

**DDS 070-1
DETERMINATION OF LIST
AND TRIM LIMITS FOR U.S. NAVY
SURFACE SHIPS**



**DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, DC 20362-5101**

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28 Oct. 1987

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070-1-a. References

- (a) General Specifications for Ships of the U.S. Navy, Publication, NAVSEA No. S9AAO-AA-SPN-010/GEN-SPEC
- (b) Ship Design Standards Manual, "List and Trim Limits," SDS 070-2, 25 February 1987.
- (c) "Stability and Buoyancy of U.S. Naval Surface Ships" Design Data Sheet, DDS 079-1, August 1975.
- (d) NAVSEA ltr 9079 Ser 55B/56 of 6 July 1987.

070-1-b. Introduction

The purpose of this design data sheet is to establish standard procedures for determination of the list and trim limits which will apply to U.S. Navy surface ships upon delivery to the Navy; the requirements of this design data sheet are applicable to ships acquired by new construction, conversion, or modernization.

The paragraphs which follow presents the procedures to be used for selecting list and trim limits appropriate to a wide range of U.S. Navy ships; the list and trim limits for new U.S. Navy ships shall be established by means of these procedures.

070-1-c. Definitions

Design Trim. Ships are normally designed to the even-keel condition, that is, with zero trim. However, a specific amount of trim by the bow or stern, is occasionally included in the design and is defined as the "design trim." Design trim, if any, must be taken into account in the determination of trim limits.

List. List defines the static transverse inclination of the ship. List is expressed as the transverse angle between the waterplane (at the DWL) and the base plane of the ship. "List" and "heel" are sometimes considered synonymous; however, heel is more precisely an inclination due to the application of a transient external force such as a beam wind or the dynamic forces which occur in a high speed turn.

Contractual List Limit. The Contractual List Limit (CCL) is the specified maximum list for a new ship in the Full Load condition upon delivery to the U.S. Navy. Normally, port and starboard list limits are the same but not in every case.

Naval Architectural List Limit (NALL). The NALL is the maximum list which a ship at its nominal design displacement condition (usually full load) can tolerate and still meet its design requirements. Port and starboard limits may be different. NALLs are usually greater than CLLs but never less than CCLs.

Trim. Trim defines the static longitudinal inclination of the ship. Trim, as used herein, is expressed as the difference between the drafts at the forward perpendicular and at the aft perpendicular but is elsewhere sometimes expressed as the longitudinal angle between the waterplane (at the DWL) and the base plane of the ship. A trim by the stern, or aft trim, means the draft aft is greater than the draft forward.

Contractual Trim Limit. The Contractual Trim Limit (CTL) is the specified maximum trim for a new ship in the full load condition upon delivery to the U.S. Navy. Contractual Trim Limits Forward (CTLF) and aft (CTLA) frequently are different.

Naval Architectural Trim Limit (NATL). The NATL is the maximum trim which a ship at its nominal design displacement condition (usually Full Load) can tolerate and still meet its design requirements. Naval architectural trim limits forward (NATLF) and aft (NATLA) are usually different. NATLs are usually greater than CTLs but never less than CTLs.

070-1-d. Symbols and Abbreviations

<u>Symbol or Abbreviation</u>	<u>Parameter or Term(s)</u>
CLL	Contractual List Limit
CLLP	Contractual List Limit, Port
CLLS	Contractual List Limit, Starboard
CTL	Contractual Trim Limit
CTLA	Contractual Trim Limit Aft
CTLF	Contractual Trim Limit Forward
NALL	Naval Architectural List Limit
NALLP	Naval Architectural List Limit, Port
NALLS	Naval Architectural List Limit, Starboard
NATL	Naval Architectural Trim Limit
NATLA	Naval Architectural Trim Limit, Aft
NATLF	Naval Architectural Trim Limit, Forward
ESWBS	Expanded Ship Work Breakdown Structure

070-1-e. General Requirements Applicable to List and Trim Limits

Section 070 of reference (a) under the requirements for "Weight and Stability Limits", specifies that the shipbuilder deliver a ship to the U.S. Navy which satisfies the full load condition list and trim limits (CLLs and CTLs, respectively) which are given in the ship specification.

Reference (b) summarizes how the CLLs and CTLs are determined and gives standard values, reproduced in Table I, which are to be used unless NALLs and NATLs are higher (that is, less restrictive). Subsequent sections of this DDS provide guidance in determining NALLs and NATLs.

