 941691 "SUBSTANTIAL EQUIVALENCE" (SE) DECISION MAKING DOCUMENTATION

REVIEWER: Mark Kosen DIVISION/BRANCH: DSRD/ORDB

TRADE NAME: Revo Rotator Cuff Repair System COMMON NAME: orthroscopic accessories

PRODUCT TO WHICH COMPARED:
(510(k) NUMBER IF KNOWN)

	YES	NO	
1. IS PRODUCT A DEVICE?			- IF NO STOP
2. DEVICE SUBJECT TO 510(k)?			- IF NO STOP
3. SAME INDICATION STATEMENT?			- IF YES GO TO 5
(4.) DO DIFFERENCES ALTER THE EFFECT OR RAISE NEW ISSUES OF SAFETY OR EFFECTIVENESS?			- IF YES STOP - NE
5. SAME TECHNOLOGICAL CHARACTERISTICS?			- IF YES GO TO 7
(6.) COULD THE NEW CHARACTERISTICS AFFECT SAFETY OR EFFECTIVENESS?			- IF YES GO TO 8
7. DESCRIPTIVE CHARACTERISTICS PRECISE ENOUGH?			- IF NO GO TO 10 - IF YES STOP - SE
(8.) NEW TYPES OF SAFETY OR EFFECTIVENESS QUESTIONS?			- IF YES STOP - NE
9. ACCEPTED SCIENTIFIC METHODS EXIST?			- IF NO STOP - NE
10. PERFORMANCE DATA AVAILABLE?			- IF NO REQUEST DATA
(11.) DATA DEMONSTRATE EQUIVALENCE?			

NOTE: IN ADDITION TO COMPLETING PAGE TWO, "YES" RESPONSES TO QUESTIONS 4, 6, 8, AND 11, AND EVERY "NO" RESPONSE REQUIRES AN EXPLANATION ON PAGE THREE AND/OR FOUR

510(k) Memorandum

Reviewer: Aric D Kaiser, Biomedical Engineer
ODE/DGRD/ORDB

Document received: April 6, 1994
Document dated: April 6, 1994
Review initiated: August 31, 1994

Document #: K941691
Linvatec Revo™ Rotator Cuff Repair System

Recommendation - The submitted devices are substantially equivalent to devices currently cleared to market.

Sponsor: Linvatec Corporation
11311 Concept Boulevard
Largo, FL 34643
registration #1017294

Carol A Weideman, PhD
Manager, New Product Applications
813-399-5281

Shutt Medical Technologies
A Division of Linvatec Corporation
545 Terrace Drive
San Dimas, CA 91773
registration #2022690

Device identification (p.2)
888.1100 - arthroscope and accessories
87LHRX class II

Intended use (2-3, Exhibit 1)
The submitted devices are intended to be used with the Revo 4mm Cancellous Screw (K924941) Driver and Drill during arthroscopic rotator cuff repair in the shoulder.

Description (1, 3-5, Appendix 2,3)
The submitted tissue repair system consists of the following instruments:

Revo Suture Threader -used to thread suture through cannulated screwdriver
non-sterile, reusable

Knot Pusher - used to advance knots
non-sterile, reusable

Crochet Hook - used to manipulate/retrieve suture
non-sterile, reusable

2mm Bone Punch - used to create pilot hole for 4mm screw
non-sterile, reusable

Hawkeye Suture Needle - used to spear through tissue and capture suture strands

sterile, single-use

Shuttle-Relay Suture Passer - used to pass suture through tissue
sterile, single-use

Suture Retrieval Forceps - used to manipulate/retrieve suture
non-sterile, reusable

Micro Scissors - used to cut excess suture above a knot
non-sterile, reusable

Suture Punch - used to spear tissue and pass suture
non-sterile, reusable

All of these instruments are stored in labeled compartments in the supplied sterilization case.

Materials (3-5, Exhibit 4-12)
The submitted devices are made from the following materials commonly used for medical instruments:
(b) (4)

Labeling (Exhibit 1)
Sample labels have been provided for all of the instruments. Sample instructions have been provided for the Hawkeye suture needle and the Shuttle-Relay suture passer. These are the only instruments whose use is not self-explanatory.

Packaging (6, Exhibit 13)
The instruments will be packaged both sterile (single-use items) and non-sterile (reusable items). Specific packaging for each instrument is provided on p.6.

Additional information ()
not required

Clinical Data
not required

Sterilization (5)
The items identified above as non-sterile and reusable are to be steam sterilized according to the following methods:

method	cycle	temperature	exposure time (min)
(b) (4)			

Substantial equivalence information (6)
No predicate devices are provided. The sponsor simply states that the submitted devices are substantially equivalent to devices currently on the market and will be used as accessories to the already cleared Revo 4mm Cancellous Screw.

A review of devices already cleared to market for use as arthroscopic accessories reveals no substantial difference between those devices and these devices. The submitted devices have no attributes which would alter the safety and effectiveness compared to predicate devices.

510(k) summary or statement (7)
The sponsor has stated that safety and effectiveness information will be made available upon request.

Confidentiality ()
The sponsor will be provided with standard confidentiality.

Log of contact with the manufacturer:
8/31/94 The manufacturer will be contacted by phone (as recommended by HXS and SPR) to alert them to required changes in the labels for products provided by Shutt Medical Technologies. The labels must be modified to contain the company address. The sponsor agreed to this change (and added the comment that "newer" versions of the labels already contain this information).

Recommendation - Based on the information provided by the sponsor and a review of appropriate predicate devices, I recommend that the devices in this submission be determined to be substantially equivalent to devices currently cleared to market.

Revised: 8-20-93

Premarket Notification (510(k)) Checklist for Acceptance Decision

K 941691 Date DMC Received 4/6/94

Device Trade Name: Revo Rotator Cuff Repair Sys.

Reason for 510(k) intent to market

Division/Branch: DGRD-CR

Administrative Reviewer Signature: Michael Cowling Date 4/19/94

Supervisory Signature: _____ Date _____

Did the firm request expedited review NO

Did we grant expedited review _____

X accepted

_____ refuse to accept

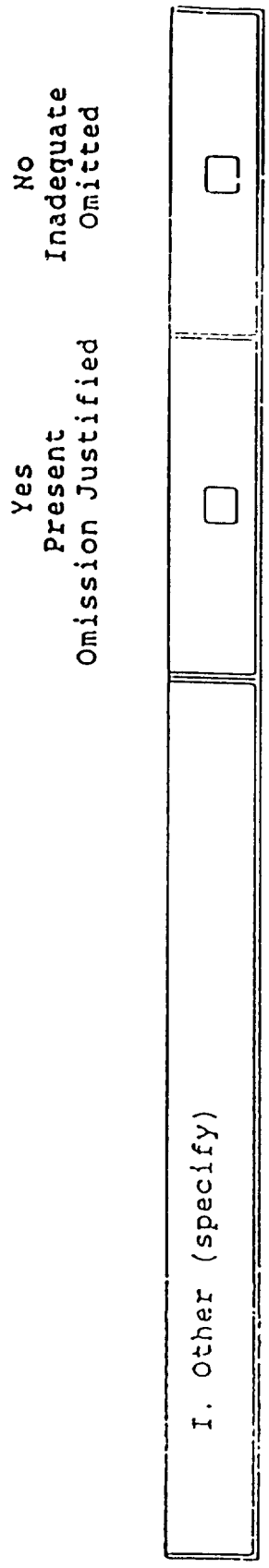
	Yes Present Omission Justified	No Inadequate Omitted
I. Critical Elements:		
A. Is the product a device?	☑	☐
B. Is the device exempt from 510(k) by regulation or policy?	☐	☑
C. Is device subject to review by CDRH?	☑	☐
D. (i) Are you aware that this device has been the subject of a previous NSE decision? (ii) If yes, does this new 510(k) address the NSE issue(s) (e.g., performance data)?	☐	☑
E. (i) Are you aware of the submitter being the subject of an integrity investigation? If yes, consult the ODE Integrity Officer.	☐	☑
(ii) Has the ODE Integrity Officer given permission to proceed with the review? (Blue Book Memo #I91-2 and Federal Register 90N-0332, September 10, 1991.)	☑	☐

	Yes Present Omission Justified	No Inadequate Omitted
F. Does the submission contain the information required under Sections 510(k), 513(f), and 513(i) of the Federal Food, Drug, and Cosmetic Act (Act) and Subpart E of Part 807 in Title 21 of the Code of Federal Regulations?:		
1. Device trade or proprietary name	☑	☐
2. Device common or usual name or classification name	☑	☐
3. Establishment registration number (only applies if establishment is registered)	☑	☐
4. Class into which the device is classified under (21 CFR Parts 862 to 892)	☑	☐
5. Classification Panel	☑	☐
6. Action taken to comply with Section 514 of the Act	☑	☐
7. Proposed labels, labeling and advertisements (if available) that describe the device, its intended use, and directions for use (Blue Book Memo #G91-1)	☑	☐

	Yes Present Omission Justified	No Inadequate Omitted
8. A 510(k) summary of safety and effectiveness or a 510(k) statement that safety and effectiveness information will be made available to any person upon request	☐	☐
9. For class III devices only, a class III certification and a class III summary	☐	☐
10. Photographs of the device	☐	☐
11. Engineering drawings for the device with dimensions and tolerances	☐	☐
12. The marketed device(s) to which equivalence is claimed including labeling and description of thedevice	☐	☐
13. Statement of similarities and/or differences with marketed device(s)	☐	☐
14. Data to show consequences and effects of a modified device(s)	☐	☐
II. Additional Information that is necessary under 21 CFR 807.87(h):		
A. Submitter's name and address	☐	☐

	Yes Present Omission Justified	No Inadequate Omitted
B. Contact person, telephone number and fax number	☐	☐
C. Representative/Consultant if applicable	☐	☐
D. Table of Contents with pagination	☐	☐
E. Address of manufacturing facility/facilities and, if appropriate, sterilization site(s)	☐	☐
III. Additional Information that <u>may be</u> necessary under 21 CFR 807.87(h):		
A. Comparison table of the new device to the marketed device(s)	☐	☐
B. Action taken to comply with voluntary standards	☐	☐
C. Performance data		
marketed device		
bench testing	☐	☐
animal testing	☐	☐
clinical data	☐	☐

	Yes Present Omission Justified	No Inadequate Omitted
new device		
bench testing	☐	☐
animal testing	☐	☐
clinical data	☐	☐
D. Sterilization information	☐	☐
E. Software information	☐	☐
F. Hardware information	☐	☐
G. If this 510(k) is for a kit, has the kit certification statement been provided?	☐	☐
H. Is this device subject to issues that have been addressed in specific guidance document(s)?	☐	☐
If yes, continue review with checklist from any appropriate guidance documents.		
If no, is 510(k) sufficiently complete to allow substantive review?		



DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Food and Drug Administration
Center for Devices and
Radiological Health
Office of Device Evaluation
Document Mail Center (HFZ-401)
1390 Piccard Drive
Rockville, Maryland 20850

April 15, 1994

LINVATEC CORP.
11311 CONCEPT BLVD.
LARGO, FL 34643
ATTN: CAROLE A. WEIDEMAN

510(k) Number: K941691
Received: 06-APR-94
Product: REVO ROTATOR CUFF REPAIR SYSTEM

The Center for Devices and Radiological Health (CDRH), Office of Device Evaluation (ODE), has received the Premarket Notification you submitted in accordance with Section 510(k) of the Federal Food, Drug, and Cosmetic Act (Act) for the above referenced product. We have assigned your submission a unique 510(k) number that is cited above. Please refer prominently to this 510(k) number in any future correspondence that relates to this submission. We will notify you when the processing of your premarket notification has been completed or if any additional information is required.

The Safe Medical Devices Act of 1990 (SMDA), signed on November 28, states that you may not place this device into commercial distribution until you receive a letter from FDA allowing you to do so. Although the traditional timeframes for reviewing 510(k)s has been 90 days, it is now taking longer. These increasing response times have been caused by many factors, including a sharp increase in ODE's workload and increasingly complex device submissions. During 1992, we received about 1,500 more total submissions than we did the preceding year. We are troubled by these increases in response times and are making every effort to regain predictability in the timing of 510(k) reviews. Due to the increase in response times, CDRH has established a 510(k) Status Reporting System through which submitters may receive a status report on their 510(k) submissions(s) as follows:

- Beginning 90 days after ODE receives your 510(k) submission, you may begin requesting status information. Submit requests via fax (301-443-8818) or via mail to:
  510(k) Status Coordinator
  Division of Small Manufacturers Assistance (DSMA) (HFZ-220)
  Center for Devices and Radiological Health, FDA
  5600 Fishers Lane
  Rockville, Maryland 20857 USA
  Because of staff limitations, we cannot answer telephone status requests.

- 510(k) status requests should include:
  (1) submitter's name and mailing address;
  (2) requester's name, affiliation with the 510(k) submitter, mailing address, fax number (if applicable), telephone number, and signature; and

(3) 510(k) information, including product name, 510(k) number, date logged in by ODE (as identified in acknowledgment letter from ODE), and name of contact person identified on firm's 510(k) submission.

Enclosed is a suggested format that you may use to ensure that you include all of the required information.

- Within three working days after DSMA receives a submitter's status request, DSMA will send the submitter a fax or letter that includes:
  (1) the branch to which the 510(k) has been assigned;
  (2) the last action, and date of that action, that CDRH has taken regarding the 510(k), e.g., logging in an amendment, preparing a decision letter; and
  (3) the position of the 510(k) in the reviewer's queue.

We request that 510(k) submitters make status inquiries no more than every four weeks. We do not have the resources to respond more frequently.

The SMDA also requires all persons submitting a premarket notification submission to include either (1) a summary of the safety and effectiveness information in the premarket notification submission upon which an equivalence determination could be based (510(k) summary), OR (2) a statement that safety and effectiveness information will be made available to interested persons upon request (510(k) statement). Safety and effectiveness information refers to information in the premarket notification submission, including adverse safety and effectiveness information, that is relevant to an assessment of substantial equivalence. The information could be descriptive information about the new and predicate device(s), or performance or clinical testing information. We cannot issue a final decision on your 510(k) unless you comply with this requirement.

Although FDA acknowledges that the law provides the 510(k) submitter an alternative, FDA encourages 510(k) submitters to provide a 510(k) statement to FDA and to make their safety and effectiveness information available to the public, excluding confidential manufacturing process information, in lieu of submitting a 510(k) summary to the agency until FDA promulgates a regulation on the content and format of 510(k) summaries. **Since the law requires that FDA must make the 510(k) summary, or the source of information referred to in the 510(k) statement, publicly available within 30 days of making a substantial equivalence determination, we advise you that we may no longer honor any request for extended confidentiality under 21 CFR 807.95.**

Additionally, the new legislation also requires any person who asserts that their device is substantially equivalent to a class III device to (1) certify that he or she has conducted a reasonable search of all information known, or otherwise available, about the generic type of device, AND (2) provide a summary description of the types of safety and effectiveness problems associated with the type of device and a citation to the literature, or other sources of information, upon which they have based the description (class III summary and certification). The

description should be sufficiently comprehensive to demonstrate that an applicant is fully aware of the types of problems to which the device is susceptible. If you have not provided this class III summary and certification in your premarket notification, please provide it as soon as possible. We cannot complete the review of your submission until you do so.

As of March 9, 1993, FDA has implemented the Good Manufacturing Practice(GMP) Pre-Clearance Inspection Program for all class III devices that are being reviewed under the premarket notification program. A letter of substantial equivalence cannot be sent until the finished device manufacturing site(s) and sterilization sites(s) as appropriate, have been identified and FDA has determined that the manufacturer(s) is in compliance with the GMP regulation (21 CFR Part 820).

Furthermore, the new legislation, section 522(a)(1), of the Act, states that if your device is a permanent implant the failure of which may cause death, you may be subject to required postmarket surveillance. If the premarket notification for your device was originally received on or after November 8, 1991, is subsequently found to be substantially equivalent to an Aneurysm Clip, Annuloplasty Ring, Artificial Embolization Device, Automatic Implanted Cardioverter Defibrillator System, Cardiovascular Intravascular Filter, Cardiovascular Permanent Pacemaker Electrode (Lead), Central Nervous System Fluid Shunt, Coronary Vascular Stent, Implantable Pacemaker Pulse Generator, Implanted Diaphragmatic/ Phrenic Nerve Stimulator, Intracardiac Patch or Pledget, Intravascular Occluding Catheter, Replacement Heart Valve, Total Artificial Heart, Tracheal Prosthesis, Vascular Graft Prosthesis (less than 6 mm diameter), Vascular Graft Prosthesis (6 mm or greater diameter), Vena Cava Clip, or Ventricular Assist Device - Implant, you will be subject to the required postmarket surveillance and so notified of this determination in your substantially equivalent letter. (Some of the above listed types of devices may require a premarket approval application). This list is subject to change without notification. If you have any questions as to whether or not your device may be subject to postmarket surveillance or about this program, please contact the Postmarket Surveillance Studies Branch at (301) 594-0639.

Please note that the SMDA may have additional requirements affecting your device. You will be informed of these requirements as they become effective.

Please remember that all correspondence concerning your submission MUST be sent to the Document Mail Center (HFZ-401) at the above letterhead address. Correspondence sent to any address other than the Document Mail Center will not be considered as part of your official premarket notification submission. Because of equipment and personnel limitations we cannot accept telefaxed material as part of your official premarket notification submission, unless specifically requested of you by an FDA official.

If you have procedural or policy questions, please contact the Division of Small Manufacturers Assistance at (301) 443-6597 or their toll-free number (800) 638-2041, or contact me at (301) 594-1190.

Sincerely yours,

Marjorie Shulman
Supervisory Consumer Safety Officer
Premarket Notification Section
Office of Device Evaluation
Center for Devices and
Radiological Health

PREMARKET NOTIFICATION (510(k)) STATUS REQUEST

TO: 510(k) Status Coordinator
Division of Small Manufacturers Assistance (HFZ-220)
Center for Devices and Radiological Health, FDA
5600 Fishers Lane
Rockville, MD 20857
USA
Fax Number: (301) 443-8818

Please provide the status of the 510(k) identified below. Please send the information to the requester identified in section B by (check one):

____ fax
____ mail

A. Sponsor Information:

1. Name of 510(k) sponsor: _____
2. Sponsor's mailing address: _____

B. Requester information:

1. Request name: _____
2. Requester affiliation with sponsor: _____
3. Requester mailing address: _____
4. Request fax number (if applicable): _____
5. Requester telephone number: _____

C. 510(k) information:

1. Product name: _____
2. 510(k) number: _____
3. Date logged in by Office of Device Evaluation (ODE) (as identified in acknowledgment letter from ODE): _____

Name of contact person identified on firm's 510(k) submission: _____

I certify that the above information is accurate and truthful to the best of my knowledge.

_____
Requester signature

(Rev:2)

K941691

Linvatec

11311 Concept Boulevard Largo, Florida 34643 813 399-5281 Fax: 813 399-5253

April 6, 1994

Office of Device Evaluation
510(k) Document Mail Center (HFZ-401)
Center for Devices & Radiological Health
Food And Drug Administration
1390 Piccard Drive
Rockville, MD 20850

Re: 510(k) Notification
Revo™ Rotator Cuff Repair System

Dear Sir/Madame:

As per part 807, Subpart E of Title 21 of the Code of Federal Regulations Linvatec Corporation is hereby submitting two copies of 510(k) Premarket Notification concerning the Revo Rotator Cuff Repair System.

We are requesting Tier I review, as this submission falls into 888.4540 Orthopedic Manual Surgical Instruments, Class I.

Please address any questions concerning this submission to my attention.

Sincerely,

Carol A. Weideman, Ph.D.
Manager, New Product Applications

Enclosures

Fed. Express

CONFIDENTIAL

510(K) NOTIFICATION

Revo™ Rotator Cuff Repair System

April 5, 1994

Linvatec Corporation
11311 Concept Boulevard
Largo, FL 34643

INTRODUCTION

The Revo 4mm Cancellous Screw is presently approved for rotator cuff repair of the shoulder under 510(k) #K924921. The items included in this submission are instruments and/or accessories which may be used in conjunction with the Revo 4mm Cancellous Screw, Driver and Drill for rotator cuff repair of the shoulder. These instruments are hand-held devices intended for medical purposes to manipulate tissue, and/or for use with other devices in orthopedic surgery.

The Revo Suture Threader (Catalog #C6103) is used to thread the suture through the cannulated portion of the Revo Screwdriver. This device is manufactured at our Largo facility.

The Knot Pusher (Catalog #C6104/C6112) is used to advance or slide knots into position. This device is manufactured at our San Dimas facility.

The Crochet Hook (Catalog #C6105) is used to manipulate and/or retrieve suture. This device is manufactured at our San Dimas facility.

The Bone Punch (Catalog #C6107) is used to create a pilot hole in the bone trough, thus providing a starter hole for the Revo 4mm Cancellous Screw. This device is manufactured at our San Dimas facility.

The Hawkeye Suture Needle (Catalog #C6001) is used to spear through tissue and with the eyelet open, capture suture strands to accomplish soft tissue stitching. This device is manufactured at our Largo facility.

The Shuttle-Relay Suture Passer (Catalog #C6004) is an instrument used to pass suture through the tissue. This device is manufactured at our Largo facility.

The Suture Retrieval Forceps (Catalog #16.1018) is used to help manipulate and/or retrieve the suture. This device is manufactured at our San Dimas facility.

The Micro Scissors (Catalog #2.10011) is an instrument used to cut excess suture above a tied knot. This device is manufactured at our San Dimas facility.

The Suture Punch (Catalog #18.1008) is an instrument used to spear through tissue and pass suture. This device is manufactured at our San Dimas facility.

The Sterilization Case (Catalog #C6108) is for convenience in storing and sterilizing manual instruments which can be used to repair rotator cuff tears. This device is manufactured at our Largo facility.

The following information is supplied in accordance with Public Law 94-295, "Medical Device Amendment", Section 510(k) requiring premarket notification.

Linvatec manufactures all its products and maintains such records as it considers necessary to satisfy the known requirements of the Act. Linvatec Corporation and Shutt Medical Technologies, A Division of Linvatec, hereby notifies the Food And Drug Administration of its intent to market the following:

1. MANUFACTURER IDENTIFICATION:

Linvatec Corporation
11311 Concept Boulevard
Largo, FL 34643
Registration No. 1017294

Shutt Medical Technologies
A Division of Linvatec Corporation
545 Terrace Drive
San Dimas, CA 91773
Registration No. 2022690

Contact Person: Carol A. Weideman
Manager, New Product Applications

2. DEVICE IDENTIFICATION:

Proprietary Name: Revo™ Rotator Cuff Repair System

Common Name:
Suture Threader
Knot Pusher
Crochet Hook
Bone Punch
Needle
Suture Passer
Forceps
Scissors
Punch
Case

Classification Name/Reference:

888.4540 Orthopedic Manual Surgical Instrument

Proposed Class/Device Product Code: Class I

3. INTENDED USE:

These devices are indicated for use in conjunction with the Revo 4mm Cancellous Screw, Screwdriver and Drill in rotator cuff repair of the shoulder.

INTENDED USE CONT'D:

A copy of advertisements and labelling are included in Exhibit 1. Pictures of the devices are included in Exhibit 2.

4. DEVICE DESCRIPTION:

The Revo Suture Threader is used to thread the suture through the cannulated portion of the Revo Screwdriver.

The Knot Pusher is used to advance or slide knots into position.

The Crochet Hook is used to manipulate and/or retrieve suture.

The Bone Punch is used to create a pilot hole in the bone trough, thus providing a starter hole for the Revo 4mm Cancellous Screw.

The Hawkeye Suture Needle is used to spear through tissue and with the eyelet open, capture suture strands to accomplish soft tissue stitching.

The Shuttle-Relay Suture Passer is an instrument used to pass suture through the tissue.

The Suture Retrieval Forceps is used to help manipulate and/or retrieve the suture.

The Micro Scissors is an instrument used to cut excess suture above a tied knot.

The Suture Punch is an instrument used to spear through tissue and pass suture.

The Sterilization Case is for convenience in storing and sterilizing manual instruments which can be used to repair rotator cuff tears.

Engineering drawings are included in Exhibit 3.

5. MATERIALS:

(b) (4)

MATERIALS CONT'D:

(b) (4)

MATERIALS CONT'D:

(b) (4)

6. LABELING:

Labeling and advertisements are included in Exhibit 1.

7. ADDITIONAL INFORMATION:

Additional information is not needed to prove substantial equivalence of these devices.

8. CLINICAL DATA:

Clinical data are not required.

9. STERILITY INFORMATION:

The Suture Threader, Knot Pusher, Crochet Hook, Bone Punch, Suture Retrieval Forceps, Micro Scissors, Suture Punch and Sterilization Case are supplied non-sterile, reusable and can be steam sterilized as follows:

Steam Sterilization Guidelines:

(b) (4)

10. PACKAGING DESCRIPTION:

The Suture Threader is packaged non-sterile in 20 Pt. SBS Folding Carton. Product identification and lot number will be accomplished with a label applied to the outside of the carton.

The Knot Pusher is packaged non-sterile in a paperboard box with foam inserts to protect the instrument from movement. Product identification and lot number will be accomplished with a label applied to the outside of the box.

The Crochet Hook, Bone Punch, Suture Retrieval Forceps, Micro Scissors, and Suture Punch are packaged non-sterile in a clear plastic case with foam inserts to protect the instrument from movement. Product identification and lot number will be accomplished with a label applied to the outside of the case.

The Hawkeye Suture Needle is packaged sterile, single use in a polyethylene peel pouch with spunbonded olefin lidding and then placed into a folding carton. Product identification and lot number will be accomplished with a label applied to the outside of the pouch and folding carton.

The Shuttle-Relay Suture Passer is packaged sterile, single use in a spunbonded olefin/polymylar peel pouch and then into a SBS folding carton. Product identification and lot number will be accomplished with a label applied to the outside of the pouch and folding carton.

The Sterilization Case is packaged non-sterile. The base tray and lid, are placed into plastic bags. The closed tray is then wrapped in bubble-wrap for protection. The wrapped tray is placed in a C-Flute corrugated box and sealed. Product identification and lot number will be accomplished with a label applied to the outside of the box. Packaging drawings are included in Exhibit 13.

11. SUBSTANTIAL EQUIVALENCE INFORMATION:

The Revo Rotator Cuff Repair System instruments are substantially equivalent to orthopedic manual surgical instruments currently on the market. This 510(k) is being filed for their use with and/or as accessories to the Revo 4mm Cancellous Screw K924921, a class II device.

12. **510(k) STATEMENT:**

Safety and efficacy information for the Revo Rotator Cuff Repair System Accessories is available, excluding confidential manufacturing processes, to interested persons upon written request.

I certify, to the best of my knowledge, that a reasonable search of all information known or otherwise presently available to Linvatec Corporation has been conducted concerning the safety and effectiveness information for the Revo Rotator Cuff Repair System Accessories.

Signature of responsible person — Date: 4/6/94

Name of individual signing certification:
Carol A. Weideman, Ph.D.

