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ENGINEERING

APPARATUS INSTRUCTIONS

ELECTRO-MOTIVE DIVISION
General Motors Corporation
LaGrange, Illinois

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2400

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SUPERSEDES

SUBJECT	GENERAL TOLERANCES FOR MACHINED, FABRICATED, CAST, AND FORGED PARTS AND ASSEMBLIES
AFFECTS MODELS	
PART NOS AFFECTED	
REF. DRAWINGS	

1. PURPOSE AND SCOPE

- 1.1 This Apparatus Instruction establishes general tolerance applicable to all dimensions not individually tolerated.
- 1.2 General tolerances larger or smaller than here stated will be observed only when tolerances are specifically stated on the drawing.
- 1.3 This Apparatus Instruction becomes a part of all General Motors Locomotive Group drawings unless otherwise stated by the drawing. It replaces and supersedes AI 2100 on all GMLG Drawings.

PHILOSOPHY OF ENGINEERING DRAWING INTENT.

Product Engineering drawings are dimensioned line to line and arranged to suit the function and mating relationship of parts to design requirements.

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2. GENERAL

All dimensions are in inches unless otherwise specified on the drawing.

- 2.1 Dimensions describing features may be either nominal or specific. Nominal dimensions convey size information as a result of common usage and relation to published standards, but do not in themselves represent specific size. Commonly used nominal dimensions are pipe sizes, mill rolled sections, structural shapes, sheet metal gages and letter or number sizes of drills and screw threads. The specific dimensions for the nominal sizes are obtained from standard references.

2.1.1 Fractional tolerances apply to fractional dimensions.

- 2.2 No manufacturing or measurement process can produce absolutely exact sizes, and acceptable variances from desired size are applied to descriptive dimensions to insure that part function, interchangeability and appearance are controlled. Acceptable variations of size may be stated either through the use of limit dimensions or nominal dimensions to which a tolerance is applied.

2.2.1 Tolerances and dimensions which are affected by subsequent welding, machining and fabricating processes are not covered by AI 2400.

- 2.3 Limit dimensions are the applicable maximum and minimum size differential.

2.3.1 Bilateral Tolerance

A tolerance in which variation is permitted in both directions from the specified dimension.

2.3.2 Examples of dimensions

4.754

4.750 + .004
- .002

4.748

LIMIT
DIMENSIONS

NOMINAL DIMENSION
BILATERAL TOLERANCE

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- 2.4 Reference Dimension

A dimension, usually without tolerance, used only for information purposes and does not govern production or inspection operations. A reference dimension may be derived from other values shown on the drawing or on a related drawing.

- 2.5 Basic Dimension

A numerical value used to describe the theoretically exact size, shape or location of a feature or datum target. It is the basis from which permissible variations are established by tolerances on other dimensions, in notes or within feature control symbols. Gage dimensions (untoleranced dimensions used to establish gaging points, line or planes) may be specified as "basic" dimensions.

- 2.6 Where interpretation of drawings or dimensioning is required, reference should be made to the General Motors Drafting Standards, 1973 issue, as amended by the Locomotive Group.

3. SHEARED, BURNED, OR FORMED PARTS AND FABRICATED ASSEMBLIES

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- 3.1 For qualification by Quality Control, all fabricated sheet steel assemblies shall be manufactured to a flatness not exceeding 0.19 (3/16) inch deviation in 24.00. The deviation limit shall be proportionately lower when surfaces under 24.00 inches are measured. For example, the allowable flatness deviation will be 0.12(1/8) in 16.00 or 0.06(1/16) in 8.00 inches.
- 3.2 The dimensions as shown on the drawing (unless otherwise stated on the drawing) are line to line allowing for root gap where required, but making no allowance for weld shrinkage, fixture, or assembly fit up clearance.
- 3.3 Tolerances and actual sizes of parts to be fabricated (the responsibility of manufacturing service department and manufacturing department) will be established, as required, to produce parts or fabricated assemblies meeting the following tabulated tolerances or the assembly drawing tolerance, if given.

3.3.1 Tolerances for individual parts, less than 1/4 (.25) thick unless otherwise specified.

DIMENSION	DECIMAL OR FRACTIONAL	Parts 1/4 or less thick & both length & width 36.00" or less	Parts 1/4 or less thick & either length or width greater than 36.00"
		TOLERANCE	
To 15.00 Include	±.06(1/16)	±.08(5/64)	
Over 15.00 to 25.00 Incl.	±.06(1/16)	±.08(5/64)	
Over 25.00 to 36.00 Incl.	±.06(1/16)	±.09(3/32)	
Over 36.00 to 46.00 Incl.	±.06(1/16)	±.11(7/64)	
Over 46.00 to 57.00 Incl.		±.11(7/64)	
Over 57.00 to 67.00 Incl.		±.12(1/8)	
Over 67.00 to 77.00 Incl.		±.12(1/8)	
Over 77.00 to 200.00 Incl.		±.20(13/64)	
Over 200 Incl.		±.30(19/64)	

3.3.2 Example: The tolerance on a part .25 (1/4) x 30.00 x 77.00 would be ± .09 (3/32) on the 30.00 dimension and ± .12 (1/8) on the 77.00 dimension.