070-1-f. General Approach to Selection of Naval Architectural List and Trim Limits

In order to establish realistic naval architectural list and trim limits (NALLs and NATLs, respectively) for a particular type and size of ship, the sensitivity of numerous aspects of ship stability and hydrodynamic performance, of all ship systems and subsystems, and of the numerous ship operations, to varying amounts of list and trim is determined as outlined in 070-1-g through 070-1-j, below. The most critical values become the governing NALLs and NATLs for the ship. Since performance requirements, ship system characteristics, and operations can vary substantially from one ship type to another, and can sometimes be quite varied for ship classes within a given ship type, it can be anticipated that governing NALL and NATL values will be different for each ship class.

070-1-g. Determination of Naval Architectural List and Trim Limits Applicable to Ship Stability

List and trim limits applicable to stability are defined as those applicable to a ship's ability to withstand flooding and to a ship's capability to provide required stability after damage.

The applicable requirements for stability after damage and flooding are set forth in reference (c). Based on these criteria, the designer determines the values of intact drafts, list, and/or trim which would not allow a violation of one of the flooding or after-damage stability criteria. Such drafts, list, and/or trim values would then become limiting values with respect to ship stability performance. The limiting draft values from this analysis are known as the subdivision limiting drafts (or corresponding displacement as the subdivision limiting displacement).

070-1-h. Determination of Naval Architectural List and Trim Applicable to Ship Hydrodynamic Performance

Naval architectural list and trim limits applicable to ship hydrodynamic performance are defined as those applicable to the ship's ability to meet its speed-power, seakeeping, maneuvering, and propeller-induced vibration performance requirements. List and trim limits applicable to hydrodynamic performance must be determined by the ship designer after examination of the potential degradation of such performance due to excessive list and trim. To aid in this determination, some potential effects of excessive list and trim on hydrodynamic performance are given in Table II which tabulates the most common effects of list and trim on ship hydrodynamic performance. The ship designer must determine those aspects of hydrodynamic performance which are apt to be the most seriously affected by excessive list and trim and then determine the applicable limiting list and trim values.

070-1-i. Determination of Naval Architectural List and Trim Limits Applicable to Ship Systems and Subsystems

Ship systems and subsystems are considered to be those included in the Expanded Ship Work Breakdown Structure (ESWBS) Groups 1 through 7. List and trim limits must be determined by the ship designer after examination of the potential degradation of the performance of such systems and subsystems due to excessive list and trim. Table III lists considerations in determining these effects. Those aspects of system/subsystem performance which are associated with specific ship operations are discussed in 070-1-j.

070-1-j. Determination of Naval Architectural List and Trim Limits Applicable to Ship Operations

Care must be taken in determining list and trim limits derived from specific operating requirements. Unlike basic design requirements which must be met for the ship in a nominal full load condition at delivery without ballast, once the ship is operational, compliance with fairly stringent operational list and trim limits within a range of displacement conditions may be achieved by use of the ships installed variable ballast capability. Nevertheless, the capability of the variable ballast system to meet these operational limits is still dependent on the ships trim and list status at delivery.

For example, if a ship at delivery is predicted to be just within one of the standard CLLs and CTLs, determined from table I, is not limited by other more stringent NALLs or NATLs but has insufficient variable ballast capability to meet its operational trim requirements, then the CLL or CTL would have to be reduced below the standard value to ensure a satisfactory ship.

Aircraft carriers are a case in point. Operational list and trim limits of reference (d) and the standard limits from table I are compared in table IV. If design calculations indicate that the carrier's variable ballast tanks will permit the ship to meet the operational requirements within the range of expected operating displacement conditions, then the standard values or lowest NALL or NATL can become the CLLs and CTLs. Otherwise, the CLLs and/or CTLs must be reduced or the ship provided with more variable ballast capability.

070-1-k. Selection of Governing Naval Architectural List and Trim Limits

After determination of the potential limiting list and trim values, based on naval architectural considerations and derived in accordance with the discussions under 070-1-g, 070-1-h, 070-1-i, and 070-1-j, above, the most critical list and trim limits are selected; these limits then become the governing naval architectural list and trim limits.

070-1-l. Development of Contractual List and Trim Limits, Ship Specification Inputs

The governing naval architectural list and trim limits (NALLs and NATLs, respectively) are compared with the standard CLLs and CTLs given in table I for the appropriate ship type. Whichever limits are less stringent become the CLLs and CTLs incorporated in Section 070 of the Ship Specifications.