Title: Manager, New Product Applications

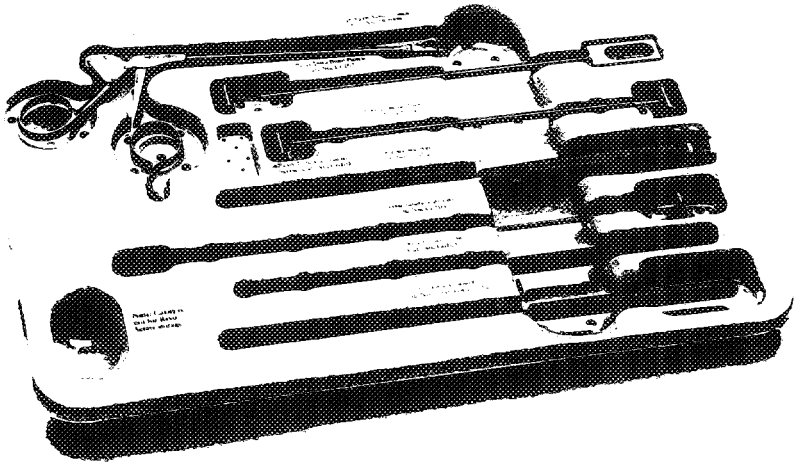
Company Name: Linvatec Corporation

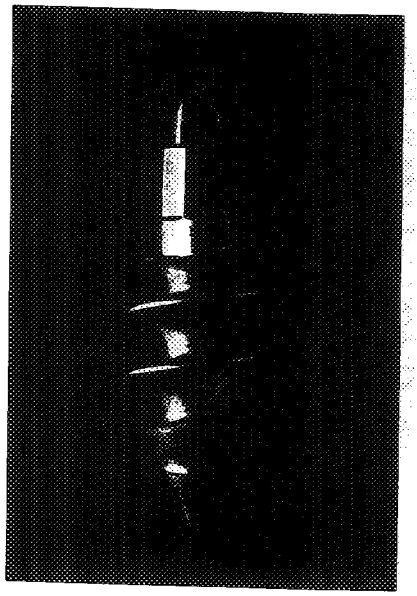
Address: 11311 Concept Boulevard, Largo, FL 34643

Phone: 813/399-5334

CONTENTS

Revo™ Rotator Cuff Repair System





	Cat. No.
4mm Revo Cancellous Screw (sterile, single use)	C6101

Revo Instrument Set

Revo Screwdriver	C6102
Revo Suture Threader	C6103
Knot Pusher	C6104
Crochet Hook	C6105
2mm Drill Bit	C6106
2mm Bone Punch	C6107
Sterilization Case	C6108

Accessories

Hawkeye Suture Needle (sterile, single-use, 6 per box)	C6001
Shuttle-Relay Suture Passer (sterile, single-use, 10 per box)	C600-4
Suture Retrieval Forceps	16.1018
2.75mm Micro Scissors, Straight	2.10011
4mm Tip, Suture Punch, Slotted Jaw (modified)	18.1008

Revo Rotator Cuff Repair System*

- Designed specifically for arthroscopic and open rotator cuff repair, the Revo screw has 4mm wide cancellous threads that provide superior bone purchase. With over 2½ times more pullout strength than the break strength of #2 braided suture, strong fixation is assured.
- Can be safely and completely retrieved from bone should the suture fail.
- Can be introduced into the joint without a cannula, thereby providing unrestricted placement.

* *Developed in conjunction with Stephen J. Snyder, M.D., Van Nuys, CA*

Revo™ Rotator Cuff Repair System

LABELLING

REVO™ THREADER
NON STERILE

CAUTION: FEDERAL LAW RESTRICTS THIS DEVICE TO SALE BY OR ON THE ORDER OF A PHYSICIAN.

LOT NO.XXXXXX
A55-485-701 A 5-979

Linvatec 11311 CONCEPT BLVD..LARGO FL 34643
Concept Arthroscopy

CAT.NO.C6103 REVO™THREADER
QUANTITY: 1

P60-524-000

Shutt®
Medical Technologies

CATALOG NO: C6112
LOOP KNOT PUSHER

Lot No. XXXX

P0011 *Not Sterile*

Shutt®
Medical Technologies

CATALOG NO: C6105
REVO(TM) CROCHET HOOK

Lot No. XXXX

P0011 *Not Sterile*

Revo™ Rotator Cuff Repair System

LABELLING

Shutt®
Medical Technologies

CATALOG NO: C6107
REVO(TM) 2MM BONE PUNCH

Lot No. XXXX

P0011 *Not Sterile*

Revo™ Rotator Cuff Repair System

LABELLING

[redacted]

HAWKEYE™ SUTURE NEEDLE
STERILE, SINGLE USE. DO NOT RESTERILIZE.
STERILITY GUARANTEED IF PACKAGE HAS NOT
BEEN OPENED OR DAMAGED. PATENT PENDING
CAUTION: FEDERAL LAW RESTRICTS THIS DEVICE
TO SALE BY OR ON THE ORDER OF A PHYSICIAN
LOT NO XXXXXX STERILE XX/XX
A30-404-700 A 523 Co60 2.5 M Rad

Linvatec Corporation
11311 Concept Blvd.
Largo, FL 34643 USA
P60-204-000

Linvatec
Concept Arthroscopy

HAWKEYE™ SUTURE NEEDLE STRAIGHT
STERILE, SINGLE USE
DO NOT RESTERILIZE
STERILITY GUARANTEED IF PACKAGE HAS NOT BEEN
OPENED OR DAMAGED.
CAUTION: FEDERAL LAW RESTRICTS THIS DEVICE
TO SALE BY OR ON THE ORDER OF A PHYSICIAN.
PATENT PENDING
LOT NO. XXXXXX STERILE XX/XX
A30-404-702 B 977 Co60 2.5 M Rad

LINVATEC

QUANTITY: 6
CAT.NO.C6001

HAWKEYE™ SUTURE NEEDLE STRAIGHT
P60-524-000

HAWKEYE SUTURE NEEDLE, STRAIGHT LOT NO.XXXXXX
CAT.NO.C6001 LINVATEC CORPORATION
A30-404-701 A 546 LARGO, FL. 34643

IMPORTANT PRODUCT INFORMATION

Hawkeye™ Suture Needle

A. Description

The Hawkeye Suture Needle provides a unique means of passing or retrieving any suture type up to a USP #2 for various applications for arthroscopic tissue repair of the shoulder and knee. The Hawkeye Suture Needle can be used to create simple, mattress or complex suture patterns.

Note: The Hawkeye Suture Needle is intended for single use only and is packaged sterile, six per box.

B. Directions for use

1. **Suture passing** - The desired suture is loaded in the needle by opening the atraumatic eyelet with the actuator located on the handle. The eyelet is opened by sliding the actuator proximally. The suture is captured in the eyelet and the actuator is retracted distally. **It is important to keep the eyelet closed during the passage through tissues.** The tip of the Hawkeye Suture Needle passes through to expose the tissues and the previously loaded suture is visualized in the tip. The eyelet is opened by sliding the actuator proximally and the suture is disengaged. The eyelet is then completely closed and carefully retracted from the tissue, leaving a loop of suture through the tissues. The loop can be retrieved by using suture retrieval forceps and the previous steps are repeated until the desired stitch is completed and the sutures are ready to tie.

2. **Suture retrieval** - The Hawkeye Suture Needle is passed through a cannula into the joint. **It is important to keep the eyelet closed during the passage through tissues.** The suture needle is passed through both edges of the tissue. The eyelet of the suture needle is opened by sliding the actuator located on the handle proximally. The suture is inserted into the eyelet of the needle and the eyelet is closed by retracting the actuator distally. The needle is retracted out through the tissue and the steps are repeated until the desired stitch is completed and the sutures are ready to tie.

C. Warnings

The Hawkeye Suture Needle contains a sharp tip at the distal end; handle with care. **It is important to keep the eyelet closed during the passage through tissues.**

D. Information

For information, or a demonstration, contact your local Linvatec Representative, or call 1-800-327-0169. Written inquiries should be addressed to:
Linvatec Corporation, 11311 Concept Boulevard, Largo, Florida 34643.

P55-045-000

Linvatec
Concept Arthroscopy

Revo™ Rotator Cuff Repair System

LABELLING

[redacted]

CONCEPT® SHUTTLE-RELAY™

SUTURE PASSING SYSTEM

STERILE. SINGLE USE

DO NOT RESTERILIZE. STERILITY GUARANTEED
IF PACKAGE HAS NOT BEEN OPENED OR DAMAGED.

CAUTION: FEDERAL LAW RESTRICTS THIS DEVICE
TO SALE BY OR ON THE ORDER OF A PHYSICIAN.

U. S. PATENT NO. 5,250,053

LOT NO. XXXXX STERILE XX/XX

A35-636-701 C 822 Co60 2.5 M Rad

Linvatec Corporation
11311 Concept Blvd.
Largo, FL 34643 USA
P60-200-000

Linvatec
Concept Arthroscopy

Shutt®
Medical Technologies

CATALOG NO: 16.1018
SUTURE RETRIEVAL FORCEPS
ARTHROSCOPIC
U.S. PATENT NO: D274,096
Lot No. XXXX

P0011 *Not Sterile*

Shuttle-Relay™

The Concept® Shuttle-Relay™ Suture Passing System
Surgical Technique

Linvatec
Concept Arthroscopy

The Concept® Shuttle-Relay™ Suture Passing System Cat. No. C6004

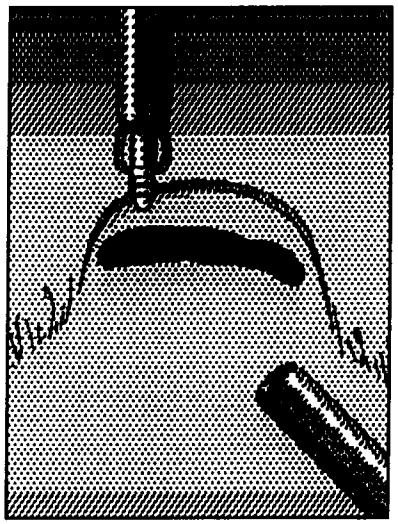
The Concept Shuttle-Relay Suture Passing System allows braided suture to be used for intraarticular suturing of soft tissue. This system provides an effective approach in certain orthopaedic surgical procedures such as arthroscopic repair of the anterior capsule and labrum, rotator cuff, SLAP lesions, biceps tenodesis, meniscal repair, and the refixation of avulsed anterior cruciate ligaments.

Developed in conjunction with
and surgical technique described by
Stephen J. Snyder, M.D.
Southern California Orthopaedic Institute
Van Nuys, CA

Patent Pending

Surgical Technique

Figure 1
Drill a small hole into the prepared site and implant a bone anchor, loaded with non-absorbable braided suture.



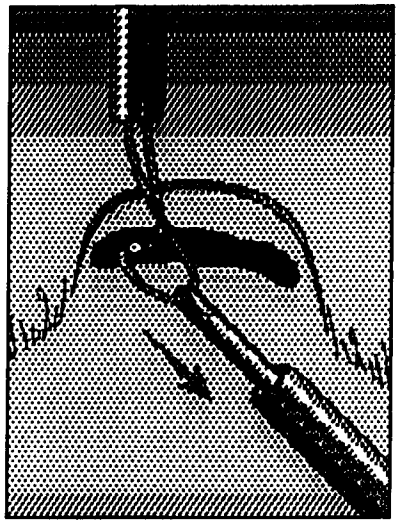
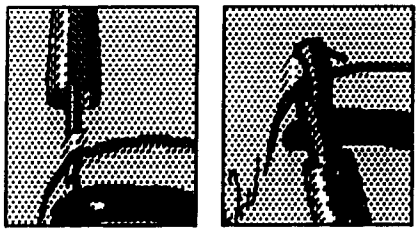


Figure 2
Retrieve one suture limb out the second cannula with Suture Retrieval Forceps or a crochet hook.

Surgical Technique

Figure 3
Insert a Suture Hook, Suture Punch, or hollow needle into the first cannula and pass the tip through the tissue.



Advance the Shuttle-Relay through the instrument and retrieve it with a grasper out the second cannula until the shuttle eyelet is visible outside of the joint.

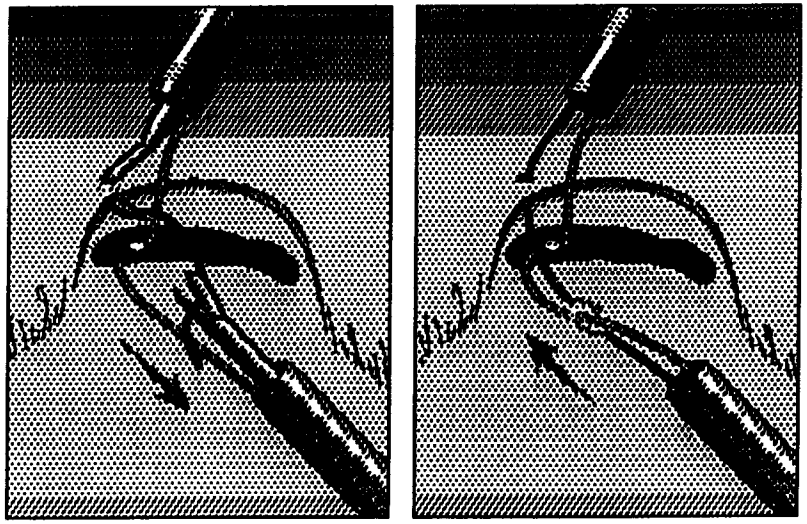


Figure 4
Load the suture limb into the shuttle eyelet outside the second cannula, then retract the Shuttle-Relay back into the joint.

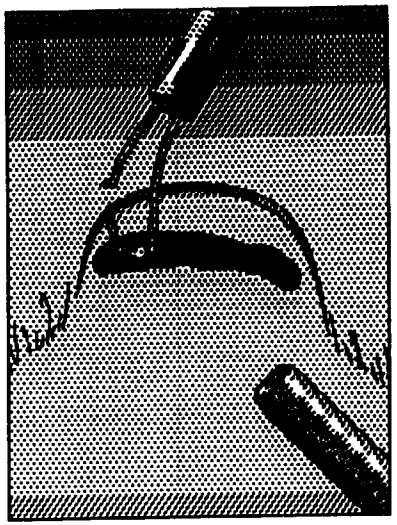


Figure 5
Fully retract the opposite end of the Shuttle-Relay to pull the eyelet loaded with the suture limb through the tissue and out the first cannula. If desired, a slip knot can be thrown to complete a single stitch at this time.

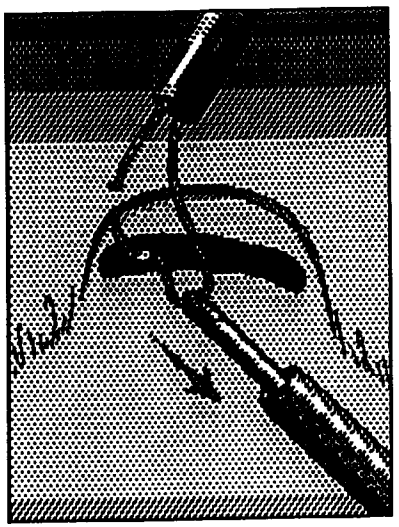


Figure 6
To complete a mattress stitch, grasp the second suture limb with Suture Retrieval Forceps or a crochet hook and retract it out the second cannula.

Figure 7
Insert the Suture Hook, Suture Punch, or hollow needle into the first cannula and pass the tip through the tissue approximately 6mm away from the first pass.

Again, advance the Shuttle-Relay through the instrument and retrieve it with a grasper out the second cannula until the shuttle eyelet is visible outside of the joint.

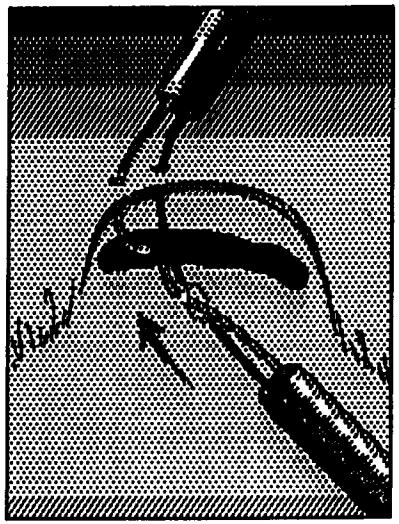


Figure 8
Load the suture limb into the shuttle eyelet outside the second cannula, then retract the Shuttle-Relay back into the joint.

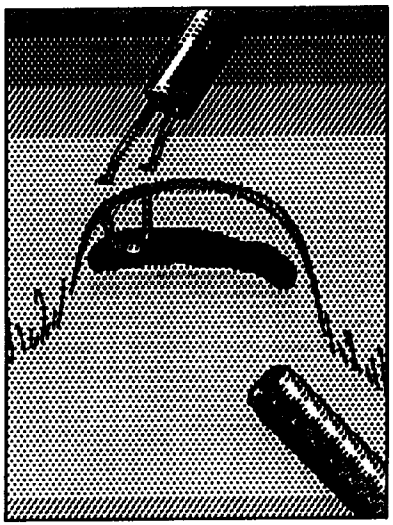


Figure 9
Fully retract the opposite end of the Shuttle-Relay to pull the eyelet with the suture through the tissue and out the first cannula.

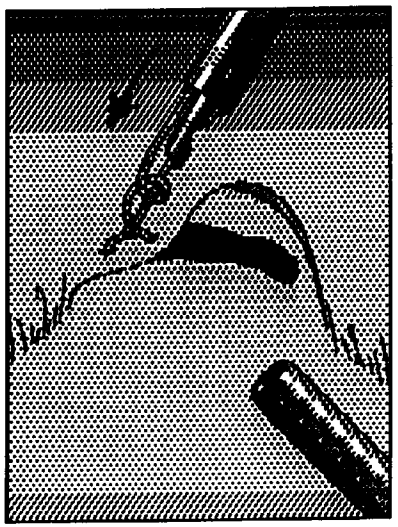


Figure 10
To complete the mattress stitch, tie the suture using a knot pusher.

To secure a larger section of tissue, repeat this procedure using a series of bone anchors and several single stitches or mattress stitches.

Ordering Information

Description	Cat. No.
The Concept® Shuttle-Relay™ Suture Passing System (ten per box)	C6004

Linvatec
Concept Arthroscopy

Linvatec Corporation
11311 Concept Boulevard
Largo, Florida 34643 USA

813-392-6464
800-237-0169
FAX 813-399-5256
A35-636-702B

Revo™ Rotator Cuff Repair System

LABELLING

Shutt®
Medical Technologies

CATALOG NO: 2.10011
MICRO SCISSORS, 2.75MM DIA.
STRAIGHT
U.S. PATENT NO: D274,096

Lot No. XXXX

P0011 *Not Sterile*

Shutt®
Medical Technologies

CATALOG NO: 18.1008
SLOTTED SUTURE PUNCH
MODIFIED JAW, 4MM
PAT. 4,890,615; 4,923,461;
4,957,498

Lot No. XXXX

P0011 *Not Sterile*

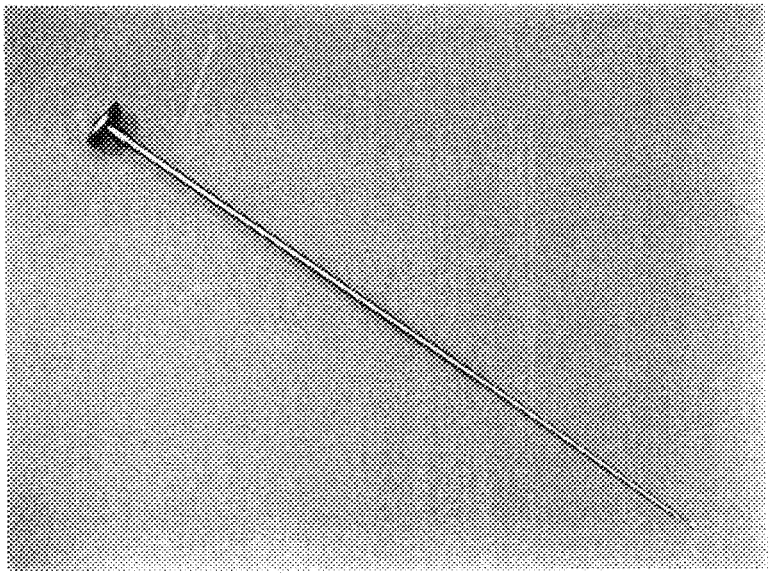
[redacted]

REVO™ ROTATOR CUFF
FIXATION SYSTEM
STERILIZATION TRAY
CAUTION: FEDERAL LAW RESTRICTS THIS DEVICE TO SALE BY OR ON THE ORDER OF A PHYSICIAN.
LOT NO. XXXXXX
A55-474-700 A 584
Linvatec Corporation
11311 Concept Blvd.
Largo, FL 34643 USA
P60-204-000