3.3.3 The above tolerances will also apply to a machined surface located from a sheared, burned, formed, or rough surface of a piece part, unless otherwise specified.

3.3.4 On all formed parts the radius specified is to the inside, unless otherwise indicated.

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General Tolerances For Machined, Fabricated, Cast, And Forged Parts And Assemblies

3.4 Tolerance for parts over 1/4 (.25) thick and assemblies unless otherwise specified.

DIMENSION	Parts over 1/4 thick and assemblies
	DECIMAL OR FRACTIONAL TOLERANCE
To 15.00 Include.	$\pm .08(5/64)$
Over 15.00 to 25.00 Incl.	$\pm .09(3/32)$
Over 25.00 to 36.00 Incl.	$\pm .11(7/64)$
Over 36.00 to 46.00 Incl.	$\pm .12(1/8)$
Over 46.00 to 57.00 Incl.	$\pm .14(9/64)$
Over 57.00 to 67.00 Incl.	$\pm .16(5/32)$
Over 67.00 to 77.00 Incl.	$\pm .17(11/64)$
Over 77.00 to 200.00 Incl.	$\pm .20(13/64)$
Over 200	$\pm .30(19/64)$

3.5 Tolerances for underframe assembly and hood lengths are to be $\pm .31 (5/16)$ unless otherwise specified.

3.6 Underframe fabrication and hole quality are to be per AI 2134 unless otherwise specified.

3.7 All punched and pierced holes to be free of burrs and sharp edges.

3.7.1 Tolerance on punched and pierce holes $\pm .010$.

3.8 Squareness tolerance for individual parts or fabricated assemblies.

Overall length or width	Parts 1/4 or less thick & assemblies	Parts over 1/4 thick
To 12.00	$.03(1/32)$	$.05(3/64)$
Over 12.00 to 24.00 Incl.	$.06(1/16)$	$.09(3/32)$
Over 24.00 to 36.00 Incl.	$.09(3/32)$	$.14(9/64)$
Over 36.00	$.12(1/8)$	$.16(5/32)$

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4. CAST PARTS GENERAL

4.1 Dimensional tolerance for all castings unless otherwise specified:

Wall Thickness	$+.09(3/32)$ $-.03(1/32)$
Outside Diameter	$+.09(3/32)$ $-.03(1/32)$
Length and Width	$+.09(3/32)$ $-.03(1/32)$
Corner and Fillet Radii	$+.06(1/16)$ $-.00$
Draft (from specified angle)	$+.03/in.(1/32)$ $-.01/in.(1/64)$
Flash Extension	$.12(1/8)$
Actual Mismatch (at parting line)	$.00$ to $.06(1/16)$
Total Mismatch (at parting line)	$.00$ to $.12(1/8)$

5. CAST PARTS SPECIFIC

5.1 Dimensional tolerance for sand castings unless otherwise specified.

Not exceeding 14.00	$+.05$ $-.02 + .003/in.$ of nominal lineal dimension
Over 14.00	$+.09$ $-.03$ plus $.001/in.$ of nominal lineal dimension

5.1.1 Tolerances to a machined surface located from a rough cast surface $+.05/-.02$

5.1.2 Draft angles to be 2° and added to the lineal dimension unless otherwise specified on drawing.

5.1.3 Tolerance on draft angles to be $(\pm 1/2^\circ)$ $.008/in.$, not to exceed a maximum deviation of $.12(1/8)in.$

5.1.4 Angular relationships between any two features $\pm 1^\circ$ unless otherwise specified on drawing.

5.2 Tolerances for large or critical castings will be completely specified on Design Engineering drawings.

5.3 Tolerances for truck frames and bolsters are to be per AI 2401.

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- 5.4 Dimensional tolerance for investment castings per the Investment Casting Institute (I.C.I.) handbook, unless otherwise specified.
- 5.5 Dimensional tolerance for die castings per the American Die Casting Institute (A.D.C.I.) handbook, unless otherwise specified.
- 5.6 Dimensional tolerance for permanent mold castings per the Aluminum Association Inc. (A.A.I.) handbook, unless otherwise specified.

6. FORGED PARTS

- 6.1 Dimensional tolerance for forged parts, unless otherwise specified.

Thickness	$+.09(3/32)$ $-.03(1/32)$
Outside Diameter	$+.09(3/32)$ $-.03(1/32)$
Length and Width	$+.09(3/32)$ $-.03(1/32)$
Corner and Fillet Radii	$\pm(.06)(1/16)$
Draft (from specified angle)	$+.03/\text{in. } (1/32)$ $-.01/\text{in. } (1/64)$
Flash Extension	$.12(1/8)$
Actual Mismatch (at parting line)	$.06(1/16)$
Total Mismatch (at parting line)	$.12(1/8)$

NOTE: Total mismatch is measured parallel to the main parting lines of the dies.

- 6.1.1 These tolerances will also apply to a machined surface located from a rough forged surface.

- 6.1.1.1 Tolerance on draft angles to be $+1/2$ degree ($.008/\text{in.}$), not to exceed a maximum deviation of $.12(1/8)\text{in.}$ from nominal.

