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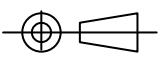
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FORM 09-01	THIRD ANGLE PROJECTION		CUSTODIAN ENGINEERING MANAGEMENT COMMITTEE	REVISION 1
	PROCUREMENT SPECIFICATION NONE	TITLE ADAPTIVE CONTROL SYSTEM FOR NUMERICALLY CONTROLLED MILLING MACHINES	CLASSIFICATION SPECIFICATION NAS994	SHEET 1 OF 21

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1.0 SCOPE

1.1 Purpose

This specification provides a standard for the manufacture, performance, reliability, inspection, and procurement of an Adaptive Control System (ACS) for Numerically Controlled milling machine tools. (Include machine tool description.) This standard lists minimum requirements and is not intended to limit design advances.

1.2 Classification

The Adaptive Control System shall be of the following types and classes:

TYPE I HARDWIRED

The response to sensor signals, i.e., the related modification to machine/controller input signals, is primarily performed by electronic hardware. This does not preclude the need for some processor software requirements such as ACS on/off and constraint codes for machine operating parameters.

TYPE II SOFTWIRED

The response to sensor signals, i.e., the related modification to machine/controller input signals, is primarily performed by software routines. This type of ACS may also include processor requirements as noted in Type I.

CLASS I Slide velocity is the control variable that is modified in response to sensed cutting conditions.

CLASS II Spindle speed is the control variable that is modified in response to sensed cutting conditions.

CLASS III A combination of Classes I and II.

LIST OF CURRENT SHEETS

NO.	REV.	NO.	REV.	NO.	REV.	NO.	REV.
1	NEW	6	NEW	11	NEW	16	NEW
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5	NEW	10	NEW	15	NEW	20	NEW

CUSTODIAN: MANUFACTURING COMMITTEE

PROCUREMENT
SPECIFICATION

TITLE
ADAPTIVE CONTROL SYSTEM FOR NUMERICALLY
CONTROLLED MILLING MACHINES

CLASSIFICATION
SPECIFICATION

NAS 994
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1.3 Intended Use

The Adaptive Control Systems described by this specification are intended for use within the aerospace manufacturing industry, as accessories to NC milling machines to optimize the metal removal process.

2.0 APPLICABLE SPECIFICATIONS, CODES AND STANDARDS

The latest revision of the following specifications, codes and standards are included as a portion of this specification. Detail requirements listed in this specification shall override any contradictory portions of the following specifications, codes and standards, except OSHA or other safety codes in which case the contradiction is to be shown to the customer.

- 2.1 The Joint Industrial Council (JIC) Electrical Standards for General Purpose Machine Tools. EPG-1-1967.
- 2.2 The Joint Industrial Council (JIC) Electronic Standards for Mass Production Equipment and General Purpose Machine Tools, EL-1-71.
- 2.3 The American National Standards Institute (ANSI).
- 2.4 Electronics Industries Association (EIA) Construction Standards, Numerical Machine Tool Control, No. RS-281A, and RS-232-C, RS-408.
- 2.5 National Electrical Code (NEC).
- 2.6 State and Local Safety and Electrical Codes.
- 2.7 National Aerospace Standard 938, Machine Axis and Motion Nomenclature.
- 2.8 National Aerospace Standard 953, Numerical Control Systems.
- 2.9 National Aerospace Standard 955, Interchangeable Perforated Tape Standards, Variable Block Format for Numerically Controlled Equipment.
- 2.10 National Aerospace Standard 972, Glossary of Manufacturing Equipment Terms.
- 2.11 Applicable National Aerospace Standards, Series 900, Machine Tool Specifications.
- 2.12 Occupational Safety and Health Standards, Part 1910 of Chapter XVII of Title 29 of the Code of Federal Regulations. Reference: Occupational Safety and Health Act (OSHA)-1970.

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3.0 REQUIREMENTS

This section sets forth the design and performance requirements for the ACS hardware and software.

3.1 Classes

The systems shall be divided into one of the following classes:

- 3.1.1 The Class I system shall control slide velocity by monitoring cutter/spindle deflection and spindle power.
- 3.1.2 The Class II system shall control spindle RPM by monitoring spindle torque and spindle power.
- 3.1.3 The Class III system shall be a combination of Classes I and II.

NOTE: Alternate controlling parameters may be proposed.

3.2 Design

The manufacturer has the choice of configuration and functional operation of the equipment, except where specifically stated in this specification.

- 3.2.1 The design of the ACS is to be such that the controlled variable(s) shall be continually optimized. This optimization shall be based on the controlling parameters and constraints calculated or established limits.
- 3.2.2 The sensor interface design shall not affect the original machine tool stiffness or impair normal machine tool operations such as use of coolant systems, part clearance, or standard tool holders.
- 3.2.3 There shall be a provision for selecting a constraint limit between 0% and 100% of the controlling parameter (such as spindle torque, spindle bearing load, or spindle horsepower). The user shall specify the controlling parameters. These may include one or more of the following:

- Spindle deflection
- Cutter deflection
- Spindle horsepower
- Spindle Torque
- Cutter temperature
- Chip temperature
- Feed force
- Piece part deflection
- Vibration
- Cutter chip load per tooth
- Tolerance
- Surface finish