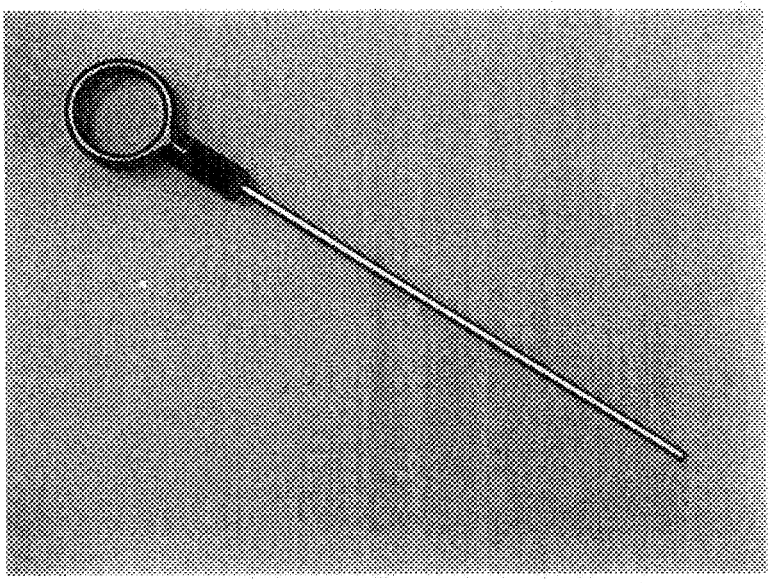
Linvatec
Concept Arthroscopy

2

Revo™ Rotator Cuff Repair System Instruments

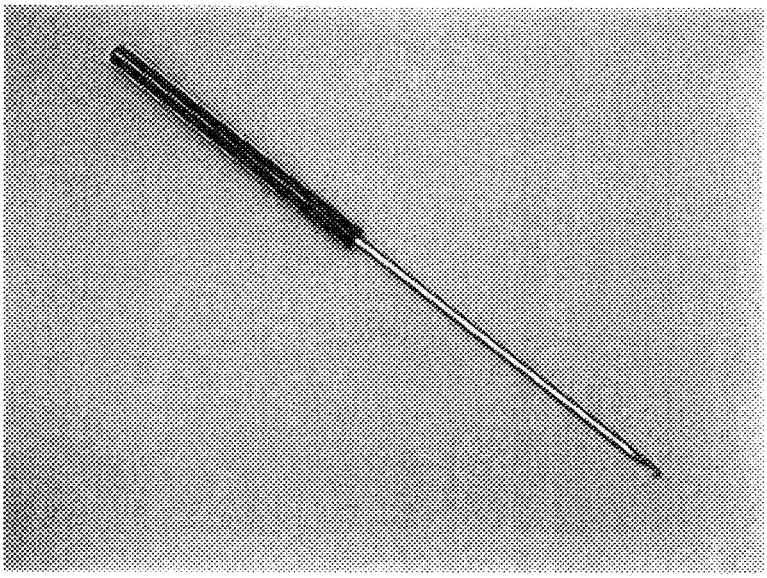


Suture Threader

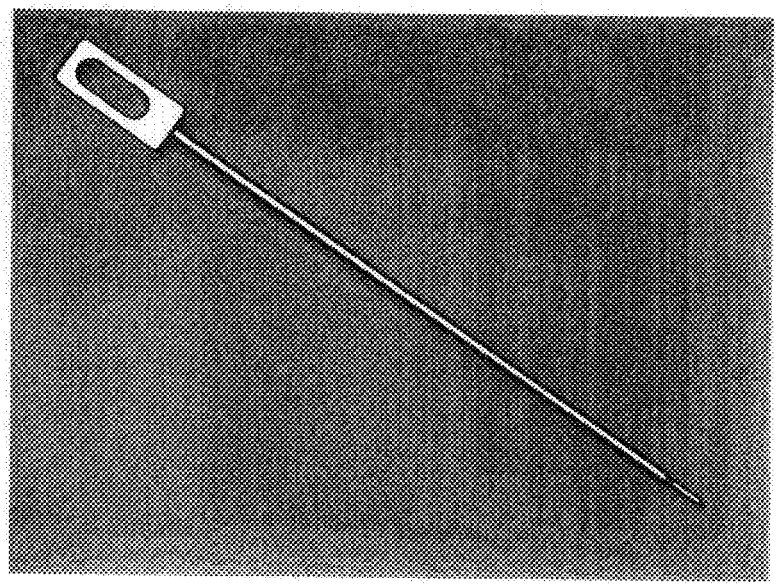


Knot Pusher

Revo™ Rotator Cuff Repair System Instruments

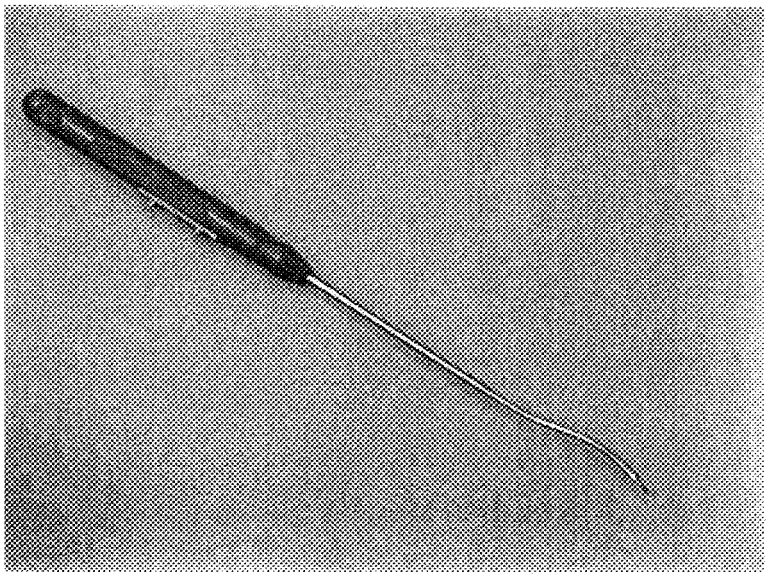


Crochet Hook

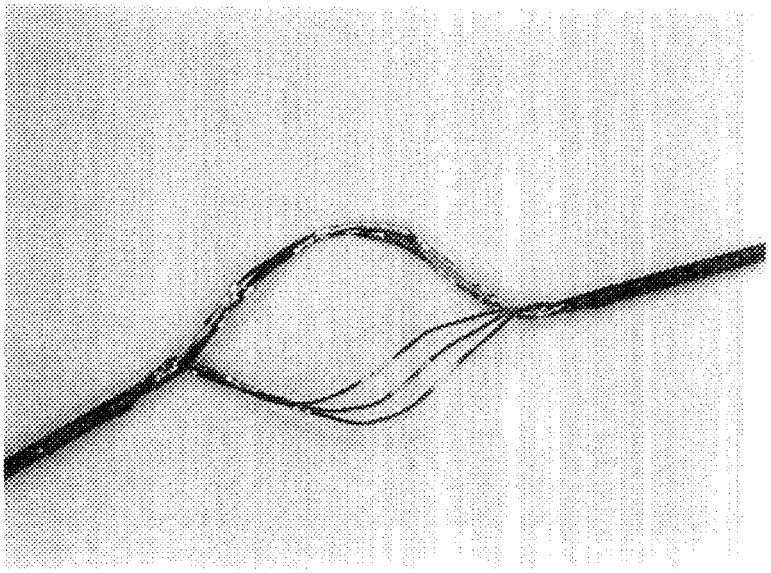


Bone Punch

Revo™ Rotator Cuff Repair System Instruments

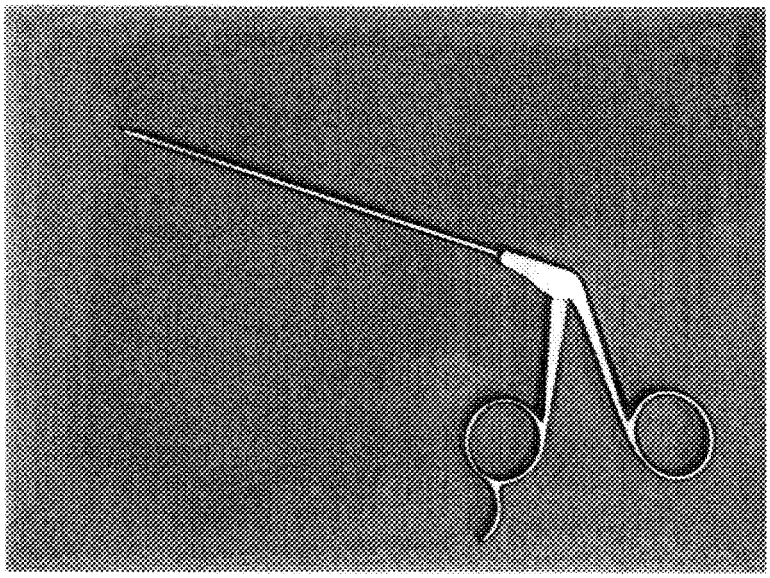


Hawkeye Suture Needle

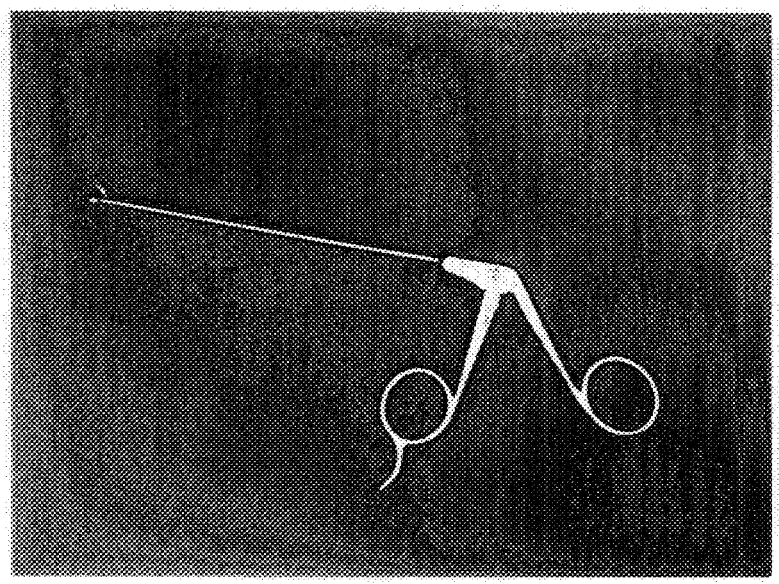


Shuttle Relay
Suture Passer

Revo™ Rotator Cuff Repair System Instruments

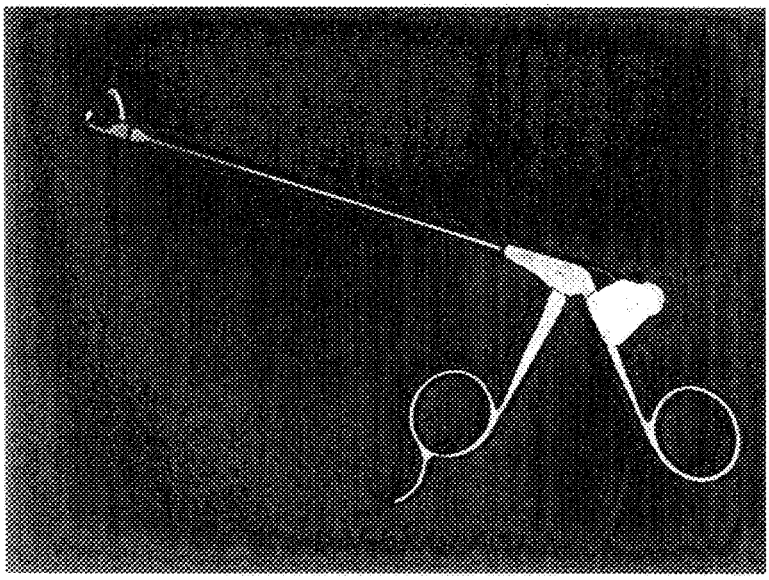


Suture Retrieval Forceps



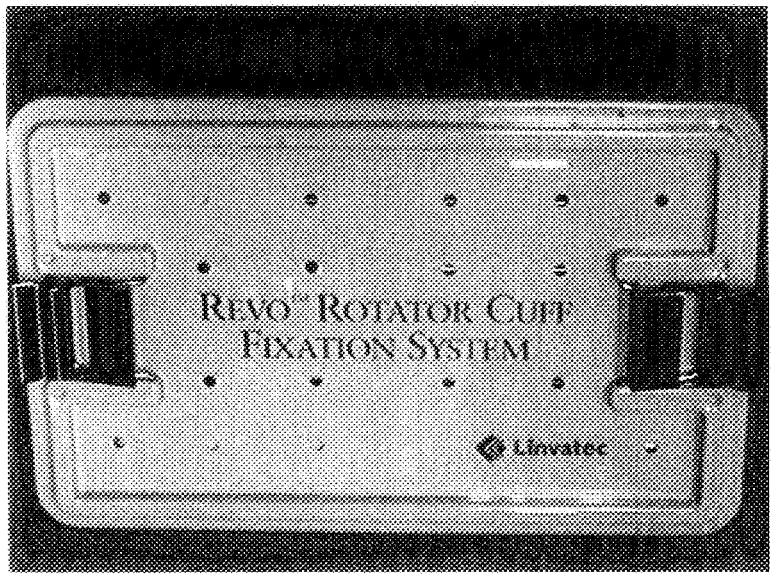
Micro Scissors

Revo™ Rotator Cuff Repair System Instruments

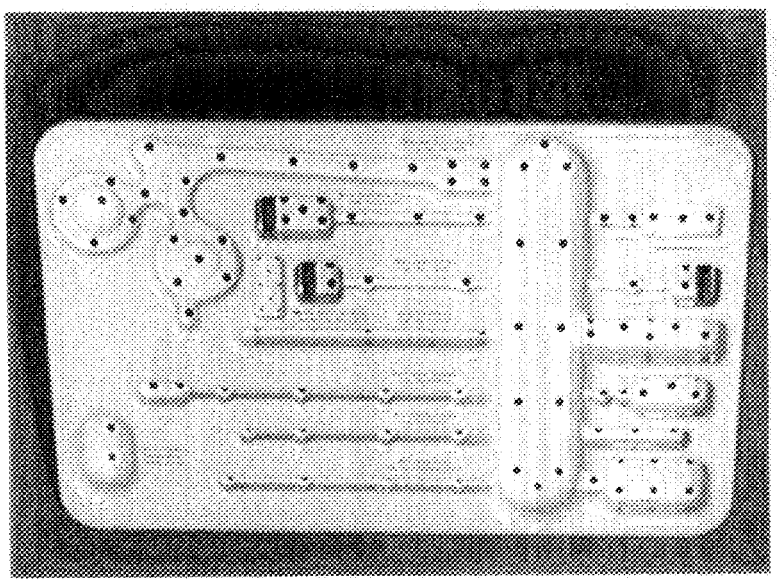


Suture Punch

Revo™ Rotator Cuff Repair System Instruments



Sterilization Case



3

(b)(4) Drawings

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(b)(4) Drawings

4

Designation: A 554 – 90

Standard Specification for Welded Stainless Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A 554; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers welded stainless steel tubing for mechanical applications where appearance, mechanical properties, or corrosion resistance is needed. The grades covered are listed in Table 1.

1.2 This specification covers as-welded or cold-reduced mechanical tubing in sizes to 16 in. (406.4 mm) outside diameter, inclusive (for round tubing) and in wall thicknesses 0.020 in. (0.51 mm) and over.

1.3 Tubes shall be furnished in one of the following shapes as specified by the purchaser: round, square, rectangular, or special.

1.4 Supplementary requirements of an optional nature are provided and when desired shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[3]

E 59 Method of Sampling Steel and Iron for Determination of Chemical Composition[3]

2.2 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, mass, or number of pieces),

3.1.2 Name of material (welded stainless steel mechanical tubing),

3.1.3 Form (round, square, rectangular, special, see

3.1.4 Dimensions:

3.1.4.1 Round-outside diameter and wall thickness f conditions (Section 8). Alternatively, for cold-reduced c tion, outside diameter and inside diameter or inside dia and wall dimensions may be specified.

3.1.4.2 Square and rectangular outside dimension: wall thickness (see 9.1),

3.1.4.3 Special (to be specified),

3.1.5 Length (mill lengths, cut lengths, or multiple le (see 9.3)),

3.1.6 Grade (Table 1),

3.1.7 Condition (see 6.1),

3.1.8 Inside diameter bead condition (see 6.2),

3.1.9 Surface finish (see 11.1 through 11.3),

3.1.10 Report of Chemical Analysis if required (S 7),

3.1.11 Individual supplementary requirements, quired,

3.1.12 End use,

3.1.13 Specification designation,

3.1.14 Special requirements,

3.1.15 Special marking (Section 14), and

3.1.16 Special packing (Section 15).

4. Process

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required b purchaser, it shall be stated on the purchase order.

4.3 The primary melting may incorporate se degassing or refining and may be followed by seco melting, such as electroslag remelting or vacu remelting. If secondary melting is employed, the heat s defined as all of the ingots remelted from a single p heat.

4.4 Steel may be cast in ingots or may be stran When steel of different grades are sequentially stran identification of the resultant transition material is re The producer shall remove the transition material established procedure that positively separates the gr

5. Materials and Manufacture

5.1 The tubes shall be made from flat-rolled stee automatic welding process without the addition c metal.

6. Condition

6.1 The tubes shall be furnished in any of the fo conditions as specified:

This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Tubing.

Current edition approved Feb. 23, 1990. Published April 1990. Originally published as A 554 – 65. Last previous edition A 554 – 88a.

[2] *Annual Book of ASTM Standards*, Vol 01.01, 01.03.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Chemical Requirements

Grade	Composition, %									
	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Columbium + Tantalum
					Austenitic					
MT-301	0.15	2.00	0.040	0.030	1.00	6.0–8.0	16.0–18.0			
MT-302	0.15	2.00	0.040	0.030	1.00	8.0–10.0	17.0–19.0			
MT-304	0.08	2.00	0.040	0.030	1.00	8.0–11.0	18.0–20.0			
MT-304L	0.035[A]	2.00	0.040	0.030	1.00	8.0–13.0	18.0–20.0			
MT-305	0.12	2.00	0.040	0.030	1.00	10.0–13.0	17.0–19.0			
MT-309S	0.08	2.00	0.040	0.030	1.00	12.0–15.0	22.0–24.0			
MT-309S-Cb	0.08	2.00	0.040	0.030	1.00	12.0–15.0	22.0–24.0			[C]
MT-310S	0.08	2.00	0.040	0.030	1.00	19.0–22.0	24.0–26.0			
MT-316	0.08	2.00	0.040	0.030	1.00	10.0–14.0	16.0–18.0	2.0–3.0		
MT-316L	0.035[A]	2.00	0.040	0.030	1.00	10.0–15.0	16.0–18.0	2.0–3.0		
MT-317	0.08	2.00	0.040	0.030	1.00	11.0–14.0	18.0–20.0	3.0–4.0		
MT-321	0.08	2.00	0.040	0.030	1.00	9.0–13.0	17.0–20.0		[B]	
MT-330	0.15	2.00	0.040	0.030	1.00	33.0–36.0	14.0–16.0			
MT-347	0.08	2.00	0.040	0.030	1.00	9.0–13.0	17.0–20.0			[C]
					Ferritic					
MT-429	0.12	1.00	0.040	0.030	1.00	0.50 max	14.0–16.0			
MT-430	0.12	1.00	0.040	0.030	1.00	0.50 max	16.0–18.0			
MT-430-Ti	0.10	1.00	0.040	0.030	1.00	0.075 max	16.0–19.5		5 × C min, 0.75 max	

[A] For small diameter or thin walls or both, where many drawing passes are required, a carbon content of 0.040 % max is necessary in grades MT-304L and MT-316L. Small outside diameter tubes are defined as those less than 0.500 in. (12.7 mm) in outside diameter and light wall tubes as those less than 0.049 in. (1.24 mm) in average wall thickness.

[B] The titanium content shall be not less than five times the carbon content and not more than 0.60 %.

[C] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00 %.

6.1.1 As welded.

6.1.2 Welded and annealed.

6.1.3 Cold reduced, and

6.1.4 Cold reduced and annealed.

6.2 The inside diameter bead shall be furnished in any of the following conditions as specified:

6.2.1 Bead not removed.

6.2.2 Bead controlled to 0.005 in. (0.13 mm) or 15 % of the wall thickness, whichever is greater, and

6.2.3 Bead removed.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that

TABLE 2 Diameter, Wall,[A] and Ovality Tolerances

(All Conditions Except Tubing with Bead Removed)

NOTE 1—Ovality is the difference between maximum and minimum outside diameters measured at any one cross section. There is no additional tolerance for ovality on tubes having a nominal wall thickness of more than 3 % of the outside diameter.

NOTE 2—For sizes up to and including 5-in. (127.0-mm) outside diameter, an ovality tolerance of twice the tabular outside diameter tolerance spread shown is added one half plus and one half minus to tubes having a nominal wall thickness of 3 % or less of the nominal outside diameter. The average of the maximum and minimum outside diameter readings should fall within the outside diameter tolerances as shown in this table.

NOTE 3—For sizes over 5-in. (127.0-mm) to and including 16-in. (406.4-mm) outside diameter, when the specified wall thickness is 3 % or less of the outside diameter the ovality shall not exceed 1.5 % of the specified outside diameter.

OD Size, in. (mm)	Wall Thickness		OD, ±	
	in.	mm	in.	mm
Under ½ (12.7)	0.020 to 0.049	0.51 to 1.24	0.004	0.10
½ to 1 (12.7 to 25.4)	0.020 to 0.065	0.51 to 1.65	0.005	0.13
½ to 1 (12.7 to 25.4)	over 0.065 to 0.134	over 1.65 to 3.40	0.010	0.25
Over 1 to 1½ (25.4 to 38.1), incl	0.025 to 0.065	0.64 to 1.65	0.008	0.20
Over 1 to 1½ (25.4 to 38.1), incl	over 0.065 to 0.134	over 1.65 to 3.40	0.010	0.25
Over 1½ to 2 (38.1 to 50.8), incl	0.025 to 0.049	0.64 to 1.24	0.010	0.25
Over 1½ to 2 (38.1 to 50.8), incl	over 0.049 to 0.083	over 1.24 to 2.11	0.011	0.28
Over 1½ to 2 (38.1 to 50.8), incl	over 0.083 to 0.149	over 2.11 to 3.78	0.012	0.30
Over 2 to 2½ (50.8 to 63.5), incl	0.032 to 0.065	0.81 to 1.65	0.012	0.30
Over 2 to 2½ (50.8 to 63.5), incl	over 0.065 to 0.109	over 1.65 to 2.77	0.013	0.33
Over 2 to 2½ (50.8 to 63.5), incl	over 0.109 to 0.165	over 2.77 to 4.19	0.014	0.36
Over 2½ to 3½ (63.5 to 88.9), incl	0.032 to 0.165	0.81 to 4.19	0.014	0.36
Over 2½ to 3½ (63.5 to 88.9), incl	over 0.165	over 4.19	0.020	0.51
Over 3½ to 5 (88.9 to 127.0), incl	0.035 to 0.165	0.89 to 4.19	0.020	0.51
Over 3½ to 5 (88.9 to 127.0), incl	over 0.165	over 4.19	0.025	0.64
Over 5 to 16 (127.0 to 406.4), incl	all	[B]	0.00125 in./in. or mm/mm of circumference	

[A] Wall tolerance ±10 % of nominal wall thickness.

TABLE 3 Diameter, Wall,[A] and Ovality Tolerances for Tubing with Bead Removed

NOTE 1—Ovality is the difference between maximum and minimum outside diameters measured at any one cross section. There is no additional tolerance for ovality on tubes having a nominal wall thickness of more than 3 % of the outside diameter.

NOTE 2—An ovality allowance of twice the outside diameter tolerance, shown in this table, is applied one half plus and one half minus to the outside diameter, for tubes having a nominal wall thickness of 3 % or less of the outside diameter. The average of the maximum and minimum outside diameter readings should fall within the outside diameter tolerances of this table.

NOTE 3—Tubing may be specified to only two of the three following dimensions—outside diameter, inside diameter, or wall.

OD Size, in. (mm)	OD, ±		ID, ±	
	in.	mm	in.	mm
Up to 3/32 (2.4), excl	0.001	0.03	0.001	0.03
3/32 to 3/16 (2.4 to 4.8), excl	0.0015	0.038	0.0015	0.038
3/16 to 1/2 (4.8 to 12.7), excl	0.003	0.08	0.005	0.13
1/2 to 1 (12.7 to 25.4), excl	0.004	0.10	0.006	0.15
1 to 1 1/2 (25.4 to 38.1), excl	0.005	0.13	0.007	0.18
1 1/2 to 2 (38.1 to 50.8), excl	0.006	0.15	0.008	0.20
2 to 2 1/2 (50.8 to 63.5), excl	0.007	0.18	0.010	0.25
2 1/2 to 3 1/2 (63.5 to 88.9), excl	0.010	0.25	0.014	0.36
3 1/2 to 5 (88.9 to 127.0), incl	0.015	0.38	0.020	0.51
Over 5 to 16 (127.0 to 406.4), incl	0.00125 in./in. or mm/mm of circumference		0.0013 in./in. or mm/mm of circumference	

[A] Wall tolerance is ±10 % of nominal wall thickness.

TABLE 4 Length Variations—Cut Length Tubes

Length, ft (m)	Outside Diameter, in. (mm)	Permissible Variations in Length, in.		
		Over[A]		Under
		in.	mm	
4 (1.2) and under	up to 2 (50.8), incl	1/16	1.6	0
	over 2 to 4 (50.8 to 101.6), incl	3/32	2.4	0
	over 4 (101.6)	1/8	3.2	0
Over 4 to 10 (1.2 to 3.0), incl	up to 2 (50.8), incl	3/32	2.4	0
	over 2 (50.8)	1/8	3.2	0
Over 10 to 24 (3.0 to 7.3), incl	all sizes	3/16	4.8	0

[A] For all diameters in lengths over 24 ft (7.3 m), an additional over tolerance of 1/8 in. (3.2 mm) for each 10 ft (3.0 m) or fraction thereof shall be permissible, up to a tolerance of 1/2 in. (12.7 mm), max.

determined from a product analysis made by the tubular product manufacturer, shall conform to requirements specified. When requested in the order or contract, a report of this analysis shall be furnished to the purchaser.

8. Permissible Variations in Dimensions—Round Tubing

8.1 For all conditions except tubing with bead removed, Table 2 shall apply.

8.2 For tubing with bead removed, Table 3 shall apply.

8.3 *Lengths*—Tubing is normally furnished in mill lengths 5 ft (1.5 m) and over. Definite cut lengths are furnished when specified, to the length tolerances shown in Table 4. For tubing ordered in multiple lengths, it is common practice to allow a definite amount over for each multiple for the purchaser's cutting operation. Thus cutting allowance should be specified in the purchase order.

TABLE 5 Square and Rectangular Tubing

Outside Dimension Tolerances		
Largest Nominal Outside Dimension Across Flats, in. (mm)	Wall Thickness,[A] in (mm)	±, in. (mm), a Flats, Conve or Concavi incl
To 1 1/4 (31.8), incl	all	0.015 (0.3
Over 1 1/4 to 2 1/2 (31.8 to 63.5), incl	all	0.020 (0.5
Over 2 1/2 to 5 1/2 (63.5 to 139.7), incl	all	0.030 (0.7

Maximum Radii of Corners	
Wall Thickness, in. (mm)	Radii of Cor max., in. (m
Over 0.020 to 0.049 (0.51 to 1.24), incl	3/32 (2.4
Over 0.049 to 0.065 (1.24 to 1.65), incl	1/8 (3.2
Over 0.065 to 0.083 (1.65 to 2.11), incl	5/64 (3.9
Over 0.083 to 0.095 (2.11 to 2.42), incl	3/16 (4.8
Over 0.095 to 0.109 (2.42 to 2.77), incl	13/64 (5.2
Over 0.109 to 0.134 (2.77 to 3.40), incl	7/32 (5.6
Over 0.134 to 0.156 (3.40 to 3.96), incl	1/4 (6.4

Twist Tolerances	
Largest Size, in. (mm)	Twist in 3 max, in (mm/m
Under 1/2 (12.7)	0.050 (1
1/2 to 1 1/2 (12.7 to 38.1), incl	0.075 (2.
Over 1 1/2 to 2 1/2 (38.1 to 63.5), incl	0.095 (2
Over 2 1/2 (63.5)	0.125 (3

Squareness of Sides
$\pm B = C \times 0.006$

where:
B = tolerance for out-of-square, and
C = length of longest side.

The straightness tolerance is 0.075 in. in 3 ft or 2.1 mm in 1 m using (1-m) straightedge and feeler gage.

[A] Wall tolerance is ±10 % of nominal wall thickness.

8.4 *Straightness Tolerance*—The straightness tole shall be 0.030 in. (0.76 mm) maximum in any 3-ft (0. length of tubing. The straightness tolerance on sh lengths and on special requirements shall be agreed between the purchaser and producer.

9. Permissible Variations in Dimensions—Square and anguiar Tubing

9.1 Square and rectangular welded stainless mecha tubing is supplied as cold worked unless otherwise spec For this tubing, variations in dimensions from those s fied shall not exceed the amounts prescribed in Table 5 lengths, see 8.3.

10. Workmanship, Finish, and Appearance

10.1 Finished tubes shall have smooth ends free of b They shall be free of injurious defects and shall ha workmanlike finish. Surface imperfections such as han marks, straightening marks, light mandrel and die m shallow pits, and scale patterns will not be consider serious defects, provided the imperfections are remo within 10 % of the nominal wall or 0.002 in. (whichever is greater. The removal of surface impe not required, unless special finishes are specified.

11. Surface Finish

11.1 Tubes shall be free of scale

11.2 If special finishes are required, they shall be stated in the order.

11.3 When polishing is required for tubing other than round, polishing is generally performed prior to shaping.

12. Rejection

12.1 Tubing that fails to meet the requirements of this specification shall be set aside and the manufacturer notified.

13. Coating

13.1 Stainless steel tubing is commonly shipped without protective coating. If special protection is needed, details shall be specified in the order.

14. Product Marking

14.1 *Civilian Procurement*—Each box, bundle or lift, and piece (when individual pieces are shipped) shall be identified by a tag or stencil with the manufacturer's name or brand, specified size, purchaser's order number, this specification number, and grade.

14.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for Military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

15. Packaging

15.1 *Civilian Procurement*—On tubing of 0.065-in. (1.65-mm) wall and lighter, the manufacturer will, at his option, box, crate, carton, package in secure lifts or bundles to ensure safe delivery. Tubing heavier than 0.065-in. wall will normally be shipped loose, bundled, or in secured lifts. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified in the order.

15.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order and the necessary tests made at the mill. Mechanical tests shall be performed in accordance with the applicable sections of Methods and Definitions A 370.

S1. Hardness Test

S1.1 Round annealed tubes shall conform to the requirements as to the hardness limits prescribed in Table 6.

NOTE—There are tubing diameters, walls, or combinations which limit the applicability of particular hardness values.

S1.2 When specified, the hardness test shall be performed on a specimen from one tube from each 2500 ft (760 m) or fraction thereof from each heat of steel.

S2. Tension Test

S2.1 The tubes shall conform to the requirements as to tensile properties prescribed in Table 7. When cold-reduced tempers are ordered, the manufacturer shall be consulted.

S2.2 When the tension test is specified, one test shall be performed on a specimen from one tube of each lot of 2500 ft (760 m) or fraction thereof from each heat of steel, prior to cutting to length.

S2.3 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5 % of the gage length under load shall be determined.

TABLE 6 Hardness Requirements (Round Annealed Condition)

Grade	Hardness	
	Brinell, max	Rockwell B, max
All austenitic	192	90
MT 429 and MT 430	190	90
MT-430-Ti	190	90

S3. Nondestructive Test

S3.1 Various types of nondestructive test are available. When any such test is required, the test to be used and the inspection limits shall be specified in the order.

S4. Test Reports

S4.1 Mill test reports will be furnished when specified in the order.

S4.2 When specified on the purchase order, or when a specific type of melting has been specified, the type of melting used to produce the material shall be included with the test report.

S5. Certification for Government Orders

S5.1 A producer's or supplier's certification shall be

TABLE 7 Tensile Requirements (Round Annealed Condition)

Grade	Tensile Strength, min		Yield Strength, min		Elongation[A] in 2 in. or 50 mm, min, %
	ksi	MPa	ksi	MPa	
MT 429 and MT 430	60	414	35	241	20
MT-430-Ti	60	414	30	207	20
MT 304 L & MT 316 L	70	483	25	172	35
All other austenitic steels	75	517	30	207	35

[A] For longitudinal strip tests, the width of the gage section shall be 1 in. (25.4 mm) and a deduction of 1.75 percentage points for austenitic grades and 1.0 percentage points for MT 429 and MT 430 shall be permitted from the basic minimum elongation for each $\frac{1}{32}$-in. (0.79-mm) decrease in wall thickness below $\frac{5}{16}$ in. (7.94 mm).

(b) (4)

5

Designation: A 564/A 564M – 92a

Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless and Heat-Resisting Steel Bars and Shapes[1]

This standard is issued under the fixed designation A 564/A 564M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers bars, and shapes of age-hardening stainless and heat-resisting steels. Hot-finished or cold-finished rounds, squares, hexagons, bar shapes, angles, tees, and channels are included; these shapes may be produced by hot rolling, extruding, or forging. Billets or bars for reforging may be purchased to this specification.

1.2 These steels are generally used for parts requiring corrosion resistance and high strength at room temperature, or at temperatures up to 600°F [315°C]; 700°F [370°C] for Type 632. They are suitable for machining in the solution-annealed condition after which they may be age-hardened to the mechanical properties specified in Section 7 without danger of cracking or distortion. Type XM-25 is machinable in the as-received fully heat treated condition.

1.3 Types 631 and 632 contain a large amount of ferrite in the microstructure and can have low ductility in forgings and larger diameter bars. Applications should be limited to small diameter bar.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies an "M" designation, the material shall be furnished to inch-pound units.

NOTE 1—For forgings, see Specification A 705/A 705M.
NOTE 2—For billets and bars for forging see Specification A 314.

2. Referenced Documents

2.1 *ASTM Standards:*

A 314 Specification for Stainless and Heat-Resisting Steel Billets and Bars for Forging[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings[3]

A 705/A 705M Specification for Age-Hardening, Stainless and Heat-Resisting Steel Forgings[3]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[4]

E 527 Practice for Numbering Metals and Alloys (UNS)[5]

2.2 *Other Documents:*

SAEJ1086 Recommended Practice for Numbering Metals and Alloys (UNS)[6]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Type or UNS designation (Table 1),

3.1.3 Heat treated condition (5.1),

3.1.4 Transverse properties when required (7.6),

3.1.5 Finish (Specification A 484/A 484M),

3.1.6 Surface preparation of shapes (5.2),

3.1.7 Size, or applicable dimension including diameter, thickness, width, length, etc.,

3.1.8 Preparation for delivery (Specification A 484/A 484M),

3.1.9 Special requirements (refer to 7.4 and 8.3),

3.1.10 Marking requirements (Specification A 484/A 484M), and

3.1.11 ASTM designation and date of issue if other than that currently published.

3.2 If possible, the intended use of the item should be given on the purchase order especially when the item is ordered for a specific end use or uses.

NOTE 3—A typical ordering description is as follows: 5000 lb [2270 kg] Type 630, Solution-Annealed Cold Finished Centerless Ground, 1½ in. [38.0 mm] round bar, 10 to 12 ft [3.0 to 3.6 m] in length, ASTM A 564 dated ___ End use: valve shafts.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specifications A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 564/A 564M constitutes nonconformance with this specification.

5. Manufacture

5.1 *Heat Treatment:*

5.1.1 Material of types other than XM-16, XM-25, and

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.08 on Wrought Stainless Steel Products.