- 6.2 Large or critical forgings will be completely dimensioned on Design Engineering Drawings.

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7. MACHINED PARTS

7.1 The following tolerances will apply to all untoleranced dimensions between machined surfaces:

- ± .02 allowed on two place decimals.
- ± .010 allowed on three place decimals and all fractional dimensions.
- ± .0050 allowed on four place decimals.
- ± 0 degrees 30' allowed on angles.

7.1.1 For dimensions between a machined and an unfinished surface the applicable casting, forging, or fabricated tolerance will apply.

7.1.2 Machined surfaces are to be true such that deviations from flatness, parallelism, circularity, or angularity (profile of a surface) are less than .002 per inch of lineal dimension to a maximum of the applicable general tolerance. Any measurement of a dimension is to fall within the tolerance band as stated in Paragraph 7.1 or otherwise specified on the drawing.

7.2 Runout of machined diameters not covered by specific drawing notes is to be within .020 total indicator reading (TIR) or full indicator reading (FIM) between any two diameters.

7.3 Locations of holes in flanges, mounting pads, etc., are to be within .028 diameter of the true position determined by the untoleranced basic dimensions whether located by coordinates or by bolt circle and angular relationship.

7.4 Diametrical tolerances for drilled holes not otherwise restricted are:

Under .250 Dia.	Plus .006 Minus .002
.250 to .750 Dia.	Plus .009 Minus .003
Over .750 to 1.500 Dia.	Plus .010 Minus .005
Over 1.500 Dia.	Plus .015 Minus .005

7.4.1 Drilled holes are to be within .010 per inch of nominal perpendicular or other specified angle unless otherwise specified.

7.5 Surface finish specifications are in accordance with GM Engineering Standards. Surface finish of machined surfaces not having specific designations are to be no greater than 200 micro-inches average roughness when measured in accordance with GM Standards.

7.6 All blind tapped holes must have a countersink of 90° to 118° x one thread deep. All through tapped holes must have a countersink of 90° to 118° x one thread deep on the tap entry side only.

All tapping pads must be applied with the 90° to 118° x one thread deep countersink facing the fastener entry.

7.7 Break all sharp corners .015 $\begin{matrix} +.010 \\ -.000 \end{matrix}$ x 45°

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8. COMMERCIAL TOLERANCES

- 8.1 Commercial tolerance apply to sheet metal gauges, plates, structural, bar stock, tubing, pipe, roller, drawn or extruded sections and standard parts.

9. PIPE, TUBE, CONDUIT DETAILS & ASSEMBLIES

- 9.1 The cutting length tolerance for all pipe, tube and conduit details unless otherwise specified; $\pm .06$.

- 9.2 The following tolerance will apply to all pipe and brazed tube assemblies unless otherwise specified:

Threaded pipe per joint	$\pm .06$
Welded or brazed per joint	$\pm .03$

- 9.2.1 The maximum accumulated allowable tolerance per assembly must not exceed $\pm .25$.

- 9.2.2 Symmetrical welded flange flatness $.03(1/32)$ must not be concave. Non-symmetrical welded flange flatness $.06(1/16)$ must not be concave.

- 9.2.3 Angularity tolerance of threaded fittings $\pm 2^\circ$ brazed or welded fittings $\pm 1/2^\circ$.

- 9.2.4 End to end after bending one or two bends $\pm .12(1/8)$ three or more bends $\pm .25(1/4)$.

- 9.2.5 Break sharp corners on piping means deburr and ream.

- 9.2.6 Angularity tolerance for bend offsets is $\pm 1/2^\circ$.

10. GEOMETRIC DIMENSIONING AND TOLERANCE

- 10.1 Geometric dimensioning and tolerancing is in accordance with GM Drafting Standards, Dated November 1989 Pages A-91 Page 1 through A-91 Page 198 and GMLG Supplements to GM Drafting Standards as issued.

- 10.2 Tolerances as specified in the geometric control block are absolute.

- 10.2.1 Unless otherwise specified on the drawing, perfect form at maximum material condition is required.

- 10.2.2 Unless otherwise specified on the drawing, for diametric features, roundness must be within the maximum material condition (MMC) and the least material condition (LMC). Separate true position callouts may be gaged separately, regardless of datum reference.

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11. METRIC TOLERANCES

- 11.1 Metric Dimensional tolerances are lineal conversions utilizing 25.4 mm/in., unless otherwise specified.
- 11.2 Machining tolerances on metric dimensions, unless otherwise specified on the drawing:
 - ± 0.5 mm allowed on one place decimals
 - ± 0.25 mm allowed on two place decimals
 - ± 0.127 mm allowed on three place decimals
- 11.3 Fabrication tolerance on all metric dimensions for detail drawings unless otherwise specified on the drawing:
 - ± 2.0 mm on one place decimals
 - ± 1.00 mm on two place decimals
- 11.4 Casting/forging tolerances on all metric dimensions are lineal conversions from those specified in Sections 4, 5, and 6.
- 11.5 Fabrication assembly tolerances are lineal conversions from those specified in Section 3.3 and 3.4.

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