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- 3.2.3.1 At customer option, the selected constraint limits may be input by manual methods, by software or by both.
- 3.2.4 The ACS shall be designed so as to not require or permit operator intervention during the cutting operation.
- 3.2.4.1 A customer option may provide for override of the ACS and allow for manual entries such as on/off, null, etc., from the existing operator's control station.
- 3.2.5 On multi-spindle machines the spindle having the highest controlling parameter shall be the controlling spindle. The sum or average of the controlling signals shall not be used.
- 3.2.5.1 At customer's option, visual indicators shall be provided for identification of the controlling and/or overloaded spindle. The indicators shall be of sufficient size to allow the operator, when in his normal operating area, to see the indicators.
- 3.2.5.2 When operating with less than all spindles, the spindles not in use shall not have to be running.
- 3.2.6 The ACS shall be provided with an automatic null control which will nullify all errors resulting from conditions such as temperature variations, vibrations, spindle runout, bearing runout and shift, or spindle residual magnetic fields. A system null control shall be included.
- 3.2.7 Where possible, the G50 series codes per NAS 955 shall be used to control the ACS mode of operation when programmed commands are required.
- 3.2.7.1 G50 through G55....unassigned
 - G56....ACS OFF, Mode 1
 - G57....ACS OFF, Mode 2
 - G58....ACS ON, Mode 1
 - G59....ACS ON, Mode 2
- 3.2.7.2 Should the manufacturer elect to use other codes that are available per NAS 955 (Ref. d,e,p,q,r,u,v, and w), the ACS shall include the required detection, decoding, and storage circuitry.
- 3.2.8 At the customer's option there shall be a self testing feature permitting the operator to perform a brief confidence test of the electronics and calibration. It shall be impossible to leave the ACS in the self test mode.
- 3.2.9 The system shall be so designed that after initial installation a complete calibration can be accomplished without disconnecting wiring or unsoldering connections. The manufacturer is to specify the time required to perform this calibration.

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- 3.2.10 The ACS shall have sensor(s) that detect cutter deflection either directly or by spindle deflection. The deflection may be equated to a vectorial force value. (Classes I and III).
- 3.2.11 At customer option, the ACS shall have the ability to automatically adjust the spindle RPM in order that cutter chip load can be maintained at a constant or within a specified range. (Classes II and III).
- 3.2.12 To facilitate air-gap traversing, the ACS shall respond with speed adequate to protect the cutter, machine, and work piece over the full range of the machine. This pertains to entry to or exit from a cut.
- 3.2.13 With the ACS switched off, the machine shall perform in the normal NC mode on standard NC part programs.
- 3.2.14 Power input to the spindle shall be monitored. The ACS shall control the feedrate in such a manner that the customer defined maximum allowable spindle deflection (force value) and/or spindle power inputs are not exceeded. (Classes I and III).
- 3.2.15 The ACS shall be applicable to rough and finish milling.
- 3.2.16 The ACS shall be capable of monitoring and controlling the forces on standard cutters of 3/8 inch diameter and above.
- 3.2.17 Dimensional integrity and machined finish of the work piece shall not be degraded by implementation of the system on any applicable machine tool.
- 3.3 System Components
 - 3.3.1 The ACS shall be of digital and/or analog circuits using general industry recognized solid state devices and appropriate sensors for monitoring and controlling machine performance.
 - 3.3.2 The ACS shall include some or all of the following components:
 - 3.3.2.1 Sensors for monitoring the controlling parameters.
 - 3.3.2.2 Interconnecting cables between the sensors and the control electronics.
 - 3.3.2.3 Control logic that responds to the sensor inputs and produces signals to modify machine feeds and/or speeds.
 - 3.3.2.4 A separate enclosure and control panel (retrofit applications only).
 - 3.3.2.5 Interface between the ACS and the machine control unit (retrofit applications only).

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3.3.3 Operator's Control.

3.3.3.1 All operating control switches and indicators shall be located convenient to the operator when he is in the normal and established operating position. The location of the controls is to be approved by the customer.

3.3.3.2 The control panel shall include but not be limited to the following:

OPERATING MODE INDICATOR(S)
A FEEDRATE/RPM OVERRIDE METER
NULL INDICATOR

3.3.3.3 At customer's option, controls shall be provided for:

MANUAL CALIBRATION TEST SWITCH
ACS ON/OFF SWITCH
CONTROL OVERRIDE SWITCH
INDICATORS TO IDENTIFY CONTROLLING/OVERLOADED SPINDLE
MANUAL DATA INPUT SWITCH(ES)

3.3.3.4 Interlocks shall be installed to prevent manual interruption of the ACS cycle.

3.3.3.5 At customer's option, outlets from the ACS controller shall be provided to allow instrumentation recordings to be taken during machining. Variables to be recorded shall include RPM, deflection, feedrate, per cent override, or as opted by the customer.

3.4 Construction

The ACS shall be constructed to comply with the requirements of this specification.

3.4.1 Components sensitive to vibration shall be protected.

3.4.2 Components shall be protected from solvents, oils, coolants, lubricants, chips, and other detrimental materials commonly found in the vicinity of machine tool operation.

3.4.3 If used, the spindle deflection sensor package at the machine tool spindle nose shall be constructed to prohibit the entrance of contaminants into the spindle bearing assembly.

3.4.4 All plug-in components (and sub-units that are replaceable as a package) shall be installed so that testing, removal, and replacement may be conveniently effected without removal of other components.

3.4.5 Quick disconnects shall be provided at each hardware component to assure ease of maintenance.