Current edition approved Oct. 15, 1992. Published December 1992. Originally published as A 564 – 66. Last previous edition A 564/A 564M – 92.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-564 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

[4] *Annual Book of ASTM Standards*, Vol 01.03, 01.05.

[5] *Annual Book of ASTM Standards*, Vols 01.01 and 01.05.

[6] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

Type 630 shall be furnished in the solution-annealed condition, or in the equalized and oven-tempered condition, as noted in Table 2, unless otherwise specified by the purchaser.

5.1.1.1 Types 630, XM-16, and XM-25 may be furnished in the solution-annealed or age-hardened condition.

5.1.2 Reforging stock shall be supplied in a condition of heat treatment to be selected by the forging manufacturer.

5.2 Shapes may be subjected to either Class A or Class C preparation as specified on the purchase order.

5.2.1 Class A consists of preparation by grinding for the removal of imperfections of a hazardous nature such as fins, tears, and jagged edges provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10 % of the thickness of the section.

5.2.2 Class C consists of preparation by grinding for the removal of all visible surface imperfections provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10 % of the thickness of the section.

6. Chemical Composition

6.1 Each alloy covered by this specification shall conform to the chemical requirements specified in Table 1.

6.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties Requirements

7.1 The material, as represented by mechanical test specimens, shall conform to the mechanical property requirements specified in Table 2 and shall be capable of developing the properties in Table 3 when heat treated as specified in Section 5.1.

7.2 Samples cut from bars for forging stock shall conform to the mechanical properties of Tables 2 and 3 when heat treated as specified in Tables 2 and 3.

7.3 The yield strength shall be determined by the offset method as described in the current edition of Test Methods and Definitions A 370. The limiting permanent offset shall be 0.2 % of the gage length of the specimen.

7.4 The impact requirement shall apply only when specified in the purchase order. When specified, the material, as represented by impact test specimens, shall be capable of developing the impact property requirements specified in Table 3 when heat treated in accordance with Section 5.1.

7.5 Longitudinal impact requirements are not applicable to bars less than ⅝ in. (16.9 mm) diameter or size or flats less than ⅝ in. (16.9 mm) thick.

7.6 Tensile and impact requirements in the transverse (through thickness) direction are not applicable to bars less than 3 in. [75 mm] diameter in size or flats less than 3 in. [75 mm] thick.

7.7 Material tensile tested and, when specified, impact tested in the transverse (through thickness) direction and meeting the requirements shown in Table 3 need not be tested in the longitudinal direction.

8. Number of Tests

8.1 At least one room temperature tension test and one or more hardness tests shall be made on each lot.

8.2 One or more hardness tests and at least one tension test shall be made from each lot on test samples heat treated as required in Section 5.1. Unless otherwise specified in the purchase order, the condition of hardening heat treatment shall be at the option of the producer. The tests shall meet the requirements of Table 3.

8.3 When specified in the purchase order, the impact test shall consist of testing three Charpy V-notch Type A specimens in accordance with Methods and Definitions A 370. The specimens shall be heat treated in accordance with Section 5.1. Unless otherwise specified in the purchase order, the condition of hardening heat treatment shall be at the option of the producer and testing shall be done at 70 to 80°F [20 to 25°C]. The tests shall meet the requirements of Table 3. When tested at temperatures other than 70 to 80°F [20 to 25°C] the impact test requirements will be as agreed upon by purchaser and producer.

TABLE 1 Chemical Requirements[A]

UNS Designation[G]	Type	Composition, %										
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Aluminum	Molybdenum	Titanium	Copper	Other Elements
S17400	630	0.07	1.00	0.040	0.030	1.00	15.00–17.50	3.00–5.00	...	...	...	3.00–5.00	[B]
S17700	631	0.09	1.00	0.040	0.030	1.00	16.00–18.00	6.50–7.75	0.75–1.50	...	...	...	...
S15700	632	0.09	1.00	0.040	0.030	1.00	14.00–16.00	6.50–7.75	0.75–1.50	2.00–3.00	...	...	...
S35500	634	0.10–0.15	0.50–1.25	0.040	0.030	0.50	15.00–16.00	4.00–5.00	...	2.50–3.25	...	...	[C]
S17600	635	0.08	1.00	0.040	0.030	1.00	16.00–17.50	6.00–7.50	0.40	...	0.40–1.20	...	...
S15500	XM-12	0.07	1.00	0.040	0.030	1.00	14.00–15.50	3.50–5.50	...	...	...	2.50–4.50	[B]
S13800	XM-13	0.05	0.20	0.010	0.008	0.10	12.25–13.25	7.50–8.50	0.90–1.35	2.00–2.50	...	...	[D]
S45500	XM-16	0.03	0.50	0.015	0.015	0.50	11.00–12.50	7.50–9.50	...	0.50	0.90–1.40	1.50–2.50	[E]
S45503	...	0.010	0.50	0.010	0.010	0.20	11.00–12.50	7.50–9.50	...	0.50	1.00–1.35	1.50–2.50	[E]
S45000	XM-25	0.05	1.00	0.030	0.030	1.00	14.00–16.00	5.00–7.00	...	0.50–1.00	...	1.25–1.75	[F]

[A] Limits are in percent maximum unless shown as a range or stated otherwise.
[B] Columbium plus tantalum 0.15–0.45.
[C] Nitrogen 0.07–0.13.
[D] Nitrogen 0.01.
[E] Columbium plus tantalum 0.10–0.50.
[F] Columbium 8 times carbon minimum.
[G] New designation established in accordance with Practice E 527 and SAEJ1086.

TABLE 2 Solution Treatment

UNS Designation	Type	Condition	Solution Treatment	Mechanical Test Requirements in Solution Treated Condition[A]							
				Tensile Strength, min		Yield Strength, min[B]		Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min %	Hardness[C]	
				ksi	[MPa]	ksi	[MPa]			Rockwell C, max	Brinell, max
S17400	630	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F (32°C))	...	...	...	...	...	...	38	363
S17700	631	A	1900 ± 25°F [1040 ± 15°C] (water quench)	...	...	...	...	...	...	Rb98	229
S15700	632	A	1900 ± 25°F [1040 ± 15°C] (water quench)	...	...	...	...	...	...	Rb100	269[D]
S35500	634[E]	A	1900 ± 25°F [1040 ± 15°C] quench, hold not less than 3 h at minus 100°F or lower	...	...	...	...	...	...	...	363[E]
S17600	635	A	1900 ± 25°F [1040 ± 15°C] (air cool)	120	[825]	75	[515]	10	45	32	302
S15500	XM-12	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F (32°C))	...	...	...	...	...	...	38	363
S13800	XM-13	A	1700 ± 25°F [925 ± 15°C] Cool as required to below 60°F [16°C]	...	...	...	...	...	...	38	363
S45500	XM-16	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	...	...	...	...	...	...	36	331
S45000	XM-25	A	1900 ± 25°F [1040 ± 15°C] (cool rapidly)	130[F]	[895]	95	[655]	10	40	32	321
S45503	...	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	...	...	...	...	...	...	36	331

[A] See 7.1.
[B] See 7.2.
[C] Either Rockwell C hardness or Brinell is permissible. On sizes ½ in. (12.70 mm) and smaller, Rockwell C is preferred.
[D] 321 BH for rounds cold drawn after solution treating.
[E] Equalization and over-tempering treatment 1425 ± 50°F [775 ± 30°C] for not less than 3 h, cool to room temperature, heat to 1075 ± 25°F [580 ± 15°C] for not less than 3 h.
[F] 130 – 165 ksi [895 – 1140 MPa] for sizes up to ½ in. (13 mm).

TABLE 3 Mechanical Test Requirements After Age Hardening Heat Treatment[A]

Type	Condition	Suggested Hardening or Aging Treatment, or both[M,N,P] Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min ksi	Tensile Strength, min [MPa]	Yield Strength, min[B] ksi	Yield Strength, min [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of area, min, %	Hardness[G] Rockwell C, min	Hardness[G] Brinell, min	Impact Charpy-V, min ft-lbf	Impact Charpy-V, min J
630	H900	900 [480]	1.0	air cool	Up to 3 in. incl [75 mm] (L)	190	[1310]	170	[1170]	10	40	40	388		
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (L)						35				
	H925	925 [495]	4.0	air cool	Up to 3 in. incl [75 mm] (L)	170	[1170]	155	[1070]	10	44	38	375	5	6.8
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (L)						38				
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
	H1075	1075 [580]	4.0	air cool		145	[1000]	125	[860]	13	45	32	311	20	27
	H1100	1100 [595]	4.0	air cool		140	[965]	115	[795]	14	45	31	302	25	34
	H1150	1150 [620]	4.0	air cool		135	[930]	105	[725]	16	50	28	277	30	41
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool				115	[795]	75	[515]	18	55	24	255	55	75
631	RH950	1750°F [955°C] for not less than 10 min, but not more than 1 h, cool rapidly to room temperature. Cool within 24 h to minus 100 ± 10°F [75°C], hold not less than 8 h. Warm in air to room temperature. Heat to 950°F [510°C], hold 1 h, air cool.			Up to 4 in. incl [100 mm] (L)	185	[1275]	150	[1035]	6	10	41	388	...	...
	TH1050	Alternative treatment: 1400°F [760°C] hold 90 min, cool to 55 ± 5°F [15 ± 3°C] within 1 h. Hold not less than 30 min, heat to 1050°F [565°C] hold for 90 min, air cool.			Up to 6 in. incl [150 mm] (L)	170	[1170]	140	[965]	6	25	38	352	...	...
632	RH950	Same as Type 631			Up to 4 in. incl [100 mm] (L)	200	[1380]	175	[1210]	7	25	...	415	...	...
	TH1050				Up to 6 in. incl [150 mm] (L)	180	[1240]	160	[1100]	8	25	...	375	...	...
634[C]	H1000	1750 [955] for not less than 10 min, but not more than 1 h. Water quench. Cool to not higher than minus 100°F [75°C]. Hold for not less than 3 h. Temper at 1000°F [540°C], holding for not less than 3 h.				170	[1170]	155	[1070]	12	25	37	341	...	...
635	H950	950 [510]	0.5	air cool		190	[1310]	170	[1170]	8	25	39	363	...	...
	H1000	1000 [540]	0.5	air cool		180	[1240]	160	[1100]	8	30	37	352	...	...
	H1050	1050 [565]	0.5	air cool		170	[1170]	150	[1030]	10	40	35	331	...	...
XM-12	H900	900 [480]	1.0	air cool	Up to 12 in. incl [300 mm][O] (L)	190	[1310]	170	[1170]	10	35	40	388	...	...
					Up to 12 in. incl [300 mm][O] (T)					6	15				
	H925	925 [495]	4.0	air cool	Up to 12 in. incl [300 mm][O] (L)	170	[1170]	155	[1070]	10	38	38	375	5	6.8
					Up to 12 in. incl [300 mm][O] (T)					-	20				

TABLE 3 *Continued*

Type	Condition	Suggested Hardening or Aging Treatment, or both[M,N,P] Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min ksi	Tensile Strength, min [MPa]	Yield Strength, min[B] ksi	Yield Strength, min [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of area, min, %	Hardness[G] Rockwell C, min	Hardness[G] Brinell, min	Impact Charpy-V, min ft·lbf	Impact Charpy-V, min J
XM12	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm][O] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
					Up to 12 in. incl [300 mm][O] (T)					8	27			10	14
	H1075	1075 [580]	4.0	air cool	Up to 12 in. incl [300 mm][O] (L)	145	[1000]	125	[860]	13	45	32	311	20	27
					Up to 12 in. incl [300 mm][O] (T)					9	28			15	20
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm][O] (L)	140	[965]	115	[795]	14	45	31	302	25	34
					Up to 12 in. incl [300 mm][O] (T)					10	29			15	20
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm][O] (L)	135	[930]	105	[725]	16	50	28	277	30	41
					Up to 12 in. incl [300 mm][O] (T)					11	30			20	27
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm][O] (L)	115	[795]	75	[515]	18	55	24	255	55	75
					Up to 12 in. incl [300 mm][O] (T)					14	35			35	47
XM-13	H950	950 [510]	4.0	air cool	Up to 12 in. incl [300 mm][O] (L)	220	[1520]	205	[1410]	10	45	45	430	...	...
					Up to 12 in. incl [300 mm][O] (T)						35				
	H1000	1000 [540]	4.0	air cool	Up to 12 in. incl [300 mm][O] (L)	205	[1410]	190	[1310]	10	50	43	400	...	...
					Up to 12 in. incl [300 mm][O] (T)					10	40				
	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	185	[1275]	175	[1210]	11	50	41	380	...	...
					Up to 12 in. incl [300 mm] (T)						45				
	H1050	1050 [565]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	175	[1210]	165	[1140]	12	50	40	372	...	...
					Up to 12 in. incl [300 mm] (T)						45				
	H1100	1100 [540]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	150	[1030]	135	[930]	14	50	34	313	...	...
					Up to 12 in. incl [300 mm] (T)						50				
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	135	[930]	90	[620]	14	50	30	283	...	...
					Up to 12 in. incl [300 mm] (T)						50				
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm] (L)	125	[860]	85	[585]	16	55	26	259	...	...
					Up to 12 in. incl [300 mm] (T)						55				
XM-16[K]	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	235	[1620]	220	[1520]	8	30	47	444	...	...
	H950	950 [510]	4.0	air cool		220	[1520]	205	[1410]	10	40	44	415	...	...
	H1000	1000 [540]	4.0	air cool		205	[1410]	185	[1280]	10	40	40	363	...	...

TABLE 3 *Continued*

Type	Condition	Suggested Hardening or Aging Treatment, or both[M,N,P] Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min ksi	Tensile Strength, min [MPa]	Yield Strength, min[G] ksi	Yield Strength, min [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of area, min, %	Hardness[G] Rockwell C, min	Hardness[G] Brinell, min	Impact Charpy-V, min ft-lbf
S45503[K]	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	235	[1620]	220	[1515]	8	30	47	444	
					Up to 6 in. incl [150 mm][K] (T)					4	15			
	H950	950 [510]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	220	[1520]	205	[1415]	10	40	44	415	... ...
					Up to 6 in. incl [150 mm][K] (T)					5	20			
	H1000	1000 [540]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	205	[1410]	185	[1280]	10	40	40	363	... ...
					Up to 6 in. incl [150 mm][K] (T)					6	25			
XM-25[K]	H900	900 [480]	4.0	air cool	Up to 8 in. incl [200 mm] (L)	180	[1240]	170	[1170]	10	40	39	363	... ...
					Up to 12 in. incl 300 mm[K] (L)					10	40			
					Up to 12 in. incl [300 mm][K] (T)					6	20			
	H950	950 [510]	4.0	air cool	Up to 8 in. incl [200 mm][O] (L)	170	[1170]	160	[1100]	10	40	37	341	
					Up to 12 in. incl [300 mm][K] (L)					10	40			
					Up to 12 in. incl [300 mm][K] (T)					7	22			
	H1000	1000 [540]	4.0	air cool	Up to 8 in. incl [200 mm][O] (L)	160	[1100]	150	[1030]	12	45	36	331	... ...
					Up to 12 in. incl [300 mm][K] (L)					12	45			
					Up to 12 in. incl [300 mm][K] (T)					8	27			
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm][O] (L)	150	[1030]	140	[965]	12	45	34	321	... ...
	H1050	1050 [565]	4.0	air cool	Up to 8 in. incl [200 mm][O] (L)	145	[1000]	135	[930]	12	45	34	321	
					Up to 12 in. incl [300 mm][K] (L)					12	45			
					Up to 12 in. incl [300 mm][K] (T)					9	30			
	H1100	1100 [595]	4.0	air cool	Up to 8 in. incl [200 mm][O] (L)	130	[895]	105	[725]	16	50	30	285	... ...
					Up to 12 in. incl [300 mm][K] (L)					16	50			
					Up to 12 in. incl [300 mm][K] (T)					11	30			
	H1150	1150 [610]	4.0	air cool	Up to 8 in. incl [200 mm][O] (L)	125	[860]	75	[520]	15	50	26	262	... ...
					Up to 12 in. incl [300 mm][K] (L)					18	55			
					Up to 12 in. incl [300 mm][K] (T)					12	35			

[A] See 7.1.
[B] See 7.2.
[C] Refer to Table 2 for details on equalize and over temper heat treatment.
[D] Applies to consumable electrode vacuum remelted.
[F] (L) - Longitudinal axis of specimen parallel to direction of grain flow during rolling or forging. (T) - Transverse axis of specimen perpendicular to direction of grain flow during rolling or forging.
[G] Either Rockwell C or Brinell is permissible. On sizes ½ in. [12.70 mm] and smaller, Rockwell C is preferred.
[H] Only tensile strength applicable to sizes up to ½ in. (13 mm).
[K] Consumable electrode remelted only.
[M] Time refers to minimum time material is at temperature and may be extended to obtain required ductility properties.
[N] Unless otherwise noted, temperatures shown are suggested temperatures and may be varied to obtain required tensile properties.
[P] Intermediate temperatures must meet the ductility requirements of the next highest suggested hardening or aging temperature, or both. Example: Type 630 at 1050°F [565°C] must have 13 % elongation and 45 % reduction, same as for age hardening at 1075°F [580°C].
[Q] Air melt.

6

Designation: B 211 – 92a

Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire[1]

This standard is issued under the fixed designation B 211; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the exact year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification[2] covers rolled or cold-finished bar, rod, and wire in alloys (Note 1) and tempers as shown in Table 2.

NOTE 1—Throughout this specification use of the term *alloy* in the general sense includes aluminum as well as aluminum alloy.

NOTE 2—The term *cold finished* is used to indicate the type of surface finish, sharpness of angles, and dimensional tolerances produced by drawing through a die.

NOTE 3—See Specification B 221 for aluminum and aluminum-alloy extruded bars, rods, wire, shapes, and tubes; and Specification B 316 for aluminum and aluminum-alloy rivet and cold-heading wire and rods.

1.2 Alloy and temper designations are in accordance with ANSI H35.1. The equivalent UNS alloy designations are those of Table 1 preceded by A9, for example, A91100 for aluminum 1100 in accordance with Practice E 527.

1.3 A complete metric companion to Specification B 211 has been developed—B 211M; therefore, no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 557 Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products[3]

B 594 Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products for Aerospace Applications[3]

B 597 Practice for Heat Treatment of Aluminum Alloys[3]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[3]

B 666 Practice for Identification Marking of Aluminum Products[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Alloys[5]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[3,5]

E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[6]

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[7]

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere[6]

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis[3,6]

E 1004 Test Method for Electromagnetic (Eddy-Current) Measurements of Electrical Conductivity[8]

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon Atmosphere, Point-to-Plane, Unipolar Self Initiating Capacitor Discharge[6]

G 47 Test Method for Determining Susceptibility to Stress-Corrosion Cracking of High-Strength Aluminum-Alloy Products[3]

2.1.2 *ANSI Standards:*

H35.1 Alloy and Temper Designation Systems for Aluminum[3]

H35.2 Dimensional Tolerances for Aluminum Mill Products[3]

2.1.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[9]

2.1.4 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[9]

2.1.5 *Military Specification:*

MIL-H-6088 Heat Treatment of Aluminum Alloys[9]

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[1] This specification is under the jurisdiction of ASTM Committee B-7 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum-Alloy Wrought Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-211 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 02.02.

[4] *Annual Book of ASTM Standards*, Vols 02.03 and 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 03.06.

[7] *Annual Book of ASTM Standards*, Vols 01.01 through 01.05 inclusive and 02.01 through 02.05, inclusive.

[8] *Annual Book of ASTM Standards*, Vol 03.03.

[9] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

*** A Summary of Changes section appears at the end of this specification.**

3. Terminology

3.1 *Definitions:*

3.1.1 *bar*—a solid product that is long in relation to cross section which is square or rectangular (excluding plate and flattened wire) with sharp or rounded corners or edges, or is a regular hexagon or octagon, and in which at least one perpendicular distance between parallel faces is 0.375 in. or greater.

3.1.2 *cold-finished bar*—bar brought to final dimensions by cold working to obtain improved surface finish and dimensional tolerances.

3.1.3 *rod*—a solid product 0.375 in. or greater in diameter that is long in relation to cross section.

3.1.4 *cold-finished rod*—rod brought to final dimensions by cold working to obtain improved surface finish and dimensional tolerances.

3.1.5 *wire*—a solid section long in relation to its cross-sectional dimensions, having a cross section that is round, hexagonal, or octagonal and whose diameter, width, or greatest distance between parallel faces is less than 0.375 in., or having a symmetrical cross section that is square or rectangular (excluding flattened wire) with sharp or rounded corners or edges.

3.1.6 *drawn wire*—wire brought to final dimensions by drawing through a die.

3.1.7 *alclad wire*—wire having on its surface a metallurgically bonded aluminum or aluminum-alloy coating that is anodic to the core alloy to which it is bonded, thus electrolytically protecting the core alloy against corrosion.

3.1.8 *flattened wire*—a solid section having two parallel flat surfaces and rounded edges produced by roll-flattening round wire.

3.1.9 *flattened and slit wire*—flattened wire which has been slit to obtain square edges.

3.1.10 *producer*—the primary manufacturer of the material.

3.1.11 *supplier*—includes only the category of jobbers and distributors as distinct from producers.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of*—The term *capable of* as used in this specification means that the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 This specification number,

4.1.2 Quantity in pieces or pounds,

4.1.3 Alloy (Section 7),

4.1.4 Temper (Section 9),

4.1.5 Diameter for rounds; distance across flats for square-cornered squares, hexagons, or octagons; width and depth for square-cornered rectangles (orders for squares, hexagons, octagons, or rectangles with rounded corners usually require a drawing),

4.1.6 Length,

4.1.7 Whether heat treatment in accordance with Practice B 597 is required (8.2),

4.1.8 Whether 7075-O material is required to develop requirements for T73 temper (see 10.1.2),

4.1.9 When specified finish of bar and rod is not required (Section 15),

4.1.10 Whether marking for identification is required (Section 16),

4.1.11 Whether ultrasonic inspection is required (Section 17, Table 4),

4.1.12 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (Section 19),

4.1.13 Whether certification is required (Section 21), and

4.1.14 Whether Practices B 660 apply, and if so, the levels of preservation, packaging, and packing required (Section 22).

5. Manufacture

5.1 The products covered by this specification shall be produced either by hot extruding and cold finishing or by hot rolling with or without cold finishing, at the option of the producer.

6. Quality Assurance

6.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser in the order or at the time of contract signing. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

6.2 *Lot Definition*—An inspection lot shall be defined as follows:

6.2.1 For heat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and nominal dimensions traceable to a heat-treat lot or lots, and subjected to inspection at one time.

6.2.2 For nonheat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and nominal dimensions subjected to inspection at one time.

7. Chemical Composition

7.1 *Limits*—The bars, rods, and wire shall conform to the chemical composition limits specified in Table 1. Conformance shall be determined by the producer by analyzing samples taken at the time the ingots are poured, or samples taken from the finished or semifinished product. If the producer has determined the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product.

NOTE 4—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

7.2 *Number of Samples*—The number of samples taken

TABLE 1 Chemical Composition Limits [A,B,C]

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Bismuth	Lead	Titanium	Other Elements [D]		Aluminum
											Each	Total [E]	
1060	0.25	0.35	0.05	0.03	0.03	...	0.05	...	...	0.03	0.03 [J]	...	99.60 min [F]
1100	0.95 Si + Fe		0.05–0.20	0.05	...	...	0.10	...	...	...	0.05	0.15	99.00 min [F]
2011	0.40	0.7	5.0–6.0	...	...	...	0.30	0.20–0.6	0.20–0.6	...	0.05	0.15	remainder
2014	0.50–1.2	0.7	3.9–5.0	0.40–1.2	0.20–0.8	0.10	0.25	...	...	0.15	0.05	0.15	remainder
2017	0.20–0.8	0.7	3.5–4.5	0.40–1.0	0.40–0.8	0.10	0.25	...	...	0.15	0.05	0.15	remainder
2024	0.50	0.50	3.8–4.9	0.30–0.9	1.2–1.8	0.10	0.25	...	...	0.15	0.05	0.15	remainder
2219	0.20	0.30	5.8–6.8	0.20–0.40	0.02	...	0.10	...	...	0.02–0.10	0.05 [G]	0.15 [G]	remainder
3003	0.6	0.7	0.05–0.20	1.0–1.5	...	...	0.10	...	...	...	0.05	0.15	remainder
5052	0.25	0.40	0.10	0.10	2.2–2.8	0.15–0.35	0.10	...	...	...	0.05	0.15	remainder
5056	0.30	0.40	0.10	0.05–0.20	4.5–5.6	0.05–0.20	0.10	...	...	...	0.05	0.15	remainder
Alclad 5056	5056 alloy clad with 6253 alloy				...	...	...	...	...	...	...	...	...
5154	0.25	0.40	0.10	0.10	3.1–3.9	0.15–0.35	0.20	...	...	0.20	0.05	0.15	remainder
6061	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.35	0.25	...	...	0.15	0.05	0.15	remainder
6110	0.7–1.5	0.8	0.20–0.7	0.20–0.7	0.50–1.1	0.04–0.25	0.30	...	...	0.15	0.05	0.15	remainder
6253 cladding [H]	[I]	0.50	0.10	...	1.0–1.5	0.04–0.35	1.6–2.4	...	...	...	0.05	0.15	remainder
6262	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.14	0.25	0.40–0.7	0.40–0.7	0.15	0.05	0.15	remainder
7075	0.40	0.50	1.2–2.0	0.30	2.1–2.9	0.18–0.28	5.1–6.1	...	...	0.20	0.05	0.15	remainder

[A] Limits are in weight percent maximum unless otherwise shown.

[B] Analysis shall be made for the elements for which limits are shown in this table.

[C] For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with the rounding-off method of Practice E 29.

[D] *Others* includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered non-conforming.

[E] *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.

[F] The aluminum content shall be calculated by subtracting from 100.00 % the sum of all the metallic elements present in amounts of 0.010 % or more each, rounded to the second decimal before determining the sum.

[G] Vanadium 0.05–0.15 % zirconium 0.10–0.25 %. The total for other elements does not include vanadium and zirconium.

[H] Composition of cladding alloy as applied during the course of manufacture. Samples from finished wire shall not be required to conform to these limits.

[I] 45 to 65 % of magnesium content.

[J] Vanadium 0.05 %, max.

for determination of chemical composition shall be as follows:

7.2.1 When samples are taken at the time the ingots are poured, at least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal.

7.2.2 When samples are taken from the finished or semifinished product, a sample shall be taken to represent each 4000 lb, or fraction thereof, in the lot, except that no more than one sample shall be required per piece.

7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, clipping, etc., a representative piece or pieces to obtain a weight of prepared sample not less than 75 g. Sampling shall be in accordance with Practice E 55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E 716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

NOTE 5—It is difficult to obtain a reliable analysis of each of the components of clad materials using material in its finished state. A reasonably accurate determination of the core composition can be made if the cladding is substantially removed prior to analysis. The cladding composition is more difficult to determine because of the relatively thin layer and because of diffusion of core elements to the cladding. The correctness of cladding alloy used can usually be verified by a combination of metallographic examination and spectrochemical analysis of the surface at several widely separated points.

7.4 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34), or spectrochemical (Test Methods E 101, E 227, E 607, and E 1251), methods. Other methods may be used only when no published ASTM method is available. In case of dispute, the methods of analysis shall be agreed upon between the purchaser and the producer.

8. Heat Treatment

8.1 Unless otherwise specified in 8.2, producer or supplier heat treatment for the applicable tempers in Table 2 shall be in accordance with MIL-H-6088.

8.2 When specified, heat treatment of applicable tempers in Table 2 shall be in accordance with Practice B 597.

9. Tensile Properties of Material As Supplied

9.1 *Limits*—The bars, rods, and wire shall conform to the tensile requirements specified in Table 2.

9.2 *Number of Specimens:*

9.2.1 For material having a nominal weight of less than 1 lb/linear ft, one tension test specimen shall be taken for each 1000 lb or fraction thereof in the lot. Only one specimen shall be taken from any one piece when more than one piece is available.

9.2.2 For material having a nominal weight of 1 lb or more/linear ft, one tension test specimen shall be taken for each 1000 ft or fraction thereof in the lot. Only one specimen shall be taken from any one piece when more than one piece is available.

9.3 *Test Specimens*—Geometry of test specimens and the location in the product from which they are taken shall be as specified in Methods B 557.

9.4 *Test Methods*—The tension tests shall be made in

TABLE 2 Tensile Property Limits [A]

Temper	Specified Diameter or Thickness, in.	Tensile Strength, ksi		Yield Strength [B] (0.2 % offset), min, ksi	Elongation [B] in 2 in. or 4 × Diameter, min, %
		min	max		
		Aluminum 1060			
O	0.124 and under	8.0	...	...	...
	0.125 and over	8.0	...	2.5	25
H14	0.374 and under	12.0	...	10.0	...
H18	0.374 and under	16.0	...	13.0	...
		Aluminum 1100			
O	0.124 and under	11.0	15.5	...	...
	0.125 and over	11.0	15.5	3.0	25
H12	0.374 and under	14.0	...	...	...
H14	0.374 and under	16.0	...	...	...
H16	0.374 and under	19.0	...	...	...
H18	0.374 and under	22.0	...	...	...
H112	all	11.0	...	3.0	...
F	all	[C]	...	[C]	...
		Alloy 2011			
T3	0.125–1.500	45.0	...	38.0	10
	1.501–2.000	43.0	...	34.0	12
	2.001–3.250	42.0	...	30.0	12
T4 and T451 [D]	0.125–8.000	40.0	...	18.0	16
T8	0.125–3.250	54.0	...	40.0	10
		Alloy 2014 [K]			
O	0.124 and under	...	35.0	...	...
	0.125–8.000	...	35.0	...	12
T4, T42 [E], and T451 [D]	0.124 and under	55.0	...	...	...
	0.125–8.000 [F]	55.0	...	32.0	16
T6, T62 [E], and T651 [D]	0.124 and under	65.0	...	...	...
	0.125–8.000 [F]	65.0	...	55.0	8
		Alloy 2017 [K]			
O	0.124 and under	...	35.0	...	...
	0.125–8.000	...	35.0	...	16
T4, T42 [E], and T451 [D]	0.124 and under	55.0	...	...	...
	0.125–8.000 [F]	55.0	...	32.0	12
		Alloy 2024 [K]			
O	0.124 and under	...	35.0	...	...
	0.125–8.000	...	35.0	...	16
T36	0.124 and under	69.0	...	...	...
	0.125–0.375	69.0	...	52.0	10
T4 [G]	0.124 and under	62.0	...	...	...
	0.125–0.499	62.0	...	45.0 [G]	10
	0.500–4.500	62.0	...	42.0	10
	4.501–6.500 [J]	62.0	...	40.0	10
	6.501–8.000	58.0	...	38.0	10
T42 [E]	0.124 and under	62.0	...	...	...
	0.125–6.500 [J]	62.0	...	40.0	10
T351 [D]	0.500–6.500 [J]	62.0	...	45.0	10
T6	0.124 and under	62.0	...	...	...
	0.125–6.500 [J]	62.0	...	50.0	5
T62 [E]	0.124 and under	60.0	...	...	...
	0.125–6.500 [J]	60.0	...	46.0	5
T851 [D]	0.500–6.500 [J]	66.0	...	58.0	5
		Alloy 2219			
T851 [D]	0.500–2.000	58.0	...	40.0	4
	2.001–4.000	57.0	...	39.0	4

TABLE 2 *Continued*

Temper	Specified Diameter or Thickness, in.	Tensile Strength, ksi		Yield Strength[B] (0.2 % offset), min, ksi	Elongation[B] in 2 in. or 4 × Diameter, min, %
		min	max		
		Alloy 3003			
O	all	14.0	19.0	5.0	25
H12	0.374 and under	17.0	...	...	...
H14	0.374 and under	20.0	...	...	...
H16	0.374 and under	24.0	...	...	...
H18	0.374 and under	27.0	...	...	...
H112	all	14.0	...	5.0	...
F	all	[C]	...	[C]	...
		Alloy 5052			
O	0.124 and under	...	32.0	...	...
	0.125 and over	25.0	32.0	9.5	25
H32	0.124 and under	31.0	...	...	...
	0.125–0.374	31.0	...	23.0	...
H34	0.374 and under	34.0	...	26.0	...
H36	0.124 and under	37.0	...	...	...
	0.125–0.374	37.0	...	29.0	...
H38	0.374 and under	39.0	...	...	...
F	all	[C]		[C]	...
		Alloy 5056			
O	0.124 and under	...	46.0	...	...
	0.125 and over	...	46.0	...	20
H111	0.374 and under	44.0	...	...	...
H12	0.374 and under	46.0	...	...	...
H32	0.374 and under	44.0	...	...	...
H14	0.374 and under	52.0	...	...	...
H34	0.374 and under	50.0	...	...	...
H18	0.374 and under	58.0	...	...	...
H38	0.374 and under	55.0	...	...	...
H192	0.374 and under	60.0	...	...	...
H392	0.374 and under	58.0	...	...	...
		Alclad Alloy 5056			
H192	0.374 and under	52.0	...	...	...
H392	0.374 and under	50.0	...	...	...
H393	0.120–0.192	54.0	...	47.0	...
		Alloy 5154			
O	all	30.0	41.0	11.0	25
H32	0.374 and under	36.0	...	...	...
H34	0.374 and under	39.0	...	...	...
H36	0.374 and under	42.0	...	...	...
H38	0.374 and under	45.0	...	...	...
H112	all	30.0	...	11.0	...
		Alloy 6061[K]			
O	0.124 and under	...	22.0	...	...
	0.125–8.000	...	22.0	...	18
T4 and T451[D]	0.124 and under	30.0	...	...	...
	0.125–8.000[H]	30.0	...	16.0	18
T42[E]	0.125–8.000[H]	30.0	...	14.0	18
T6, T62[E], and T651[D]	0.124 and under	42.0	...	...	...
	0.125–8.000[H]	42.0	...	35.0	10
T89 and T94	0.374 and under	54.0	...	47.0	...
		Alloy 6110			
T9	0.374 and under	65.0	...	63.0	2
		Alloy 6262			
T6 and T651[D]	0.125–8.000[F]	42.0	...	35.0	10
T9	0.125–2.000	52.0	...	48.0	5
	2.001–3.000	50.0	...	46.0	5

TABLE 2 *Continued*

Temper	Specified Diameter or Thickness, in.	Tensile Strength, ksi		Yield Strength[B] (0.2 % offset), min, ksi	Elongation[B] in 2 in. or 4 × Diameter, min, %
		min	max		
		Alloy 7075[K]			
O	0.124 and under	...	40.0	...	...
	0.125–8.000	...	40.0	...	10
T6, T62[E], and T651[D]	0.124 and under	77.0	...	...	...
	0.125–4.000[I]	77.0	...	66.0	7
T73 and T7351[D]	0.124 and under	68.0	...	...	...
	0.125–3.000	68.0	...	56.0	10

[A] To determine conformance to this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5 %, both in accordance with the rounding-off method of Practice E 29. The basis for establishment of tensile property limits is shown in Annex A1.

[B] The measurement of yield strength and elongation is not required for wire less than 0.125 in. in thickness or diameter.

[C] There are no tensile requirements for material in the F temper but it usually can be expected that material 1½ in. or less in thickness or diameter (except sections over 4 in. in width) will have a strength about equivalent to the H14 or H34 temper. As size increases the strength decreases to nearly that of the O temper.

[D] For stress-relieved tempers, characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic tempers.

[E] Material in the T42 or T62 tempers is not available from the materials producers.

[F] For rounds, maximum diameter is 8.000 in.; for square, rectangular, hexagonal, or octagonal bar, maximum thickness is 4 in. and 36 in.^{2} maximum cross-sectional area.

[G] Minimum yield strength of coiled 2024-T4 wire and rod 0.125 in. and larger in thickness or diameter is 40.0 ksi.

[H] For bar, maximum cross-sectional area is 50 in.^{2}.

[I] For rounds, maximum diameter is 4 in.; for square, hexagonal, or octagonal bar, maximum thickness is 3½ in.; for rectangular bar, maximum thickness is 3 in. with corresponding maximum width of 6 in.; for rectangular bar less than 3 in. in thickness, maximum width is 10 in.

[J] Properties listed for this size increment are applicable to rod with a maximum diameter of 6.500 in. and to square, rectangular, hexagonal or octagonal bar having a maximum thickness of 4 in. and maximum cross-sectional area of 36 in.^{2}.

[K] Also available in the F temper for which no properties are specified and no tension tests are performed but for which tests are performed for confirmation of heat-treat response as required by Section 10.

accordance with Methods B 557.

10. Producer Confirmation of Heat-Treat Response

10.1 In addition to the requirements of 9.1, material in Alloys 2014, 2017, 2024, and 6061 produced in the O or F temper (within the size limits specified in Table 2) shall, after proper solution heat treatment and natural aging for not less than 4 days at room temperature, conform to the properties specified in Table 2 for T42 temper material. The heat-treated samples may be tested prior to four days natural aging, but if they fail to conform to the T42 temper properties, the tests may be repeated after completion of four days natural aging without prejudice.

10.1.1 Alloy 7075 material produced in the O or F temper (within the size limits specified in Table 2) shall, after proper solution heat treatment and precipitation heat treatment, conform to the properties specified in Table 2 for T62 temper material.

10.1.2 When specified, 7075-O material (within the size limits specified in Table 2) shall, after proper solution and precipitation heat treatment, conform to the properties specified for T73 temper in Table 2 and Section 12.

10.2 *Number of Specimens*—The number of specimens from each lot of O temper material and F temper material to verify conformance with 10.1 shall be as specified in 9.2.

11. Heat Treatment and Reheat Treatment Capability

11.1 As-received material in the O or F temper and in Alloys 2014, 2017, 2024, and 6061 (within the size limitation specified in Table 2 and without the imposition of cold work) shall, after proper solution heat treatment and natural aging for not less than 4 days at room temperature, conform to the properties specified in Table 2 for T42 temper material.

11.2 As-received Alloy 7075 material in the O or F temper (within the size limitation specified in Table 2 and without the imposition of cold work) shall, after proper solution and precipitation heat treatment, conform to the properties specified in Table 2 for T6 and T62 tempers.

11.3 Material in Alloys and Tempers 2014-T4, T451, T6, T651; 2017-T4, T451; 2024-T4, T6, T351, and T851, shall, after proper resolution heat treatment and natural aging for not less than 4 days at room temperature, conform to the properties specified in Table 2 for the T42 temper.

NOTE 6—Beginning with the 1975 revision 6061-T4, T6, T451, and T651, were deleted from this paragraph because experience has shown the reheat-treated material tends to develop large recrystallized grains and may fail to develop the expected level of properties.

11.4 Alloy 7075 material in T6, T651, T73, and T7351 tempers shall, after proper resolution heat treatment and precipitation heat treatment, conform to the properties specified in Table 2 for T6 and T62 tempers.

11.5 Material in T3, T4, T42, T351, and T451 tempers shall, after proper precipitation heat treatment, conform to the properties specified in Table 2 for the T8, T6, T62, T851 and T651 tempers, respectively.

12. Stress-Corrosion Resistance of 7075-T73 and T7351

12.1 Alloy 7075-T73 and T7351 material shall be capable of exhibiting no evidence of stress-corrosion cracking when subjected to the test specified in 12.2.

12.1.1 For lot-acceptance purposes, resistance to stress-corrosion cracking for each lot of material shall be established by testing the previously selected tension-test samples to the criteria shown in Table 3.

12.1.2 For surveillance purposes, each month the producer shall perform at least one test for stress-corrosion resistance in accordance with 12.2 in the T73 type temper, for each thickness range listed in Table 2, produced that

TABLE 3 Lot Acceptance Criteria for Resistance to Stress Corrosion

Alloy and Temper	Lot Acceptance Criteria: Electrical Conductivity[A], % IACS	Lot Acceptance Criteria: Level of Mechanical Properties	Lot Acceptance Status
7075-T73 and T7351	40.0 or greater	per specified requirements	acceptable
	38.0 through 39.9	per specified requirements and yield strength does not exceed minimum by more than 11.9 ksi	acceptable
	38.0 through 39.9	per specified requirements but yield strength exceeds minimum by 12.0 ksi or more	unacceptable[B]
	less than 38.0	any level	unacceptable[B]

[A] The electrical conductivity shall be determined in accordance with Test Method E 1004 in the following locations:

Product	Thickness, in.	Location
Rolled or cold finished from rolled stock	all	surface of tension-test sample
Cold finished from extruded stock	up through 0.100	surface of tension-test sample
	over 0.100 through 0.500	subsurface after removing approximately 10 % of the thickness by machining
	over 0.500 through 1.500	subsurface at approximate center of thickness on a plane parallel to the longitudinal centerline of the material
	over 1.500	subsurface of tension-test sample surface that is closest to the center of the material and on a plane parallel to the extrusion surface

[B] When material is found to be unacceptable, it shall be reprocessed (additional precipitation heat treatment or re-solution heat treatment, stress relieving and precipitation heat treatment, when applicable).

month. Each sample shall be taken from material considered acceptable in accordance with lot-acceptance criteria of Table 3. A minimum of three adjacent replicate specimens shall be taken from each sample and tested. The producer shall maintain records of all lots so tested and make them available for examination at the producer's facility.

12.2 The stress-corrosion cracking test shall be performed on material 0.750 in. and over in thickness as follows:

12.2.1 Specimens shall be stressed in tension in the short transverse direction with respect to grain flow and held at constant strain. The stress level shall be 75 % of the specified longitudinal yield strength.

12.2.2 The stress-corrosion test shall be made in accordance with Test Method G 47.

12.2.3 There shall be no visual evidence of stress-corrosion cracking in any specimen, except that the retest provisions of 20.2 shall apply.

13. Cladding Thickness

13.1 The aluminum-alloy coating of Alclad 5056 wire shall have a minimum average thickness corresponding to 16 % of the total cross-sectional area of the wire.

13.2 When the area of the coating is to be determined on finished wire, transverse cross sections of at least three wires from the lot shall be mounted to expose a transverse cross section and polished for examination with a metallurgical microscope. Using at least 100× magnification, the coating area in each sample shall be measured by use of a planimeter on the projected image, and the average of the measurements shall be taken as the area.

14. Dimensional Tolerances

14.1 Variations from specified dimensions for the material ordered shall not exceed the permissible variations specified in the following tables of ANSI H35.2.

Table No.	Title
9.1	Diameter, Round Wire and Rod
9.5	Thickness and Width, Rectangular Wire and Bar
9.6	Distance Across Flats, Square, Hexagonal and Octagonal Wire and Bar
9.7	Thickness and Width, Flattened Wire (Round Edge)
9.8	Thickness and Width, Flattened and Slit Wire
9.9	Length, Specific and Multiple
9.10	Twist, Bar in Straight Lengths
9.11	Straightness, Rod and Bar in Straight Lengths Other than Screw Machine Stock
9.13	Flatness (Flat Surfaces)
9.14	Angularity
9.15	Squareness of Saw Cuts

14.2 *Sampling for Inspection*—Examination for dimensional conformance shall be made to ensure conformance to the tolerance specified.

15. Finish

15.1 Unless otherwise specified, rod up to and including 3 in. in diameter and bar up to and including 2 in. thick (with maximum width for rectangles of 4 in.) shall be supplied cold finished. Rod and bar in larger sizes may be furnished either as rolled or cold finished, at the producer's or supplier's discretion.

16. Identification Marking of Product

16.1 When specified in the contract or purchase order all material shall be marked in accordance with Practice B 666. In addition, 2000 and 7000 series alloys furnished in the T6, T651, T73, T7351 or T851 tempers shall also be marked with the lot number in at least one location on each piece.

17. Internal Quality

17.1 When specified by the purchaser at the time of placing the order, each bar 0.500 in. or greater in thickness or smallest dimension in Alloys 2014, 2024, 2219, and 7075 shall be tested in accordance with Method B 594 to the discontinuity acceptance limits of Table 4.

18. General Quality

18.1 Unless otherwise specified, the material shall be supplied in the mill finish and shall be uniform as defined by the requirements of this specification and shall be commercially sound. Any requirement not so covered is subject to

TABLE 4 Ultrasonic Discontinuity Limits for Rolled or Cold-Finished Bar [A]

Alloys	Size			
	Thickness, in.	Maximum Weight per Piece, lb	Maximum Width to Thickness Ratio	Discontinuity Class [B]
2014, 2219, 2024, 7075	0.500–1.499	600	...	B
	1.500–3.000	600	...	A
	3.001–6.000	1000	...	B

[A] Discontinuities in excess of those listed in this table shall be allowed if it is established that they will be removed by machining or that they are in noncritical areas.

[B] The discontinuity class limits are defined in Section 11 of Method B 594.

negotiation between the producer and the purchaser.

18.2 Each bar, rod, and wire shall be examined to determine conformance to this specification with respect to general quality and identification marking. On approval of the purchaser, however, the producer may use a system of statistical quality control for such examinations.

19. Source Inspection

19.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the material prior to shipment, such agreement shall be made by the purchaser and producer as part of the purchase contract.

19.2 When such inspection or witness of inspection and testing is agreed upon, the producer shall afford the purchaser's representative all reasonable facilities to satisfy him that the material meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

20. Rejection and Retest

20.1 If any material fails to conform to all of the applicable requirements of this specification, it shall be cause for rejection of the inspection lot.

20.2 When there is evidence that a failed specimen was not representative of the inspection lot and when no other sampling plan is provided or approved by the purchaser through the contract or purchase order, at least two additional specimens shall be selected to replace each test specimen that failed. All specimens so selected for re-test shall meet the requirements of the specification or the lot shall be subject to rejection.

20.3 Material in which defects are discovered subsequent to inspection may be rejected.

20.4 If material is rejected by the purchaser, the producer or supplier is responsible only for replacement of the material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier.

21. Certification

21.1 The producer or supplier shall, on request, furnish to the purchaser a certificate of inspection stating that each lot has been sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements.

22. Packaging and Package Marking

22.1 The material shall be packaged to provide adequate protection during normal handling and transportation and each package shall contain only one size, alloy, and temper of material unless otherwise agreed. The type of packing and gross weight of containers shall, unless otherwise agreed upon, be at the producer's discretion, provided that they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

22.2 Each shipping container shall be marked with the purchase order number, material size, specification number, alloy and temper, gross and net weight, and the producer's name and trademark.

22.3 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to "Statistical Aspects of Mechanical Property Assurance" in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1. The Aluminum Association[10] holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1. A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5)	
Over 0.55 %	0.X, X.X, etc.
(except that combined Si+Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

[10] The Aluminum Association, 900 19th Street, NW, Washington, DC 20006.

SUMMARY OF CHANGES

This section identifies the principle changes to this standard that have been incorporated since the last issue.

(*1*) The elongation value of 2011-T3 in the 2.001–3.250 in. range has been revised.

(*2*) Paragraph 7.4 was clarified.

Designation: D 5205 – 91

An American National Standard

Standard Classification System for Polyetherimide (PEI) Materials[1]

This standard is issued under the fixed designation D 5205; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This classification system covers unfilled, filled, and reinforced polyetherimide materials suitable for injection molding and extrusion.

1.2 This classification system is not intended for the selection of materials, but only as a means to call out plastic materials to be used for the manufacture of parts. The selection of these materials is to be made by personnel with expertise in the plastics field where the environment, inherent properties of the materials, performance of the parts, part design, manufacturing process, and economics are considered.

1.3 The properties included in this classification system are those required to identify the compositions covered. There may be other requirements necessary to identify particular characteristics important to specific applications. These may be specified by using suffixes as described in Section 5.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 The following precautionary caveat pertains only to the test method portion, Section 12, of this classification system: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Note 4.

2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials[2]

D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials[2]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 638 Test Method for Tensile Properties of Plastics[3]

D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load[3]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[3]

D 792 Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement[3]

D 883 Terminology Relating to Plastics[3]

D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 1897 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials[3]

D 2584 Test Method for Ignition Loss of Cured Reinforced Resins[4]

D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)[4]

D 3418 Test Method for Transition Temperatures of Polymers by Thermal Analysis[4]

D 3892 Practice for Packaging/Packing of Plastics[4]

D 4000 Classification System for Specifying Plastic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance to Specifications[5]

E 662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials[6]

2.2 *Underwriters Laboratories Standards:*

UL 94 Tests for Flammability of Plastic Materials for Parts in Devices and Appliances[7]

3. Terminology

3.1 *Definitions:*

3.1.1 The terminology used in this classification system is in accordance with Terminology D 883 and Terminology D 1600.

3.2 *Abbreviation:*

3.2.1 The polyetherimide materials will be designated "PEI" as specified in Terminology D 1600.

4. Classification

4.1 Unfilled polyetherimide materials are classified into groups according to their composition. These groups are subdivided into classes and grades as shown in Table PEI.

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[1] This classification system is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials.

Current edition approved Nov. 15, 1991. Published January 1992.

[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 04.07.

[7] Available from Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60066.

NOTE 1—An example of this classification system is given below. The designation PEI 0114 indicates the following:

PEI=polyetherimide as found in Terminology D 1600,
01=polyetherimide (group),
1=general purpose (class), and
4=requirements given in Table PEI (grade).

4.1.1 To facilitate incorporation of future or special materials the "other" category (0) for group, class, and grade is shown in Table PEI. The basic properties of these materials can be obtained from Tables A or B as they apply.

4.2 Reinforced, pigmented, filled, and lubricated versions of polyetherimide materials are classified in accordance with Tables PEI and A or B. Table PEI is used to specify the unreinforced material and Table A or B is used to specify the property requirements after the addition of reinforcements, pigments, fillers, or lubricants at the nominal level indicated (see 4.2.1).

4.2.1 A single letter shall be used to indicate the major category of the reinforcement, along with two numbers that indicate the percentage of additive(s) by mass, with the tolerances as tabulated below:

Category	Material	Tolerance (Based on the Total Mass)
C	Carbon and graphite fiber-reinforced	± 2 percentage points
G	Glass-reinforced	
	< 15 % glass content	± 2 percentage points
	> 15 % glass content	± 3 percentage points
L	Lubricants (such as PTFE, graphite, silicone, and molybdenum disulfide)	Variable. To be specified by user.
M	Mineral-reinforced	± 2 percentage points
R	Reinforced-combination/mixtures of reinforcements or other fillers/reinforcements	± 3 percentage pints based on the total reinforcement

NOTE 2—If necessary, additional requirements may be specified using suffixes as described in Section 5. Special agreements on tolerances may be required when levels are below 5 %. Ash content of filled or reinforced materials may be determined using Test Method D 2584 where applicable.

4.2.2 Specific requirements for reinforced, filled, or lubricated polyetherimide materials shall be shown by a six-character designation. The designation will consist of the letter "A" or "B" and the five digits comprising the cell numbers for the property requirements in the order as they appear in Tables PEI or A.

4.2.2.1 Although the values listed are necessary to include the range of properties available in existing materials, users should not infer that every possible combination of the properties exists or can be obtained.

4.2.3 When the grade of the basic materials is not shown, or is not important, the use of "O"-grade classification shall be used for reinforced materials in this system.

NOTE 3—An example of this classification for a polyetherimide material is given below. The designation PEI0110G10A48266 would indicate the following material requirements:

PEI 0110 = general-purpose polyetherimide from Table PEI,
G10 = glass reinforced at nominal 10 % level,
A = Table A property requirements,
4 = 110 MPa tensile strength, minimum,
8 = 13790 MPa flexural modulus, minimum,
2 = 4 g/10 min; melt flow, minimum,
6 = 205 MPa flexural strength, minimum, and
6 = 230°C deflection temperature, minimum.

If no properties are specified, the designation would be PEI0110G10A00000.

5. Suffixes

5.1 When requirements not covered by the basic cell tables need to be specified suffixes shall be used. The following suffixes shall be used when appropriate. Additional suffixes may also be defined according to Classification System D 4000 when needed.

5.1.1 *E* = Electrical requirements as designated by the following digits:

First Digit

0 = specimen to be specified by user.
1 = specimens as appropriate for test methods as defined in Table 1.

Second Digit

0 = to be specified by user.
1 = meets requirements of Table 1, Column A
2 = meets requirements of Table 1, Column B
3 = meets requirements of Table 1, Column C
4 = meets requirements of Table 1, Column D
5 = meets requirements of Table 1, Column E

5.1.2 *F* = Flammability requirements as designated by the following digits:

NOTE 4: **Precaution**—By publication of this specification and its of flammability ratings, ASTM does not intend that their use in any reflects hazards presented under actual fire conditions.

First Digit

0 = to be specified by user,
1 = product is tested according to UL94 at 3.05 mm minimum thickness,
2 = product is tested according to UL94 at 1.47 mm minimum thickness,
3 = product is tested according to UL94 at 0.71 mm minimum thickness,
4 = product is tested according to Test Method D 2863,
5 = product is tested according to Test Method E 662.

Second Digit

0 = To be specified by user
1 = 94V-0 flammability class
2 = 94V-1 flammability class
3 = 94V-2 flammability class
4 = 94-5V flammability class
5 = Oxygen index 44 % minimum
6 = Specific optical density, flaming mode, D4 ≤ 2, D max ≤ 50

6. General Requirements

6.1 The plastic compositions shall be uniform and shall conform to the requirements specified herein.

TABLE PEI Polyetherimide Materials Detail Requirements

NOTE—The values listed were developed for "natural colors." Pigments or other additives, or both, may alter these properties.

Group	Description	Class	Description[A]	Grade	Description	Flow-Rate[B] Test Method D 1238, g/10 min	Specific Gravity Test Methods D 792	Deflection[C] Temperature (DTUL) min Test Method D 648, C min	Tensile[D] Strength Test Method D 638, MPa min	Flexural[E] Strength Test Methods D 790, MPa min	Flexural[E] Modulus Test Methods D 790, MPa min
01	Polyether-imide	1	General-Purpose	1		< 2	1.25–1.30	194	103	152	3030
				2		2–8	1.25–1.30	194	103	152	3030
				3		6–12	1.25–1.30	194	103	152	3030
				4		10–16	1.25–1.30	194	103	152	3030
				5		15–22	1.25–1.30	194	103	152	3030
				6		20–30	1.25–1.30	192	90	138	2900
				7		> 30	1.25–1.30	190	83	138	2900
				0	Other	...	...	...	...	...	...
		2	Impact-Modified	1		< 2	1.22–1.28	180	83	117	2410
				2		2–8	1.22–1.28	180	83	117	2410
				3		6–12	1.22–1.28	180	83	117	2410
				4		10–16	1.22–1.28	180	83	117	2410
				5		15–22	1.22–1.28	180	83	117	2410
				6		20–30	1.22–1.28	180	69	103	2280
				7		> 30	1.22–1.28	180	69	103	2280
				0	Other	...	...	...	...	...	...
		0	Other	0	Other	...	...	...	...	...	...
02	PEI Chemical Resistant	1	General-Purpose	1		< 2	1.25–1.30	198	93	128	2760
				2		2–8	1.25–1.30	198	93	128	2760
				3		6–12	1.25–1.30	198	93	128	2760
				4		10–16	1.25–1.30	198	93	128	2760
				5		15–22	1.25–1.30	198	93	128	2760
				6		20–30	1.25–1.30	196	90	124	2760
				7		> 30	1.25–1.30	196	90	124	2760
				0	Other	...	...	...	...	...	...
		2	Impact-Modified	1		< 2	1.22–1.28	184	69	90	2070
				2		2–8	1.22–1.28	184	69	90	2070
				3		6–12	1.22–1.28	184	69	90	2070
				4		10–16	1.22–1.28	184	69	90	2070
				5		15–22	1.22–1.28	184	69	90	2070
				6		20–30	1.22–1.28	184	69	90	2070
				7		> 30	1.22–1.28	184	69	90	2070
				0	Other	...	...	...	...	...	...
		3	High-Heat Resistant	1		< 2	1.27–1.32	215	97	145	2760
				2		2–8	1.27–1.32	215	97	145	2760
				3		6–12	1.27–1.32	215	97	145	2760
				4		10–16	1.27–1.32	215	97	145	2760
				5		15–22	1.27–1.32	215	97	145	2760
				6		20–30	1.27–1.32	215	97	145	2760
				7		> 30	1.27–1.32	215	97	145	2760
				0	Other	...	...	...	...	...	...
		4	High Heat Impact-Modified	1		< 2	1.23–1.30	200	69	103	2070
				2		2–8	1.23–1.30	200	69	103	2070
				3		6–12	1.23–1.30	200	69	103	2070
				4		10–16	1.23–1.30	200	69	103	2070
				5		15–22	1.23–1.30	200	69	103	2070
				6		20–30	1.23–1.30	200	69	103	2070
				7		> 30	1.23–1.30	200	69	103	2070
		0	Other	0	Other	...	...	...	...	...	...
03	PEI Heat-Resistant	1	General-Purpose	1		< 2	1.27–1.31	210	103	145	2760
				2		2–8	1.27–1.31	210	103	145	2760
				3		6–12	1.27–1.31	210	103	145	2760
				4		10–16	1.27–1.31	210	103	145	2760
				5		15–22	1.27–1.31	210	103	145	2760
				6		20–30	1.27–1.31	210	90	131	2760
				7		> 30	1.27–1.31	210	90	131	2760
				0	Other	...	...	...	...	...	...
		2	Impact-Modified	1		< 2	1.22–1.28	196	69	110	2070
				2		2–8	1.22–1.28	196	69	110	2070
				3		6–12	1.22–1.28	196	69	110	2070
				4		10–16	1.22–1.28	196	69	110	2070
				5		15–22	1.22–1.28	196	69	110	2070
				6		20–30	1.22–1.28	196	69	110	2070
				7		> 30	1.22–1.28	196	69	110	2070
				0	Other	...	...	...	...	...	...
		3	High Heat	1		< 2	1.28–1.32	225	103	138	2760
				2		2–8	1.28–1.32	225	103	138	2760
				3		6–12	1.28–1.32	225	103	138	2760
				4		10–16	1.28–1.32	225	103	138	2760

TABLE PEI *Continued*

Group	Description	Class	Description[A]	Grade	Description	Flow-Rate[B] Test Method D 1238, g/10 min	Specific Gravity Test Methods D 792	Deflection[C] Temperature (DTUL) min Test Method D 648, C min	Tensile[D] Strength Test Method D 638, MPa min	Flexural[E] Strength Test Methods D 790, MPa min	Flexural[E] Modulus Test Methods D 790, MPa min
				5		15–22	1.28–1.32	225	103	138	2760
				6		20–30	1.28–1.32	225	103	138	2760
				7		> 30	1.28–1.32	225	103	138	2760
				0	Other	...	...	...	...	...	...
		4	High-Heat Impact-Modified	1		< 2	1.24–1.28	210	69	97	2070
				2		2–8	1.24–1.28	210	69	97	2070
				3		6–12	1.24–1.28	210	69	97	2070
				4		10–16	1.24–1.28	210	69	97	2070
				5		15–22	1.24–1.28	210	69	97	2070
				6		20–30	1.24–1.28	210	69	97	2070
				7		> 30	1.24–1.28	210	69	97	2070
				0	Other	...	...	...	...	...	...
		0	Other	0	Other	...	...	...	...	...	...
04	PEI—Flexible Resistant	1	General-Purpose	1		< 2	1.16–1.20	N/A[F]	34	52	690
				2		2–8	1.16–1.20	N/A	34	52	690
				3		6–12	1.16–1.20	N/A	34	52	690
				4		10–16	1.16–1.20	N/A	34	52	690
				5		15–22	1.16–1.20	N/A	34	52	690
				6		20–30	1.16–1.20	N/A	34	52	690
				7		> 30	1.16–1.20	N/A	34	52	690
				0	Other	...	...	...	...	...	...
		2	Semi-Rigid	1		< 2	1.16–1.20	N/A[F]	21	14	69
				2		2–8	1.16–1.20	N/A	21	14	69
				3		6–12	1.16–1.20	N/A	21	14	69
				4		10–16	1.16–1.20	N/A	21	14	69
				5		15–22	1.16–1.20	N/A	21	14	69
				6		20–30	1.16–1.20	N/A	21	14	69
				7		> 30	1.16–1.20	N/A	21	14	69
				0	Other	...	...	...	...	...	...
		3	Non-Rigid	1		< 2	1.10–1.20	N/A[F]	7	7	<69
				2		2–8	1.10–1.20	N/A	7	7	<69
				3		6–12	1.10–1.20	N/A	7	7	<69
				4		10–16	1.10–1.20	N/A	7	7	<69
				5		15–22	1.10–1.20	N/A	7	7	<69
				6		20–30	1.10–1.20	N/A	7	7	<69
				7		> 30	1.10–1.20	N/A	7	7	<69
				0	Other	...	...	...	...	...	...
		0	Other	0	Other	...	...	...	...	...	...

[A] No descriptions are listed unless needed to describe a special grade under the class. All other grades are listed by requirements.

[B] *Conditions*—Method A, 6.7 kg, 2.0955 mm inside diameter orifice:

Group-Class	Test Temperatures, °C
011, 012, 021, 022	343.3
023, 024, 031, 032, 033, 034	371
041, 042, 043	300

[C] Specimens 3.2 mm tested at 1.82 MPa.

[D] Type 1 bar, speed 5.1 mm/min.

[E] Method I, Procedure A, speed = 2.5 mm/min, span-to-depth ratio 16/1, (tangent modulus).

[F] "N/A" indicates the particular data so designated is considered "Not Applicable" to the product being considered.

7. Detail Requirements

7.1 The various materials shall conform to the requirements prescribed in the Tables and suffix requirements as they apply.

7.2 For the purpose of determining conformance, all specified limits for a specification (line callout) based on this classification system are absolute limits, as defined in Practice E 29.

7.2.1 With the absolute method, an observed value or a calculated value is not rounded, but is to be compared directly with the specified limiting value. Conformance or nonconformance is based on this comparison.

8. Sampling

8.1 Sampling shall be statistically adequate to satisfy requirements of 13.2. A "lot" of material shall be considered as a unit of manufacture as prepared for shipment, and may consist of a blend of two or more "production runs" or batches.

9. Number of Tests

9.1 The number of tests shall be consistent with the requirements of Section 8 and 13.2.

10. Specimen Preparation

10.1 Unless otherwise specified, test specimens shall be prepared by injection molding in accordance with Practice D 1897 employing the following conditions:

TABLE A Detail Requirements Filled or Reinforced PEI, or Both

NOTE—Resin samples should be dried 4 h at 160°C in an air-circulating oven before molding specimens to be used in these tests and before determining melt-flow rate.

Designation Order	Property/ASTM Test Method	Units	0	1	2	3	4	5	6	7	8	9
1	Tensile strength, min D 638,[A] Type I bar, 0.2 in/min.	MPa[B]	[C]	25	55	80	110	135	165	190	220	[D]
2	Flexural modulus, min, D 790[E]	MPa[B]	[C]	690	1720	3450	5170	6900	8620	10340	13790	[D]
3	Flow Rate, min, D 1238[F]	g/10 min	[C]	1	4	7	10	13	16	20	24	[D]
4	Flexural strength, min D 790[E]	MPa[B]	[C]	30	65	100	135	170	205	240	275	[D]
5	Deflection Temperature min, D 648[G]	°C	[C]	180	190	200	210	220	230	240	250	[D]

[A] Type I bar, speed = 5.1 mm/min.
[B] MPa × 145 = psi.
[C] Unspecified.
[D] Specific value (must be shown).
[E] Method 1, Procedure A; speed = 2.55 mm/min.
[F] *Conditions*—Method A, 6.7 kg, 2.0955 mm inside diameter orifice:

Group-Class	Test Temperatures, °C
011, 012, 021, 022	343.3
023, 024, 031, 032, 033, 034	371
041, 042, 043	300

[G] 3.2 mm thick specimen tested at 1.82 MPa.

TABLE B Detail Requirements Unreinforced/Unfilled PEI

NOTE—Resin samples should be dried 4 h at 160°C in an air-circulating oven before molding specimens to be used in these tests and before determining melt-flow rate.

Designation Order	Property/ASTM Test Method	Units	0	1	2	3	4	5	6	7	8	9
1	Tensile strength, min D 638[A]	MPa[B]	[C]	14	25	40	55	65	80	95	110	[D]
2	Flexural modulus, min, D 790[E]	MPa[B]	[C]	7	30	65	340	690	1380	2070	2760	[D]
3	Flow Rate, min, D 1238[F]	g/10 min	[C]	2	6	10	14	18	22	26	30	[D]
4	Flexural strength, min D 790[E]	MPa[B]	[C]	7	30	65	90	110	130	150	170	[D]
5	Deflecting Temperature, min, D 648[G]	°C	[C]	170	180	190	200	210	220	230	240	[D]

[A] Type I bar, speed = 5.1 mm/min.
[B] MPa × 145 = psi.
[C] Unspecified.
[D] Specific value (must be shown).
[E] Method 1, Procedure A; speed = 2.55 mm/min.
[F] *Conditions*—Method A, 6.7 kg, 2.0955 mm inside diameter orifice:

Group-Class	Test Temperatures, °C
011, 012, 021, 022	343.3
023, 024, 031, 032, 033, 034	371
041, 042, 043	300

[G] 3.2 mm thick specimen tested at 1.82 MPa.

TABLE 1 Detail Requirements

NOTE—Resin samples should be dried 4 h at 160°C in an air-circulating oven before molding specimens to be used in these tests.

Property	Condition[A]	Units	A	B	C	D	E
Dielectric constant,[B] max	48/50 + D24/23						
1 KHz, 50 % RH, 23°C		...	3.2	3.7	3.7	3.8	...
1 MHz		...	...	...	...	...	3.5
Dissipation factor,[B] max	48/50 + D24/23						
1 KHz, 50 % RH, 23°C		...	0.0015	0.0016	0.0017	0.0017	...
2450 MH, 50 % RH, 23°C		...	0.003	...	...	...	...
1 MH, 50 % RH, 23°C		...	...	...	...	...	0.007
Volume resistivity,[C] min	24/23/50	ohm-cm	10^{16}	10^{16}	10^{16}	10^{16}	...
Dielectric strength,[D] min (1.6 mm thickness, in oil, S/T)	48/50 + 96/23/50	KV/mm (V/mil)	23.6	23.0	22.0	21.0	17.0
Specific Gravity[E]	...	...	1.27	1.34	1.42	1.51	...

[A] In accordance with Method D 618.
[B] See Test Method D 150.
[C] See Test Method D 257.
[D] See Test Method D 149.
[E] See Test Method D 792 (tolerance ± 0.02).

	Minimum Mold Temperature, °C	Minimum Stock Temperature, °C
Unfilled and unreinforced	120	360
Filled or reinforced, or both	150	390

11. Conditioning

11.1 Condition test specimens at least 40 h at 23 ± 2°C and 50 ± 5 % relative humidity.

12. Test Methods

12.1 Determine the properties enumerated in this classification system using the referenced test methods.

13. Inspection and Certification

13.1 Inspection and certification of the material supplied with reference to a specification based on this classification system shall be for conformance to the requirements specified herein.

13.2 Lot acceptance inspection shall be the basis on which acceptance or rejection of the lot is made and shall consist of the test listed, as it applies, as follows: flow rate.

13.3 Periodic check inspection shall consist of the tests specified for all requirements of the material under this classification system. Inspection frequency shall be adequate to assure the material is certifiable in accordance with 13.4.

13.4 Certification shall be that the material was manufactured, sampled, tested, and inspected in accordance with this classification system and that the average values meet the requirements at the 95 % confidence level.

13.5 A report of the test results shall be furnished when requested. The report shall consist of results of the lot acceptance inspection for the shipment and the results of the most recent periodic check inspection.

14. Packing, Packaging, and Package Marking

14.1 Provisions of Practice D 3892 apply for packing, packaging, and marking of containers for plastic materials.

15. Keywords

15.1 classification; line-call-out; polyetherimide resins

APPENDIX

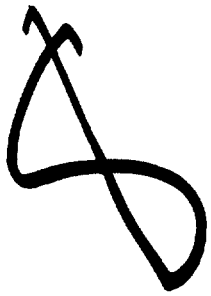
(Nonmandatory Information)

X1. CROSS REFERENCES

X1.1 The following cross references between government specifications and Classification System D 5205 are provided for information purposes only.

TABLE X1.1 Cross References Designations for Classification System D 5205 and Government Specifications

Government Specification	Classification System D 5205
MIL-P-46184	
Type I (unfilled)	PEI0113 E01F05F06
Type II Class 1 (glass reinforced)	PEI0110 G10 A49203 E02 ZU 434OMPa
Class 2 (glass reinforced)	PEI0110 G20 A99103 E03 ZU 5800MPa
Class 3 (glass reinforced)	PEI0110 G30 A99103 E04 ZK 159MPa ZU 7600MPa
MIL-M-24519B	
Type: GLT-10F (glass reinforced)	PEI0110 G10 A00290 E05 ZN 180MPa
GLT-20F (glass reinforced)	PEI0110 G20 A00190 E05 ZN 195MPa
GLT-30F (glass reinforced)	PEI0110 G30 A00190 E05 ZN 215MPa



Designation: D 4066 – 92a

An American National Standard

Standard Specification for Nylon Injection and Extrusion Materials (PA)[1]

This standard is issued under the fixed designation D 4066; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

INTRODUCTION

This specification is intended to be a means of calling out plastic materials used in the fabrication of end items or parts. It is not intended for the selection of materials. Material selection should be made by those having expertise in the plastics field after careful consideration of the design and the performance required of the part, the environment to which it will be exposed, the fabrication process to be employed, the inherent properties of the material other than those covered by this specification, and the economics.

1. Scope

1.1 This specification covers nylon materials suitable for injection molding and extrusion. Some of these compositions are also suitable for compression molding and application from solution.

1.2 The properties included in this specification are those required to identify the compositions covered. There may be other requirements necessary to identify particular characteristics important to specialized applications. These shall be agreed upon between the user and the supplier, by using the suffixes as given in Section 5.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 The following precautionary caveat pertains only to the test method portion, Section 11, of this specification. *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific hazards statement is given in 11.2.

2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials[2]

D 256 Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials[3]

D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials[2]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 638 Test Method for Tensile Properties of Plastics[3]

D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load[3]

D 789 Test Methods for Determination of Relative Viscosity, Melting Point, and Moisture Content of Polyamide (PA)[3]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[3]

D 792 Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement[3]

D 883 Terminology Relating to Plastics[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 1897 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials[3]

D 1898 Practice for Sampling of Plastics[3]

D 2584 Test Method for Ignition Loss of Cured Reinforced Resins[4]

D 3418 Test Method for Transition Temperatures of Polymers by Thermal Analysis[4]

D 3892 Practice for Packaging/Packing of Plastics[4]

D 4000 Classification System for Specifying Plastic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

2.2 *Military and Federal Specifications and Standards:*[6]

MIL-STD-105 Sampling Procedure and Tables for Inspection by Attributes

[1] This specification is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials (Section D20.15.09).

Current edition approved Dec. 15, 1992. Published February 1993. Originally published as D 4066 – 82. Last previous edition D 4066 – 92.

[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

L-P-410 Plastic, Polyamide (Nylon) Rigid: Rods, Tubes, Flats, Molded and Cast Parts
VV-I-530 Insulating Oil, Electrical (for Transformers, Switches, and Circuit Breakers)

2.3 *Underwriters Laboratories:*[7]
UL 94 Standards for Tests for Flammability for Parts in Devices and Appliances

2.4 *ISO Standard:*[8]
ISO 307 Determination of Viscosity Number of Polyamides in Dilute Solutions

3. Terminology

3.1 For definitions of technical terms pertaining to plastics used in this specification, see Terminology D 883.

4. Classification

4.1 Unreinforced nylon materials are classified into groups according to their chemical composition. These groups are subdivided into classes and grades as shown in the Basic Property Table (Table PA).

NOTE 1—An example of this classification system is as follows: The designation PA0123 would indicate:

PA = polyamide (nylon) as found in Terminology D 1600,
01 (group) = 66 nylon,
2 (class) = heat stabilized, and
3 (grade) = with a minimum relative viscosity of 100 and the requirements given in Table 1.

4.1.1 To facilitate the incorporation of future or special materials not covered by the Basic Property Table, the "other/unspecified" category (O) for group, class, and grade is shown on the table with the basic properties to be obtained from Tables A or B as they apply (see 4.3).

4.2 Reinforced and lubricated versions of the nylon materials are classified in accordance with Tables PA and A or B; where Table PA specifies the unreinforced material and Tables A or B the properties after the addition of reinforcements or lubricants at the nominal level indicated (see 4.2.1).

4.2.1 Reinforcements and additive materials. A symbol (single-letter) will be used for the major reinforcement or combination, or both, along with two numbers which indicate the percentage of addition by mass with the tolerances as tabulated below.

Symbol	Material	Tolerance (Based on the Total Mass)
C	Carbon and graphite fiber	± 2 %
G	Glass	± 2 %
L	Lubricants (for example, PTFE, graphite, silicone, and molybdenum disulfide)	by agreement between the supplier and the user
M	Mineral	± 2 %
R	Combinations of reinforcements or fillers, or both	± 3 % for the total reinforcement

NOTE 2—This part of the system uses percent of reinforcements or additives, or both, in the control of the modified basic material. The types and percentages of reinforcements and additives should be shown on the supplier's technical data sheet unless they are proprietary in nature. If necessary, additional control of these reinforcements and additives can be established by the use of the suffix part of the system, Section 5.

NOTE 3—Ash content of filled or reinforced materials may be determined using Test Method D 2584 where applicable.

4.2.2 *Table A, Detail Requirements–Reinforced Nylons*—An identifying number is made up of the letter A and five digits comprising the cell numbers for the new requirements in the designated order as they appear in Table A.

4.2.2.1 Although the values listed are necessary to include the range of properties available in existing materials, users should not infer that every possible combination of the properties exists or can be obtained.

4.2.3 When the grade of the basic material is not known or is not important, the use of "0" grade classification will be used for reinforced materials in this system. (See Note 6.)

NOTE 4—An example of a reinforced nylon of this classification system is as follows: The designation PA0315G30A22450 would indicate the following material requirements from Table A:

PA0315 = 11 nylon, from Table PA,
G30 = glass reinforced at 30 % nominal (see 4.2.1),
A = Table A property requirements,
2 = 70 MPa tensile strength, min,
2 = 4500 MPa flexural modulus, min,
4 = 100 J/m Izod impact, min,
5 = 160°C deflection temperature at 1.82 MPa, min, and
0 = unspecified.

If no properties are specified, the designation would be PA0315G30A00000.

4.3 To facilitate the specification of special materials where the basic property table does not reflect the properties required, Table B has been incorporated into this specification. This table will be used in a manner similar to Table A.

NOTE 5—Pigmented or colored nylons can differ significantly from the natural polymers in mechanical properties depending on the choice of colorants and concentrations. The main property affected is ductility, as illustrated by a reduction in Izod impact and elongation values. In a typical white pigmented nylon, elongation losses of up to 50 % and Izod impact losses of up to 30 % are common. If specific properties of pigmented nylons are required, a testing program should be arranged by the material supplier or the end user, or both. Once these agreements are reached, a cell callout using Table B should be employed to insure proper property compliance.

NOTE 6—An example of a special material using this classification system is as follows: The designation PA0220B54220 would indicate the following, with the material requirements from Table B:

PA0220 = 6 nylon, heat stabilized, from Table PA,
B = Table B property requirements,
5 = 70 MPa tensile strength, min,
4 = 2400 MPa flexural modulus, min,
2 = 40 J/m Izod impact, min,
2 = 55°C deflection temperature at 1.82 MPa, min, and
0 = unspecified.

5. Suffixes

5.1 When using the callout for the materials covered by this specification, the following suffixes may be used fo specific requirements for the material for the applicatio intended. In general, the suffix letter gives the genera requirement needed and the first number (digit) gives the tes condition, with the second number (digit) giving the specifi requirement.

Suffixes:

E = Electrical requirements as designated by the followin digits:

First Digit

0 = To be specified by user.
1 = Specimens tested dry-as-molded.
2 = Specimens tested conditions 96 h at 23°C and 50 % relative humidity.

[7] Available from Underwriters Laboratories, Inc., Publication Stock, 333 Pfingsten Road, Northbrook, IL 60062.

[8] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

TABLE PA Requirements for Unreinforced Nylons Dry-as-Molded

All DTUL requirements in Table PA were reduced 5°C in 1988 in recognition of changes in the measuring equipment commercially available.

Group	Description	Class	Description	Grade	Description[A]	Relative Viscosity,[B] min ASTM D 789	Melt Point, °C ASTM D 3418, DTA or DSC[C,D]	Specific Gravity, ASTM D 792	Tensile Strength,[E] ASTM D 638, min, MPa	Elongation[E] (ultimate) ASTM D 638, %, min	Flexural Modulus,[F] ASTM D 790, min, MPa	Izod Impact Resistance[G] ASTM D 256, min, J/m	Deflection Temperature,[H] °C, min, ASTM D 648 @ 1.82 MPa	Moisture[I] "as received" ASTM D 789, %, max
001	66 Nylon	1	General-purpose	1		45	250–265	1.13–1.15	76	50	2600	50	63	0.25
				2		60	250–265	1.13–1.15	76	50	2600	50	63	0.20
				3		100	250–265	1.13–1.15	76	50	2600	50	63	0.15
				4		200	250–265	1.13–1.15	76	100	2600	50	63	0.15
				5	recycled	35	250–265	1.13–1.15	76	10	2600	50	63	0.30
				6	recycled	45	250–265	1.13–1.15	76	25	2600	50	63	0.25
				7	recycled	45	250–265	1.13–1.15	76	50	2600	50	63	0.25
				0	other									
		2	Heat-stabilized	1		45	250–265	1.13–1.15	76	40	2600	40	63	0.25
				2		60	250–265	1.13–1.15	76	40	2600	40	63	0.20
				3		100	250–265	1.13–1.15	76	40	2600	40	63	0.15
				4		200	250–265	1.13–1.15	76	100	2600	40	63	0.15
				5	recycled	35	250–265	1.13–1.15	76	10	2600	40	63	0.30
				6	recycled	45	250–265	1.13–1.15	76	20	2600	40	63	0.25
				7	recycled	45	250–265	1.13–1.15	76	40	2600	40	63	0.25
				0	other									
		3	Nucleated	1		45	250–265	1.13–1.15	83	20	2800	40	63	0.25
				2		60	250–265	1.13–1.15	83	20	2800	40	63	0.20
				3		100	250–265	1.13–1.15	83	20	2800	40	63	0.15
				4		200	250–265	1.13–1.15	83	20	2800	40	63	0.15
				5	recycled	45	250–265	1.13–1.15	83	15	2600	40	63	0.25
				6	recycled	45	250–265	1.13–1.15	83	20	2600	40	63	0.25
				0	other									
		4	Nucleated heat-stabilized	1		Requirements the same as corresponding grades under Group 1 Class 3								
				2										
				3										
				4										
				0	other									
		5	Highly nucleated	1		45	250–265	1.13–1.15	90	5	2900	40	63	0.25
				2		60	250–265	1.13–1.15	90	5	2900	40	63	0.20
				3		100	250–265	1.13–1.15	90	5	2900	40	63	0.15
				4		200	250–265	1.13–1.15	90	5	2900	40	63	0.15
				0	other									
		6	Impact-modified	1		...	250–265	1.09–1.11	58	55	1700	150	...	0.20
				2		...	250–265	1.06–1.09	48	50	1500	800	...	0.20
				3	recycled	...	250–265	1.09–1.11	50	40	1600	80	60	0.20
				0	other									
		7	Impact-modified, heat-stabilized	1		...	250–265	1.09–1.11	58	55	1700	150	60	0.20
				2		...	250–265	1.06–1.09	48	50	1500	800	63	0.20
				3	recycled	...	250–265	1.09–1.11	50	40	1600	90	60	0.20
				0	other									
		8	Weather-stabilized[J]	1		45	250–265	1.14–1.16	83	20	2700	40	65	0.20
				2	recycled	...	250–265	1.14–1.16	65	10	2500	30	...	0.20
				0	other									
		9	Flexural modified-heat-stabilized	1		80	190–220	1.12–1.16	45	250	525 max	150	...	0.20
				0	other									

stabilized 0 other

TABLE PA *Continued*

Group	Description	Class	Description	Grade	Description[A]	Relative Viscosity,[B] min ASTM D 789	Melt Point, °C ASTM D 3418, DTA or DSC[C,D]	Specific Gravity, ASTM D 792	Tensile Strength,[E] ASTM D 638, min, MPa	Elongation[E] (ultimate) ASTM D 638, %, min	Flexural Modulus,[F] ASTM D 790, min, MPa	Izod Impact Resistance[G] ASTM D 256, min, J/m	Deflection Temperature,[H] °C, min, ASTM D 648 @ 1.82 MPa	Moisture[I] "as received" ASTM D 789, %, max
		0	Other	0	other									
02	6 Nylon	1	General-purpose	1		30	210–225	1.12–1.14	76	40	2600	40	58	0.20
				2		40	210–225	1.12–1.14	76	40	2600	50	58	0.20
				3		50	210–225	1.12–1.14	76	100	2600	50	58	0.20
				4		95	210–225	1.12–1.14	76	150	2600	55	58	0.20
				5		200	210–225	1.12–1.14	76	200	2600	55	58	0.20
				6	recycled	30	210–225	1.12–1.14	68	25	2600	40	58	0.20
				7	recycled	40	210–225	1.12–1.14	68	35	2600	40	58	0.20
				8	recycled	40	210–225	1.12–1.14	76	40	2600	40	58	0.20
				0	other									
		2	Heat-stabilized	1		30	210–225	1.12–1.14	76	40	2600	40	58	0.20
				2		40	210–225	1.12–1.14	76	40	2600	50	58	0.20
				3		50	210–225	1.12–1.14	76	100	2600	50	58	0.20
				4		95	210–225	1.12–1.14	76	150	2600	55	58	0.20
				5		200	210–225	1.12–1.14	76	200	2600	55	58	0.20
				6	recycled	30	210–225	1.12–1.14	68	25	2600	40	58	0.20
				7	recycled	40	210–225	1.12–1.14	68	35	2600	40	58	0.20
				8	recycled	40	210–225	1.12–1.14	76	40	2600	40	58	0.20
				0	other									
		3	Nucleated	1		30	210–225	1.12–1.15	82	10	2800	35	63	0.20
				2		40	210–225	1.12–1.15	82	10	2800	40	63	0.20
				3		50	210–225	1.12–1.15	82	50	2800	40	63	0.20
				4		95	210–225	1.12–1.15	82	100	2800	45	63	0.20
				5		200	210–225	1.12–1.15	82	100	2800	45	63	0.20
				6	recycled	30	210–225	1.12–1.15	70	10	2800	35	63	0.20
				7	recycled	40	210–225	1.12–1.15	70	10	2800	40	63	0.20
				8	recycled	40	210–225	1.12–1.15	82	10	2800	40	63	0.20
				0	other									
		4	Nucleated heat-stabilized	1										
				2										
				3										
				4										
				5										
				6										
				7										
				8										
				0	other									
		5	Flexural-modified	1		...	185–225	1.05–1.16	27	50	700 max	80	33	0.20
				2		...	185–225	1.05–1.16	34	50	1400 max	80	35	0.20
				3		...	185–225	1.05–1.16	41	50	2100 max	80	38	0.20
				4		...	185–225	1.05–1.16	55	50	2800 max	80	44	0.20
				0	other									
		6	Flexural-modified heat-stabilized	1										
				2										
				3										
				4										
				0	other									

Requirements the same as corresponding grades under Group 2 Class 3

Requirements the same as corresponding grades under Group 2 Class 5

TABLE PA *Continued*

Group	Description	Class	Description	Grade	Description[A]	Relative Viscosity,[B] min ASTM D 789	Melt Point, °C ASTM D 3418, DTA or DSC[C,D]	Specific Gravity, ASTM D 792	Tensile Strength,[E] ASTM D 638, min, MPa	Elongation[E] (ultimate) ASTM D 638, %, min	Flexural Modulus,[F] ASTM D 790, min, MPa	Izod Impact Resistance[G] ASTM D 256, min, J/m	Deflection Temperature,[H] °C, min, ASTM D 648 @ 1.82 MPa	Moisture[I] "as received" ASTM D 789, %, max
		7	Impact-modified	1		...	185–225	1.05–1.16	55	50	1890	55	44	0.20
				2		...	185–225	1.05–1.16	27	50	690	105	33	0.20
				3		...	185–225	1.05–1.16	27	50	550	265	33	0.20
				4		...	185–225	1.05–1.16	27	50	275	425	33	0.20
				5	recycled	...	210–225	1.05–1.16	55	30	1890	69	65	0.20
				0	other									
		8	Impact-modified heat-stabilized	1		Requirements the same as corresponding grades under Group 2 Class 7								
				2										
				3										
				4										
				0	other									
		0	Other	0	other									
03	11 Nylon	1	General-purpose	1		1.53–1.58	185–195	1.03–1.06	41	200	900	55	35	0.15
				2		1.59–1.67	185–195	1.03–1.06	45	200	900	55	40	0.12
				3		1.67–1.82	185–195	1.03–1.06	45	200	900	55	40	0.10
				4		1.83–2.00	185–195	1.03–1.06	48	200	900	55	40	0.08
				5	hydrolysis resistant[K]	1.83–2.00	185–195	1.03–1.06	48	200	900	55	40	0.08
				0	other									
		2	Heat-stabilized	1		1.59–1.67	185–195	1.03–1.06	45	200	900	55	40	0.12
				2		1.67–1.82	185–195	1.03–1.06	45	200	900	55	40	0.10
				3		1.83–2.00	185–195	1.03–1.06	48	200	900	55	40	0.08
				4	hydrolysis resistant	1.83–2.00	185–195	1.03–1.06	48	200	900	55	40	0.08
				0	other									
		3	Highly plasticized	1		1.59–1.67	185–195	1.03–1.06	45	250	300	80	35	0.10
				2		1.67–1.82	185–195	1.03–1.06	52	250	300	80	35	0.08
				3		1.83–2.00	185–195	1.03–1.06	52	250	300	80	35	0.08
				4		2.00 min	185–195	1.03–1.06	52	250	300	80	35	0.08
				0	other									
		4	Highly plasticized heat-stabilized	1		Requirements the same as corresponding grades under Group 3 Class 3								
				2										
				3										
				4										
				0	other									
		5	Moderately plasticized	1		1.59–1.67	185–195	1.03–1.06	45	250	350	80	35	0.10
				2		1.83–2.00	185–195	1.03–1.06	52	250	350	80	35	0.08
				3		1.59–1.67	185–195	1.03–1.06	45	225	450	80	35	0.08
				4		1.83–2.00	185–195	1.03–1.06	52	225	450	80	35	0.08
				5		1.83–2.00	185–195	1.03–1.06	52	225	600	80	35	0.08
				0	other									

TABLE PA *Continued*

Group	Description	Class	Description	Grade	Description[A]	Relative Viscosity,[B] min ASTM D 789	Melt Point, °C ASTM D 3418, DTA or DSC[C,D]	Specific Gravity, ASTM D 792	Tensile Strength,[E] ASTM D 638, min, MPa	Elongation[E] (ultimate) ASTM D 638, %, min	Flexural Modulus,[F] ASTM D 790, min, MPa	Izod Impact Resistance[G] ASTM D 256, min, J/m	Deflection Temperature,[H] °C, min, ASTM D 648 @ 1.82 MPa	Moisture[I] "as received" ASTM D 789, %, max
		6	Moderately plasticized heat-stabilized	1 2 3 4 5 0	other	Requirements the same as corresponding grades under Group 3 Class 5								
		0	Other	0	other									
04	12 Nylon	1	General-purpose	1		1.50–2.05	170–185	1.01–1.06	30	140	800	25[N]	35[O]	0.10
				2		1.50–2.05	170–185	1.01–1.06	35	150	1000	25	35	0.10
				3		2.06–2.35	170–185	1.01–1.06	35	150	1000	25	35	0.10
				4		2.36–2.70	170–185	1.01–1.06	35	150	1000	25	35	0.10
				0	other									
		2	Heat-stabilized	1		1.50–1.75	170–185	1.00–1.06	35	150	800	25[N]	35[O]	0.10
				2		1.76–2.05	170–185	1.00–1.06	35	150	800	25	35	0.10
				3		2.06–2.40	170–185	1.00–1.06	35	150	1000	25	35	0.10
				0	other									
		3	Nucleated	1		1.50–1.90	170–185	1.00–1.06	35	100	800	10[N]	35[O]	0.10
				2		1.91–2.25	170–185	1.00–1.06	35	100	800	25	35	0.10
				0	other									
		4	Plasticized	1		1.50–2.40	165–180	1.00–1.06	30	180	300–550	200[N]	...	0.10
				2		1.50–2.40	165–180	1.00–1.06	30	200	300–550	200	...	0.10
				3		1.50–2.40	170–185	1.00–1.06	30	200	450–750	100	...	0.10
				0	other									
		5	Plasticized heat-stabilized	1		1.50–2.40	160–175	1.00–1.06	20	200	200–350	200[N]	...	0.10
				2		1.50–2.40	165–180	1.00–1.06	30	180	300–550	200	...	0.10
				3		1.50–2.40	165–180	1.00–1.06	30	200	300–550	200	...	0.10
				4		1.50–2.40	170–185	1.00–1.06	30	200	450–750	100	...	0.10
				5		1.50–2.40	170–185	1.00–1.06	35	200	550–950	50	...	0.10
				0	other									
		0	Other	0	other									
05	69 Nylon	1	General-purpose	1		30	208–220	1.07–1.09	60	50	1900	40	47	0.20
				2		45	208–220	1.07–1.09	60	50	1900	40	47	0.20
				3		100	208–220	1.07–1.09	60	50	1900	40	47	0.20
				0	other									
		2	Heat-stabilized	1		30	208–220	1.07–1.09	60	50	1900	40	47	0.20
				2		45	208–220	1.07–1.09	60	50	1900	40	47	0.20
				3		100	208–220	1.07–1.09	60	50	1900	40	47	0.20
				0	other									
		0	Other	0	other									
06	612 Nylon	1	General-purpose	1		0.90[L]	208–220	1.05–1.07	55	50	1900	30	65	0.30
				2		1.1[L]	208–220	1.05–1.07	55	100	1900	40	65	0.25
				3		1.3[L]	208–220	1.05–1.07	55	100	1900	40	60	0.15
				0	other									
		2	Heat-stabilized	1		1.1[L]	208–220	1.05–1.07	55	50	1900	35	60	0.30
				0	other									
		3	Weather-stabilized[J]	1		1.1[L]	208–220	1.05–1.07	...	...	...	40	60	0.30
				0	other									
		0	Other	0	other	...	...	...	...	...	...	...	...	...

TABLE PA *Continued*

Group	Description	Class	Description	Grade	Description[A]	Relative Viscosity,[B] min ASTM D 789	Melt Point, °C ASTM D 3418, DTA or DSC[C,D]	Specific Gravity, ASTM D 792	Tensile Strength,[E] ASTM D 638, min, MPa	Elongation[E] (ultimate) ASTM D 638, %, min	Flexural Modulus,[F] ASTM D 790, min, MPa	Izod Impact Resistance[G] ASTM D 256, min, J/m	Deflection Temperature,[H] °C, min, ASTM D 648 @ 1.82 MPa	Moisture[I] "as received" ASTM D 789, %, max
07[M]	610 Nylon	1	General-purpose	1		25	210–222	1.05–1.09	50	50	1850	40	60	0.25
				2		40	210–222	1.05–1.09	60	70	1850	45	60	0.22
				3		60	210–222	1.05–1.09	65	70	1850	45	60	0.22
				0	other									
		2	Heat-stabilized	1		25	210–222	1.05–1.09	50	50	1850	40	60	0.25
				2		40	210–222	1.05–1.09	60	70	1850	45	60	0.22
				0	other									
		0	Other	0	other	...	...	...	...	...	...	...	...	...
08	Special	1	*n*-Alkoxy-alkyl 6:6	1		40	143–158	1.09–1.12	20	250	200	N/B[G]	...	0.20
				0	other									
		0	Other	0	other	...	...	...	...	...	...	...	...	...
09	46 Nylon	1	General-purpose	1		45	285–295	1.16–1.20	90	25	2600	50	140	0.05
				2		80	285–295	1.16–1.20	90	25	2600	50	140	0.05
				3		125	285–295	1.16–1.20	90	25	2600	50	140	0.05
				0	other									
		2	Heat-stabilized	1		45	285–295	1.16–1.20	90	25	2600	50	140	0.05
				2		80	285–295	1.16–1.20	90	25	2600	50	140	0.05
				3		125	285–295	1.16–1.20	90	25	2600	50	140	0.05
				0	other									
		0	Other	0	other									
0	Other	0	Other	0	other	...	...	...	...	...	...	...	...	...

[A] No descriptions are listed unless needed to describe a special grade under the class. All other grades are listed by requirements.

[B] Viscosities for Groups 03, 04, 06, and 08 are measured as described below. Refer to Specification D 789 for general directions and for the calculation of relative viscosities. Relative viscosities of Groups 03 and 04 shall be measured on 0.5 g of polymer dissolved in 99.5 g of *m*-cresol at 25.0 ± 0.1°C in a Cannon-Fenske No. 200 viscometer. Inherent viscosity of Group 06 shall be measured on 0.5 g of polymer dissolved in 100 mL of *m*-cresol at 25.0 ± 0.1°C in a Cannon-Fenske No. 200 viscometer. The inherent viscosity is calculated as follows:

$$\text{Inherent viscosity} = \frac{\ln(t_s/t_c)}{C}$$

where:

t_s = average efflux time for sample solution,

t_c = average efflux time for solvent, and

C = concentration, g/100 mL.

Relative viscosity of Group 08 shall be measured on 9.44 g of polymer dissolved in 100 mL of *m*-cresol at 25.0 ± 0.1°C in a Cannon-Fenske No. 450 viscometer. Details of these methods will be included in a future revision of Specification D 789.

[C] Heating rate-10°C/min.

[D] The results of an international round-robin (ISO-USA, Germany, Japan, Poland, and Italy) showed DSC melt point to be the method having the best reproducibility of results when compared to other available methods (ref. ISO 3146).

[E] Tensile strength and elongation shall be determined on Test Method D 638 test specimens 3.2 ± 0.4 mm thick. The speed of testing shall be 50 mm/min (±10 %) unless otherwise agreed.

[F] Flexural modulus shall be determined on Test Method D 790 test specimens 3.2 by 12.7 by 127 mm with a crosshead speed of 1.3 mm/min (±50 %), Procedure A.

[G] Izod impact for these materials shall be conducted on specimens with a 12.7 mm depth and a notch radius of 0.25 mm. The specimens tested are 3.17 mm in width. N/B = No Break.

[H] Requirements are based on unannealed test specimens 3,17 mm in width. Annealed specimens tend to give higher results due to the elimination of the effect of molding stresses when annealed in accordance with the supplier's recommendation.

[I] Groups 03 and 04 materials use Specification D 789 except sample to be immersed in a heat bath for 45 min at 180 ± 2°C.

[J] Carbon black content and absorbance must be 1.90 to 2.25 % and 0.230 minimum respectively as determined according to methods found in Federal Specification L-P-410a. It is possible, by agreement between the buyer and the seller, that materials incorporating other pigments or soluble stabilizers, or both, may prove adequate for particular applications.

[K] Hydrolysis-resistance test. To be agreed upon between the user and the supplier.

[L] Inherent viscosities (dL/g).

[M] Group 07 nylons are presently used commercially only as reinforced materials.

[N] Izod impact requirements for Group 04 materials based on specimens with a 12.7 mm depth, 3.17 mm width, and a notch radius of 0.25 mm.

[O] Deflection temperature requirements for Group 04 materials are based on unannealed test specimens 3.17 mm in width.

TABLE 1 Electrical Properties of Unreinforced Nylons

	ASTM Test Method	Requirement
Insulation resistance, min, MΩ	D 257 (NOTE 8)	5×10^6
Dielectric strength step-by-step test, min, kV/mm	D 149 (NOTE 9)	14.8 (NOTE 12)
Dielectric constant at 1 MHz, max	D 150 (NOTE 10)	4.0
Dissipation factor at 1 MHz, max	D 150 (NOTE 10)	0.11

Second Digit

0 = To be specified by user.
1 = Insulation resistance, dielectric strength, dielectric constant, and dissipation factor meet property limits as shown in Table 1. These are electrical limits applied to unreinforced nylons when control of their electrical properties is required.
2 = Dielectric strength, dielectric constant, and dissipation factor meet property limits as shown in Table 2. These are electrical limits applied to reinforced nylons when control of their electrical properties is required.

F = Flammability requirements as designated by the following digits:

First Digit

0 = To be specified by user.
1 = Product is recognized UL94 at 3.05 mm thickness.
2 = Product is recognized UL94 at 1.47 mm thickness.
3 = Product is recognized UL94 at 0.71 mm thickness.
4 = Product is recognized UL94 at 0.38 mm thickness.

Second Digit

0 = To be specified by user.
1 = UL94 HB
2 = UL94 V-2
3 = UL94 V-1
4 = UL94 V-0
5 = UL94 5V

Caution—See 11.2 for ASTM's position with respect to flammability standards.

Z = Other special requirement characteristics, that is, color, not covered by existing call-out capabilities may be assigned by the user. These will be spelled out in detail and identified in sequence, that is, 01, 02, 03, etc.

NOTE 7—A further list of suffixes can be found in Classification D 4000 and may be used for additional requirements as appropriate.

5.2 Additional suffixes will be added to this specification as test methods and requirements are developed.

NOTE 8—As modified by the following: Electrodes shall be American Standard No. 3 tapered pins 3 in. (76.2 mm) long having a diameter at the large end of 5.56 mm and tapering 6.35 mm per 305 mm. The specimen shall be of sufficient size so that two 4.75 mm diameter holes centrally located, 25.4 mm apart, center-to-center, and perpendicular to the faces of the specimen, may be drilled. The holes shall be drilled as above and then reamed, using a standard-tapered pin reamer, to a sufficient depth to allow the pins to extend approximately 31.75 mm beyond the small end of the hole. The electrodes shall be inserted after the specimens have been conditioned. These specimens shall be tested.

NOTE 9—As modified by the following: The test specimen shall be a disk 101.6 mm in diameter and 3.18 mm thick. Step-by-step testing shall be done after a short-time test where voltage is increased uniformly at the rate of 500 V/s. Voltage increments for the step-by-step test shall be determined from short-time test results as follows:

Breakdown by short-time test, kV	Increment for step-by-step test, kV
12.5 or less	0.5
Over 12.5 to 25, incl	1.0
Over 25 to 50, incl	2.5
Over 50 to 100, incl	5.0
Over 100	10.0

Dielectric strength testing shall be run under oil conforming

TABLE 2 Electrical Properties of Reinforced Nylons

	ASTM Test Method	Requirement
Dielectric strength step-by-step test, min, kV/mm	D 149 (NOTE 9)	14.8 (NOTE 12)
Dielectric constant at 1 MHz, max	D 150 (NOTE 10)	4.2
Dissipation factor at 1 MHz, max	D 150 (NOTE 10)	0.025

to Federal Specification VV-I-530 at a frequency not exceeding 100 Hz. Step-by-step testing shall be carried ou using five test specimens.

NOTE 10—As modified by the following: The test specimen is a dis 50.8 mm or 101.6 mm in diameter by 3.18 mm thick. The dissipatio factor is the cotangent of the dielectric phase angle or the tangent of th dielectric loss angle. Five specimens shall be tested. After the humidit conditioning specified by first digit following the E suffix, test specimer are immersed in distilled water at 50°C for 48 h followed by immersio in distilled water at 23°C for ½ h. Start the test within 2 min aft removing the specimen and wiping with a dry cloth.

NOTE 11—kV/mm × 25.4 = V/mil

6. General Requirements

6.1 The material composition shall be uniform and sha conform to the requirements specified herein.

7. Detail Requirements

7.1 The material shall conform to the requirements pr scribed in Tables PA, A, and B, and suffix requirements they apply.

7.2 For the purpose of determining conformance with th specification, all specified limits in this standard are *absolu limits*, as defined in Practice E 29.

7.2.1 With the absolute method, an observed value or calculated value is not rounded, but is to be compared direct with the specified limiting value. Conformance or noncon formance with the specification is based on this comparison

8. Sampling

8.1 Sampling shall be statistically adequate to satisfy th requirements of Section 13.4. A *lot* of material shall b considered as a unit of manufacture as prepared for shi ment and may consist of a blend of two or more productio runs or batches of material.

9. Specimen Preparation

9.1 The test specimens shall be molded by either an inje tion or compression molding process as specified in the *A nual Book of ASTM Standards* for the specific products test or they shall be molded as specified by the resin supplier.

10. Conditioning

10.1 *Conditioning*—Test data shall be obtained usi dry-as-molded specimens, defined as those which imme ately upon removal from mold are sealed in containers th are impermeable to water vapor. Maximum moisture co tent of specimens shall be 0.30 %. No moisture shall intentionally added to reach this level. Condition specim a minimum of 24 h in sealed containers at 23 ± 2°C.

NOTE 12—Physical properties of most nylon resins are highly de dent upon the moisture content of the molded item. The user is refe to the manufacturer's literature for details.

10.2 *Test Conditions*—Conduct tests in the standard

TABLE A Detail Requirements[A] Reinforced Nylons

Designation Order No.	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 638, min, MPa[B,C]	unspecified	35	70	105	140	175	210	245	280	Specify[D] value
2	Flexural modulus, ASTM D 790, min, MPa[B,E]	unspecified	1 500	4 500	7 500	10 500	13 500	16 500	19 500	22 500	Specify[D] value
3	Izod impact, ASTM D 256, min, J/m[F]	unspecified	25	50	75	100	125	150	225	300	Specify[D] value
4	Deflection temperature, ASTM D 648, 1820 kPa, °C, min	unspecified	50	85	110	135	160	185	200	235	Specify[D] value
5	To be determined	unspecified	...	...	...	...	...	...	...	...	

[A] It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of parts molded of these materials.
[B] MPA × 145 = psi.
[C] Tensile strength and elongation shall be determined on Test Method D 638 test specimens 3.2 ± 0.4 mm thick. The speed of testing shall be 5 mm/min (±25 %) unless otherwise agreed.
[D] If specific value is required, it must appear on drawing or contract, or both.
[E] Flexural modulus shall be determined on Test Method D 790 test specimens 6.4 by 13 by 130 mm with a crosshead speed of 2.8 mm/min (±50 %), Procedure A.
[F] J/m × 18.73 × 10^{-3} = ft·lbf/in.
NOTE—Moisture content of the resin shall not exceed 0.30 % "as received" based on Specification D 789, unless otherwise agreed.

TABLE B Detail Requirements[A] Unreinforced Nylons

Designation Order No.	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 638, min, MPa[B,C]	unspecified	10	25	40	55	70	85	100	115	Specify[D] value
2	Flexural modulus, ASTM D 790, min, MPa[B,E]	unspecified	300	1 000	1 700	2 400	3 100	3 800	4 500	5 200	Specify[D] value
3	Izod impact, ASTM D 256, min, J/m[C,F]	unspecified	20	40	60	100	140	180	240	300	Specify[D] value
4	Deflection temperature, ASTM D 648, 1820 kPa, °C, min	unspecified	40	55	70	85	100	115	130	145	Specify[D] value
5	To be determined	unspecified	...	...	...	...	...	...	...	...	

[A] It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of parts molded of these materials.
[B] MPA × 145 = psi.
[C] Tensile strength and elongation shall be determined on Test Method D 638 test specimens 3.2 ± 0.4 mm thick. The speed of testing shall be 50 mm/min (±10 %) unless otherwise agreed.
[D] If specific value is required, it must appear on drawing or contract, or both.
[E] Flexural modulus shall be determined on Test Method D 790 test specimens 6.4 by 13 by 130 mm with a crosshead speed of 2.8 mm/min (±50 %), Procedure A.
[F] J/m × 18.73 × 10^{-3} = ft·lbf/in.
NOTE—Moisture content of the resin shall not exceed 0.30 % "as received" based on Specification D 789, unless otherwise agreed.

oratory atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity. Individual specimens shall not be removed from sealed containers until immediately before testing.

11. Test Methods

11.1 Determine the properties enumerated in this specification by means of the test methods referenced.

11.2 *This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.*

12. Number of Tests

12.1 The number of tests conducted shall be consistent with the requirements of Sections 8 and 13.4.

13. Inspection and Certification

13.1 Inspection and certification of the material supplied under this specification shall be for conformance to the requirements specified herein.

13.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of the tests listed as they apply:

Relative viscosity,
Moisture content,
Reinforcement content,
Carbon black content (weather-stabilized materials), and
Heat stabilizer content (heat-stabilized materials, supplier's test showing positive presence).

13.3 Periodic-check inspection shall consist of the tests specified for all requirements of the material under this specification. Inspection frequency shall be adequate to ensure the material is certifiable in accordance with Section 13.4.

13.4 Certification that the material was manufactured, sampled, tested, and inspected in accordance with this specification and that the average values meet the requirements at a confidence level of 95 %.

13.5 A report of the test results shall be furnished when requested. The report shall consist of results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

14. Packing, Packaging, and Marking

14.1 For packing, packaging, and marking, the provisions of Practice D 3892 apply.

15. Keywords

15.1 line callout; nylon; nylon materials; plastics; plastics materials

APPENDIX

(Nonmandatory Information)

X1. VISCOSITY CONVERSION: ASTM TEST METHODS D 789 AND ISO 307

X1.1 The relation between relative viscosity in 90 % HCOOH (Test Methods D 789) and viscosity number in 96 % $H2SO_4$ (ISO 307) was developed in an interlaboratory round-robin study by ISO TC-61 Subcommittee 9/Work Group 8 (Plastic Materials/Polyamides). Seven laboratories, including 3 USA labs (Allied, DuPont, and Monsanto), participated in the work. A 95 ± 9 % between lab confidence interval was predicted for the measurements.

X1.2 For convenience a conversion table and graph (Fig. X1.1) are provided, using the established relationship:

$$VN = A + B \times \ln(RV)$$

where:

VN= viscosity number (ISO 307),
RV= relative viscosity (Test Methods D 789),
A = −206.52124, and
B = 90.23355.

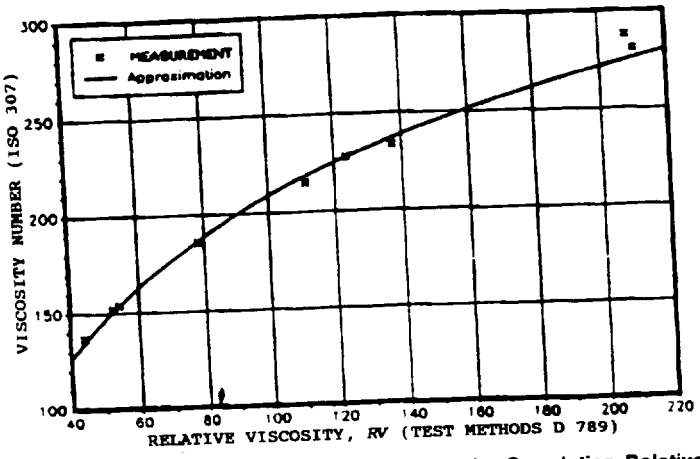


FIG. X1.1 Nylon 6 and Nylon 66 Viscosity Correlation Relative Viscosity in 90 % HCOOH (Test Methods D 789) versus Viscosity Number in 96 % $H2SO_4$ (ISO 307)

1. Sc
1.1
polypl
moldi
1.2
mater
be us
mater
plasti
the n
factu
1.3
requi
other
istics
upon
as gi
1.
as th
1.
meth
dara
asso
this
prac
tatic

2.

Designation: A 908 – 91

Standard Specification for Stainless Steel Needle Tubing[1]

This standard is issued under the fixed designation A 908; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers austenitic, stainless steel, needle tubing in hard-drawn tempers for industrial applications.

1.2 In general, needle tubing describes small-diameter tubing with outside diameters (ODs) in the range of 0.008 to 0.203 in. (0.2 to 5.2 mm) with nominal wall thicknesses in the range of 0.002 to 0.015 in. (0.05 to 0.4 mm). Needle tubing gages are normally 6 through 33.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[2]

3. Ordering Information

3.1 Orders for material in accordance with this specification should include the following, as required, to describe the material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Gage or size (outside diameter and minimum wall thickness),

3.1.3 Length (specific or random), and

3.1.4 Test report required (see the section on certification in Specification A 450/A 450M).

4. General Requirements

4.1 Material furnished in accordance with this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Process

5.1 An electric furnace or other similar primary melting process with or without degassing or refining may be used.

TABLE 1 Chemical Requirements

Carbon	0.08 max
Manganese	2.00 max
Phosphorous	0.040 max
Sulfur	0.030 max
Silicon	0.75 max
Chromium	18.0–20.0
Nickel	8.0–11.0

TABLE 2 Tensile Requirements

Tensile strength, ksi (MPa)	150–200 (1030–1370)

6. Manufacture

6.1 Needle tubing shall be made by the seamless or welded and drawn process and shall be furnished in the hard-drawn temper condition.

7. Heat Treatment

7.1 Unless otherwise specified by the purchaser, no heat treatment is required.

8. Chemical Composition

8.1 Stainless steel, Type 304, UNS S30400, in accordance with Table 1 shall be used.

8.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the manufacturer from samples made during the pour. The chemical composition thus determined shall meet the requirements of Table 1.

8.3 *Product Analysis*—An analysis may be made by the purchaser from finished tubing. The chemical composition thus determined shall meet the requirements of Table 1.

9. Mechanical Properties

9.1 *Tensile Requirements*—The tubing shall meet the tensile properties specified in Table 2. Yield strength, elongation, and hardness tests are not required for needle tubing.

9.2 *Number of Tests*—Two tension tests for each 5000 ft of product per heat shall be performed.

10. Dimensions

10.1 *Sizes and Tolerances*—Needle tubing sizes and dimensions shall be in accordance with Table 3.

11. Keywords

11.1 needle tubing; stainless steel

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Steel Tubing.

Current edition approved Dec. 15, 1991. Published February 1992.

[2] *Annual Book of ASTM Standards*, Vol 01.01.

TABLE 3 Sizes and Tolerances

Gage No.	OD, in.	OD Tolerance, in. (±)	Nominal Wall, in.	Wall Tolerance, in. (±)
6	0.203	0.001	0.015	0.001
7	0.180	0.001	0.015	0.001
8	0.165	0.001	0.015	0.001
9	0.148	0.001	0.014	0.001
10	0.134	0.001	0.013	0.001
11	0.120	0.001	0.012	0.001
12	0.109	0.001	0.012	0.001
13	0.095	0.001	0.010	0.001
14	0.083	0.0005	0.009	0.0005
15	0.072	0.0005	0.009	0.0005
16	0.065	0.0005	0.009	0.0005
17	0.059	0.0005	0.0085	0.0005
18	0.050	0.0005	0.00775	0.0005
19	0.0425	+0.0005/−0.000	0.00625	+0.000/−0.0005
20	0.0355	+0.0005/−0.000	0.00625	+0.000/−0.0005
21	0.032	+0.0005/−0.000	0.00625	+0.000/−0.0005
22	0.028	+0.0005/−0.000	0.00625	+0.000/−0.0005
23	0.025	+0.0005/−0.000	0.00525	+0.000/−0.0005
24	0.022	+0.0005/−0.000	0.00525	+0.000/−0.0005
25	0.020	+0.0005/−0.000	0.00425	+0.000/−0.0005
26	0.018	+0.0005/−0.000	0.00425	+0.000/−0.0005
27	0.016	+0.0005/−0.000	0.0035	0.00025
28	0.014	+0.0005/−0.000	0.003	0.00025
29	0.013	+0.0005/−0.000	0.003	0.00025
30	0.012	+0.0005/−0.000	0.0025	0.00025
31	0.010	+0.0005/−0.000	0.0025	0.00025
32	0.009	+0.0005/−0.000	0.002	0.00025
33	0.008			

10

Designation: A 666 – 92

Standard Specification for Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar[1]

This standard is issued under the fixed designation A 666; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers austenitic stainless steels in the annealed and normally required cold-worked conditions for various structural, architectural, pressure vessel, magnetic, cryogenic, and heat-resisting applications. (This revision of Specification A 666 replaces prior Specifications A 412 and A 177.)

1.2 The application of this specification, or the use of material covered by this specification does not automatically allow usage in pressure vessel applications. Only annealed conditions of grades specifically approved by the ASME code are permitted for pressure vessel use.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2,3]

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip[2]

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings[3]

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M or A 484/A 484M:

3.1.1 Definitions,
3.1.2 General requirements for delivery,
3.1.3 Ordering information,
3.1.4 Process,
3.1.5 Special tests,
3.1.6 Heat treatment,
3.1.7 Dimensions and permissible variations,
3.1.8 Workmanship, finish and appearance,
3.1.9 Number of tests/test methods,
3.1.10 Specimen preparation,
3.1.11 Retreatment,
3.1.12 Inspection,
3.1.13 Rejection and rehearing,
3.1.14 Material test report,
3.1.15 Certification, and
3.1.16 Packaging, marking, and loading.

4. Chemical Composition

4.1 The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall conform to applicable requirements specified in the current edition of Specification A 480/A 480M.

5. Mechanical Properties

5.1 The material shall conform to the mechanical properties specified in Tables 2 and 3, or Table 4.

6. Sampling

6.1 Tension and bend-test specimens of sheet, strip, and plate products shall be selected from finished material and shall be selected in the transverse direction, except in the case of strip under 9 in. (229 mm) in width, in which case tension test specimens shall be selected in the longitudinal direction.

6.2 Flat bar tension and bend-test specimens shall be selected from the finished material and shall be in the longitudinal direction.

6.3 Corrosion samples, if required, shall be taken from material after final annealing and descaling and prior to cold working.

7. Number of Tests

7.1 For flat bar products at least one tension test and one bend test shall be made on each size from each heat in a lot annealed in a single charge or under the same conditions in a continuous furnace.

8. Test Methods

8.1 *Tension Test:*

8.1.1 The yield strength shall be determined by the offset method as described in Test Methods and Definitions A 370. An alternative method of determining field strength may be used based on the following total extension under load:

Yield Strength, min. psi	Total Extension under Load in 2 in. Gage Length, incl.
45 000	0.0071
75 000	0.0098
110 000	0.0125
135 000	0.0144
140 000	0.0148

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.17 on Flat Stainless Steel Products.

Current edition approved July 15, 1992. Published September 1992. Originally published as A 666 – 72. Last previous edition A 666 – 91.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

8.1.2 The requirement of this specification for yield strength will be considered as having been fulfilled if the extension under load for the specified yield strength does not exceed the specified values. The values obtained in this manner should not, however, be taken as the actual yield strength for 0.2 %. In case of dispute, the offset method of determining yield strength shall be used.

8.2 *Bend Test:*

8.2.1 Bend-test specimens shall withstand cold bending without cracking when subjected to either the free-bend method or the controlled-bend (V-block) method at the condition specified by Tables 3 or 4, respectively. The choice of test method for materials in conditions other than annealed shall be at the option of the seller.

8.2.2 Free-bend test specimens shall be bent cold, either by pressure or by blows. However, in the case of dispute, tests shall be made by pressure.

8.2.3 Controlled-bend (V-block) test specimens shall be bent cold by means of V-blocks or a mating punch and die having an included angle of 45° and with proper curvature of surface at the bend areas to impart the desired shape and diameter of bend to the specimen.

TABLE 1 Chemical Composition Requirements[A]

Type	UNS Designation	Composition, %							
		Carbon, max or range	Manganese, max or range	Phosphorus, max	Sulfur, max	Silicon, max	Chromium	Nickel	Other Elements
201	S20100	0.15	5.50–7.50	0.060	0.030	0.75	16.00–18.00	3.50–5.50	N 0.25 max
202	S20200	0.15	7.50–10.00	0.060	0.030	0.75	17.00–19.00	4.00–6.00	N 0.25 max
...	S20400	0.03	7.00–9.00	0.040	0.030	1.00	15.00–17.00	1.50–3.00	N 0.15—0.30
205	S20500	0.12–0.25	14.00–15.00	0.060	0.030	0.75	16.50–18.00	1.00–1.75	N 0.32–0.40
301	S30100	0.15	2.00	0.045	0.030	0.75	16.00–18.00	6.00–8.00	N 0.10 max
302	S30200	0.15	2.00	0.045	0.030	0.75	17.00–19.00	8.00–10.00	
304	S30400	0.08	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	N 0.10 max
304L	S30403	0.030	2.00	0.045	0.030	0.75	18.00–20.00	8.00–12.00	N 0.10 max
304N	S30451	0.08	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	N 0.10–0.16
304LN	S30453	0.030	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	N 0.10–0.15
316	S31600	0.08	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	Mo 2.00–3.00
316L	S31603	0.030	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	Mo 2.00–3.00
316N	S31651	0.08	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	Mo 2.00–3.00 N 0.10–0.16
XM-11	S21904	0.04	8.00–10.00	0.060	0.030	0.75	19.00–21.50	5.50–7.50	N 0.15–0.40
XM-14	S21460	0.12	14.00–16.00	0.060	0.030	0.75	17.00–19.00	5.00–6.00	N 0.35–0.50

[A] Types XM-10 and XM-19, which appeared in Specification A 412, do not appear as XM-10 is no longer produced and XM-19 is covered in Specification A 240.

TABLE 2 Tensile Property Requirements [A]

Type	UNS Designation	Annealed						
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %	Hardness, max	
		psi	MPa	psi	MPa		Brinell	Rockwell B
201-1[B]	S20100	95 000	655	38 000	260	40	217	95
201-2	Class 1 S20100	95 000	655	45 000	310	40	255	100
202	Class 2 S20200	90 000	620	38 000	260	40	...	...
...	S20400	95 000	655	48 000	330	35	255	100
205	S20500	115 000	790	65 000	450	40	255	100
301	S30100	90 000	620	30 000	205	40	217	95
302	S30200	75 000	515	30 000	205	40	201	92
304	S30400	75 000	515	30 000	205	40	201	92
304L	S30403	70 000	485	25 000	170	40	183	88
304N	S30451	80 000	550	35 000	240	40	217	95
304LN	S30453	80 000	550	35 000	240	40	217	95
316	S31600	75 000	515	30 000	205	40	217	95
316L	S31603	70 000	485	25 000	170	40	217	95
316N	S31651	80 000	550	35 000	240	40	217	95
XM-11	S21904 Sheet, Strip	100 000	690	60 000	415	40	...	...
	Plate	90 000	620	50 000	345	45	...	...
XM-14	S21460	105 000	725	55 000	380	40	...	...

Type	UNS Designation	1/16 Hard [C]						
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
		psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100 PSS[D]	95 000	655	45 000	310	40	40	40
	FB[E]	75 000	515	40 000	275	...	...	40
205	S20500	115 000	790	65 000	450	40	40	40
301	S30100	90 000	620	45 000	310	40	40	40
302	S30200 PSS	85 000	585	45 000	310	40	40	40
	FB	90 000	620	45 000	310	...	...	40
304	S30400 PSS	80 000	550	45 000	310	35	35	35
	FB	90 000	620	45 000	310	...	...	40
304L	S30403	80 000	550	45 000	310	40	40	40
304N	S30451	90 000	620	45 000	310	40	40	40
304LN	S30453	90 000	620	45 000	310	40	40	40
316	S31600 PSS	85 000	585	45 000	310	35	35	35
	FB	90 000	620	45 000	310	...	...	40
316L	S31603	85 000	585	45 000	310	35	35	35
316N	S31651	90 000	620	45 000	310	35	35	35

Type	UNS Designation	1/8 Hard [C]						
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
		psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	100 000	690	55 000	380	45	45	45
205	S20500	115 000	790	65 000	450	40	40	40
301	S30100	100 000	690	55 000	380	40	40	40
302	S30200	100 000	690	55 000	380	35	35	35
304	S30400	100 000	690	55 000	380	35	35	35
304L	S30403	100 000	690	55 000	380	30	30	30
304N	S30451	100 000	690	55 000	380	37	37	37
304LN	S30453	100 000	690	55 000	380	33	33	33
316	S31600	100 000	690	55 000	380	30	30	30
316L	S31603	100 000	690	55 000	380	25	25	25
316N	S31651	100 000	690	55 000	380	32	32	32

TABLE 2 *Continued*

¼ Hard

Type	UNS Designation	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
		psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	125 000	860	75 000	515	25	25	25
202	S20200	125 000	860	75 000	515	12	12	...
...	S20400	140 000	965	100 000	960	20	20	20
205	S20500	125 000	860	75 000	515	45	45	45
301	S30100	125 000	860	75 000	515	25	25	25
302	S30200	125 000	860	75 000	515	10	10	12
304	S30400	125 000	860	75 000	515	10	10	12
304L	S30403	125 000	860	75 000	515	8	8	10
304N	S30451	125 000	860	75 000	515	12	12	12
304LN	S30453	125 000	860	75 000	515	10	10	12
316	S31600	125 000	860	75 000	515	10	10	12
316L	S31603	125 000	860	75 000	515	8	8	8
316N	S31651	125 000	860	75 000	515	12	12	12
XM-11	S21904	130 000	895	115 000	795	15	15	...

½ Hard

Type	UNS Designation	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
		psi	MPa	psi	Mpa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	150 000	1035	110 000	760	15	18	18
205	S20500	150 000	1035	110 000	760	15	18	18
301	S30100	150 000	1035	110 000	760	15	18	18
302	S30200	150 000	1035	110 000	760	9	10	10
304	S30400	150 000	1035	110 000	760	6	7	7
304L	S30403	150 000	1035	110 000	760	5	6	6
304N	S30451	150 000	1035	110 000	760	6	8	8
304LN	S30453	150 000	1035	110 000	760	6	7	7
316	S31600	150 000	1035	110 000	760	6	7	7
316L	S31603	150 000	1035	110 000	760	5	6	6
316N	S31651	150 000	1035	110 000	760	6	8	8

¾ Hard

Type	UNS Designation	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
		psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	175 000	1205	135 000	930	10	12	12
205	S20500	175 000	1205	135 000	930	15	15	15
301	S30100	175 000	1205	135 000	930	10	12	12
302	S30200	175 000	1205	135 000	930	5	6	6

Full Hard

Type	UNS Designation	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
		psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	185 000	1275	140 000	965	8	9	9
205	S20500	185 000	1275	140 000	965	10	10	10
301	S30100	185 000	1275	140 000	965	8	9	9
302	S30200	185 000	1275	140 000	965	3	4	4

[A] This specification defines minimum properties only and does not imply a range. Depending on the work hardening characteristics of the particular grade, either the yield or the tensile strength can be the controlling factor in meeting the properties. The noncontrolling factor normally will exceed considerably the specified minimum.

[B] Type 201 is generally produced with a chemical composition balanced for rich side (Type 201-1) or lean side (Type 201-2) austenite stability depending on the properties required for specific applications.

[C] Annealed material that naturally meets mechanical properties may be applied.

[D] PSS means plate, strip, sheet.

[E] FB means flat bar.

TABLE 3 Free Bend Requirements

Annealed and 1/16 and 1/8 Hard

Type	UNS Designation	Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	1	180	1
202	S20200	180	1	180	1
...	S20400	180	1	180	1
205	S20500	180	1	180	1
301	S30100	180	1	180	1
302	S30200	180	1	180	1
304	S30400	180	1	180	1
304L	S30403	180	1	180	2
304N	S30451	180	1	180	1
304LN	S30453	180	1	180	2
316	S31600	180	1	180	2
316L	S31603	180	1	180	2
316N	S31651	180	1	180	1
XM-11	S21904	180	1	180	1
XM-14	S21460	180	1	180	2

¼ Hard

Type	UNS Designation	Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	1	90	2
202	S20200	180	2	90	2
...	S20400	180	1	90	2
205	S20500	180	1	90	2
301	S30100	180	1	90	2
302	S30200	180	1	90	2
304	S30400	180	1	90	2
304L	S30403	180	2	90	3
304N	S30451	180	1	90	2
304LN	S30453	180	2	90	3
316	S31600	180	2	90	2
316L	S31603	180	2	90	3
316N	S31651	180	1	90	2
XM-11	S21904	90	2	90	2

½ Hard

Type	UNS Designation	Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	2	90	2
205	S20500	180	2	90	2
301	S30100	180	2	90	2
302	S30200	180	2	90	2
304	S30400	180	2	90	2
304L	S30403	180	3	90	3
304N	S30451	180	2	90	2
304LN	S30453	180	3	90	3
316	S31600	180	3	90	3
316L	S31603	180	3	90	3
316N	S31651	180	2	90	2

¾ Hard

Type	UNS Designation	Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	3	90	3
205	S20500	180	3	90	3
301	S30100	180	3	90	3
302	S30200	180	4	90	5

Full Hard

Type	UNS Designation	Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	4	90	5
205	S20500	180	4	90	5
301	S30100	180	4	90	5
302	S30200	180	6	90	8

TABLE 4 V-Block Bend Requirements

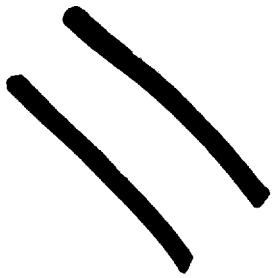
Type	UNS Designation	Annealed and ⅛ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	2	135	3
202	S20200	135	4	135	4
205	S20500	135	2	135	3
301	S30100	135	2	135	3
302	S30200	135	2	135	3
304	S30400	135	2	135	3
304L	S30403	135	5	135	6
304N	S30451	135	3	135	4
304LN	S30453	135	4	135	5
316	S31600	135	5	135	6
316L	S31603	135	6	135	7
316N	S31651	135	5	135	6

Type	UNS Designation	¼ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	2	135	3
205	S20500	135	2	135	3
301	S30100	135	2	135	3
302	S30200	135	2	135	3
304	S30400	135	2	135	3
304L	S30403	135	5	135	6
304N	S30451	135	3	135	4
304LN	S30453	135	4	135	5
316	S31600	135	5	135	6
316L	S31603	135	6	135	7
316N	S31651	135	5	135	6

Type	UNS Designation	½ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	4	135	4
205	S20500	135	4	135	4
301	S30100	135	4	135	4
302	S30200	135	4	135	4
304	S30400	135	4	135	4
304L	S30403	135	7	135	8
304N	S30451	135	5	135	6
304LN	S30453	135	6	135	7
316	S31600	135	7	135	8
316L	S31603	135	8	135	9
316N	S31651	135	7	135	8

Type	UNS Designation	¾ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	6	135	7
205	S20500	135	6	135	7
301	S30100	135	6	135	7
302	S30200	135	8	135	9

Type	UNS Designation	Full Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
		Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	6	135	8
205	S20500	135	6	135	8
301	S30100	135	6	135	8
302	S30200	135	8	135	10



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12

Designation: A 269 – 92

Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service[1]

This standard is issued under the fixed designation A 269; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers grades of nominal-wall-thickness, stainless steel tubing for general corrosion-resisting and low- or high-temperature service, as designated in Table 1.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ¼ in. (6.4 mm) in inside diameter and larger and 0.020 in. (0.51 mm) in nominal wall-thickness and heavier.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. (3.2 mm) in inside diameter or 0.015 in. (0.38 mm) in thickness.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf (20 J) energy absorption or 15 mils lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by ANSI B31.3, for service at temperatures as low as −425°F (−254°C) without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325°F (−198°C) without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when services temperatures are lower than −50°F (−46°C).

1.4 Optional supplementary requirements are provided and, when one or more of these are desired, each shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2,3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[3]

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip[2]

A 632 Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service[3]

2.2 *ANSI Standard:*

B31.3 Chemical Plant and Petroleum Refinery Piping[4]

2.3 *ASME Pressure Vessel Code:*

Section VIII Division 1, Pressure Vessels[5]

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless or welded tubes),

4.1.3 Grade (Table 1),

4.1.4 Size (outside diameter and nominal wall thickness),

4.1.5 Length (specific or random),

4.1.6 Optional requirements (10.6 and Section 12),

4.1.7 Test report required (see Section on Inspection of Specification A 450/A 450M),

4.1.8 Specification designation, and

4.1.9 Special requirements and any supplementary requirements selected.

5. Manufacture

5.1 The tubes shall be made by the seamless or welded process.

5.2 At the manufacturer's option, tubing may be furnished either hot finished or cold finished.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Tubing.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

[5] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

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TABLE 1 Chemical Requirements

Grade	TP 304	TP 304L	TP 304LN	TP 316	TP 316L	TP 316LN	TP 317	TP 321	TP 347	TP 348	TP XM-10	TP XM-11	TP XM-15	TP XM-19	TP XM-29	...	...	...	...	...
UNS Designation[B]	S30400	S30403	S30453	S31600	S31603	S31653	S31700	S32100	S34700	S34800	S21900	S21903	S31300	S22100	S28300	S31254	S31725	S31726	S30600[A]	S24565
	Composition, %																			
Carbon, max	0.08	0.035[C]	0.035[C]	0.08	0.035[C]	0.035[C]	0.08	0.08	0.08	0.08	0.08	0.04	0.08	0.060	0.08	0.020	0.03	0.03	0.18	0.03
Manganese, max[D]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	8.00–10.00	8.00–10.00	2.00	4.00–6.00	11.50–14.50	1.00	2.00	2.00	2.0	5.0–7.0
Phosphorus, max	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.060	0.060	0.030	0.040	0.060	0.030	0.040[E]	0.040[E]	0.02	0.030
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.010	0.030	0.030	0.02	0.010
Silicon[D]	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.00	1.00	1.50–2.50	1.00	1.00	0.80	0.75	0.75	3.7–4.3	1.00
Nickel	8.00–11.0	8.00–13.0	8.00–13.0	11.0–14.0[F]	10.0–15.0	10.0–15.0	11.0–14.0	9.00–13.0	9.00–13.0	9.00–13.0	5.50–7.50	5.50–7.50	17.5–18.5	11.5–13.5	2.25–3.75	17.5–18.5	13.5–17.5	13.5–17.5	14.0–15.5	16.0–18.0
Chromium	18.0–20.0	18.0–20.0	18.0–20.0	16.0–18.0	16.0–18.0	16.0–18.0	18.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	19.0–21.5	19.0–21.5	17.0–19.0	20.5–23.5	17.0–19.0	19.5–20.5	18.0–20.0	17.0–20.0	17.0–18.5	23.0–25.0
Molybdenum				2.0–3.0	2.0–3.0	2.0–3.0	3.0–4.0	...	...	...	...	...	...	1.50–3.00	...	6.00–6.50	4.0–5.0	4.0–5.0	.20	4.0–5.0
Titanium								[G]			...	...		...	...	...	...	...	...	...
Columbium + tantalum									[H]	[H]	...	...		0.10–0.30	...	...	...	...	...	0.1 max
Tantalum, max									...	0.10	...	...		...	...	...	...	...	...	...
Nitrogen[I]			0.10–0.16	...	...	0.10–0.16	...	...	...	...	0.15–0.40	0.15–0.40	...	0.20–0.40	0.20–0.40	0.180–0.220	0.10 max	0.10–0.20	...	0.4–0.6
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	0.10–0.30	...	...	...	...	...	...
Copper	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.50–1.00	0.75 max	0.75 max	0.50 max	...

[A] In previous editions, S30600 was incorrectly shown as S01815.
[B] New designation established in accordance with ASTM E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
[C] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. (12.7 mm) in outside diameter and light wall tubes as those less than 0.049 in. (1.24 mm) in average wall thickness (0.044 in. (1.12 mm) in minimum wall thickness).
[D] Maximum, unless otherwise noted.
[E] For welded tubing, the phosphorus maximum shall be 0.045.
[F] For welded TP316 tubes, the nickel range shall be 10.0–14.0 %.
[G] Grade TP321 shall have a titanium content of not less than five times the carbon content and not more than 0.70 %.
[H] Grade TP347 and TP348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1.0 %.
[I] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

6. Heat Treatment

6.1 All material shall be furnished in the heat-treated condition. Except as provided in 6.2, the heat-treatment procedure shall, except for S31254 (see 6.3 and S24565 (See 6.4)), consist of heating the material to a minimum temperature of 1900°F (1040°C) and quenching in water or rapidly cooling by other means.

6.2 Controlled structural or special service characteristics shall be specified as a guide for the most suitable heat treatment. If the final heat treatment is at a temperature under 1900°F and is so specified on the order, each tube shall be stenciled with the final heat treatment temperature in degrees Fahrenheit after the suffix "HT."

6.3 S31254 shall be heat-treated to a minimum temperature of 2100°F (1150°C) followed by quenching in water or rapidly cooling by other means.

6.4 S24565 shall be heat-treated in the range 2050°F (1120°C) to 2140°F (1170°C) followed by quenching in water or rapidly cooling by other means.

6.5 A solution annealing temperature above 1950°F (1065°C) may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP347, and TP348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S3).

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition as prescribed in Table 1.

8. Product Analysis

8.1 An analysis of either one billet or one length of flat-rolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 A product analysis tolerance of Table A1.1 in Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of .04 % or less.

8.3 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot shall be rejected or, at the option of the producer, each billet, length of flat-rolled stock, or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes which do not meet the requirements of the specification shall be rejected.

9. Mechanical Tests Required

9.1 *Flaring Test (Seamless Tubes)*—One test shall be made on specimens from one end of one tube from each lot (Note 2) of finished tubes.

NOTE 2—The term lot applies to all tubes prior to cutting to length of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a heat-treatment lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a heat-treatment lot shall be determined from the size of the tubes as prescribed in Table 2.

TABLE 2 Number of Tubes in a Lot Heat Treated by the Continuous Process

Size of Tube	Size of Lot
2 in. and over in outside diameter and 0.200 in. (5.08 mm) and over in wall thickness	not more than 50 tubes
Less than 2 in. but over 1 in. in outside diameter or over 1 in. in outside diameter and under 0.200 in. (5.08 mm) in wall thickness	not more than 75 tubes
1 in. or less in outside diameter	not more than 125 tubes

9.2 *Flange Test (Welded Tubes)*—One test shall be made on specimens from one end of one tube from each lot (Note 2) of finished tubes.

9.3 *Hardness Test*—Brinell or Rockwell hardness determination shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

9.4 When more than one heat is involved, the flaring, flanging, and hardness test requirements shall apply to each heat.

9.5 *Reverse Flattening Test*—For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft (460 m) of finished tubing. Coiled tubing greater than 1500 ft (450 m) in length shall be sampled at both ends. A coil must be continuous without any circumferential butt welds.

9.6 *Hydrostatic or Nondestructive Electric Test*—Each tube, seamless or welded, shall be subjected to the Nondestructive Electric Test or the Hydrostatic Test. Unless specified by the purchaser, either test may be used at the option of the producer.

10. Hardness Requirements

10.1 Grade TPXM-29 and S24565 tubes shall have a hardness number not exceeding 256 HB/270 HV or 100 HRB. Grades TPXM-10, TPXM-11, and TPXM-19 tubes shall have a hardness number not exceeding 269 HB/285 HV or 25 HRC. S31254 shall have a hardness number not exceeding 220 HB/230 HV or 96 HRB. Tubes made from all other grades shall have a hardness number not exceeding 192 HB/200 HV or 90 HRB.

10.2 For tubing less than 0.065 in. (1.65 mm) in wall thickness, it is permissible to use the Rockwell superficial hardness test or the Vickers hardness test. When the Vickers test is used, the values of 11.1 will apply. The superficial hardness number for Grade TPXM-29 tubes shall not exceed 80 on the 30 T scale or 92 on the 15 T scale. The hardness number for Grades TPXM-10, TPXM-11, and TPXM-19 tubes shall not exceed 46 on the 30 N scale or 73 on the 15 N scale. The hardness number for S31254 shall not exceed 79 on the 30 T scale or 91 on the 15 T scale. Tubes made from

TABLE 3 Permissible Variations in Dimensions

Group	Size, Outside Diameter, in.	Permissible Variations in Outside Diameter, in. (mm)	Permissible Variations in Wall Thickness,[A] %	Permissible Variations in Cut Length, in. (mm)[B]		Thin Walled Tubes[C]
				Over	Under	
1	Up to ½	±0.005 (0.13)	±15	⅛ (3.2)	0	...
2	½ to 1½, excl	±0.005 (0.13)	±10	⅛ (3.2)	0	less than 0.065 in. (1.65 mm) nominal
3	1½ to 3½, excl	±0.010 (0.25)	±10	3/16 (4.8)	0	less than 0.095 in. (2.41 mm) nominal
4	3½ to 5½, excl	±0.015 (0.38)	±10	3/16 (4.8)	0	less than 0.150 in. (3.81 mm) nominal
5	5½ to 8, excl	±0.030 (0.76)	±10	3/16 (4.8)	0	less than 0.150 in. (3.81 mm) nominal

[A] When tubes as ordered require wall thicknesses ¾ in. (19.0 mm) or over, or an inside diameter 60 % or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in wall thickness of 12.5 % over or under will be permitted.
For tubes less than ½ in. (12.7 mm) in inside diameter which cannot be successfully drawn over a mandrel, the wall thickness may vary ±15 % from that specified.
[B] These tolerances apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft an additional over tolerance of ⅛ in. (3.2 mm) for each 10 ft (3.0 m) or fraction thereof shall be permissible, up to a maximum tolerance of ½ in. (12.7 mm).
[C] Ovality provisions of 11.2 apply.

all other grades shall not exceed 74 on the 30 T scale or 88 on the 15 T scale.

10.3 The hardness test shall not be required on tubes smaller than ¼ in. (6.4 mm) in inside diameter or tubes having a wall thickness thinner than 0.020 in. (0.51 mm) (see S8.4 of Methods and Definitions A 370). Smaller or thinner tubes should be tension tested only, in accordance with Specification A 632.

11. Permissible Variations in Dimensions

11.1 Variations in outside diameter, wall thickness, and length, from those specified, shall not exceed the amounts prescribed in Table 3.

11.2 The permissible variations in outside diameter given in Table 3 are not sufficient to provide for ovality in thin-walled tubes, as defined in the Table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than twice the permissible variation in outside diameter given in Table 3; however, the mean diameter at that cross section must still be within the given permissible variation.

12. Surface Condition

12.1 The tubes shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether the tubing is seamless or welded and the final heat-treatment temperature in degrees Fahrenheit after the suffix "HT" if the final heat treatment temperature is under 1900°F (1040°C).

13.2 When the Nondestructive Electric Test is performed, each length of tubing shall be marked with the letters "NDE," and the certification, when required, shall also indicate this test.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved-annealed condition.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1550 to 1650°F (845 to 900°C) after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes and additional details of this supplementary requirement shall be agreed upon between the manufacturer and purchaser.

S2. Air Underwater Pressure Test

S2.1 Each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi (1034 kPa) minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

S3. Stabilizing Heat Treatment

S3.1 Subsequent to the solution anneal required in Section 6, Grades TP321, TP347, and TP348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S4. Intergranular Corrosion Test

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 3—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S4.2 A stabilization heat treatment in accordance with Supplementary Requirement S3 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

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(b)(4) Drawings

(b)(4) Drawings

(b)(4) Drawings

(b)(4) Drawings

(b)(4) Drawings

(b)(4) Drawings