TABLE I. Standard values of contractual list and trim limits for new U.S. Navy surface ships.¹

<u>SHIP TYPE</u>	<u>Contractual List Limit (CLL)</u>	<u>Contractual Trim Limits</u>	
		<u>Forward (CTLF)</u>	<u>Aft (CTLA)</u>
Aircraft Carriers	0.50 deg	2.00 Feet	2.00 Feet
Surface Combatants	0.50	0.50	1.50
Amphibious Warfare Ships	0.50	1.00	2.00
Auxiliaries	LBP < 400 ft. 0.50	1.00	2.00
	LBP 400-600 ft. 0.50	1.00	3.00
	LBP > 600 ft. 0.50	1.00	4.00

¹ Specified values are relative to the even-keel (zero trim) condition or, for those ships having design trim, the design trim condition.

TABLE II. Effects of excessive list and trim on hydrodynamic performance.

Effect can be significantly affected by:

	<u>List</u>	<u>Trim Forward</u>	<u>Trim Aft</u>
<u>I. Speed-Power</u>			
Resistance increase	-	X	X
Bulbous bow efficiency	-	X	X
Propulsive efficiency	-	X	X
Propeller immersion	-	X	-
<u>II. Seakeeping</u>			
Foredeck wetness	X	X	-
Bow thruster emergence	-	-	X
Keel slamming	-	-	X
Sonar dome emergence	-	-	X
Stern wetness	X	-	X
Roll stabilization tank performance	X	-	-
Aircraft elevator wetness	X	X	X
<u>III. Maneuvering</u>			
Directional stability	-	X	X
<u>IV. Propeller-Induced Vibration</u>			
Propeller immersion	-	X	-

TABLE III. Considerations in determining effects of excessive list and trim on ship systems.

<u>ESWBS</u>	<u>SYSTEM</u>	<u>CONSIDERATION</u>
100	Structure	Scantling displacement (draft) limit may affect NATLF and NATLA.
130	Deck Plating	The effectiveness of deck sheer and camber in clearing decks of standing water is reduced or negated.
200	Machinery	Operating "list and trim" limits are given in Sect. 070 of reference (a). These will rarely be governing NALLs or NATLs.
300	Electrical	Same as ESWBS 200
400	Command and Control	Same as ESWBS 200
500	Auxiliary (General)	Same as ESWBS 200
526	Scuppers and Deck Drains	The majority of gravity-type drainage systems onboard U.S. Navy ships are required to use a piping gradient of 0.5 inch per foot, or approximately 2.4 degrees, hence problems with drainage may occur when the list is greater than 2.4 degrees. A trim exceeding 0.5 inch per foot would result in a trim of 20 feet for a 480-foot ship. Hence, drainage systems considerations will usually not be a primary factor in determining a ship trim limit.
528	Plumbing Drainage	Same as ESWBS 526
529	Drainage Ballasting	Same as ESWBS 526
571	Replenishment-at-sea (RAS)	Vertical replenishment (VERTREP) operations are subject to the limitations applicable to helicopter operations; hence, the discussion under ESWBS 586 is applicable. The equipment and machinery used in connected replenishment (CONREP) operations is designed to perform efficiently at ship roll angles up to 15 degrees and ship pitch angles up to 4 degrees. Excessive "built-in" list could degrade CONREP capability in that the available deckedge-to-load clearance would be reduced on the high side of the ship and the available load touch down area (outboard of the kingpost) would be reduced on the low side of the ship. A more restrictive limitation

TABLE III. Considerations in determining effects of excessive list and trim on ship systems. - Continued

<u>ESWBS</u>	<u>SYSTEM</u>	<u>CONSIDERATION</u>
571 (cont'd)		which affects some VERTREP and CONREP operations is that the fork lift trucks used for handling the cargo (on the decks of the ships involved in operations) cannot be used safely at deck inclination angles greater than 7 degrees from the horizontal. Hence, any permanent list will tend to directly limit the conditions (sea-state ship-speed/ship-heading combinations) under which the fork lift trucks can be used.
581	Anchor Handling	Anchor handling systems on U.S. Navy ships are designed such that the anchor will not strike the hull, when being raised or lowered, in a moderate seaway. The criterion is that the flukes of the anchor, when extended toward the hull, must clear the hull by 2 feet when the ship is heeled 5 degrees away from the side on which the anchor is being handled. Excessive list could then result in the anchor striking and damaging the hull bulbous bow, or bow sonar dome. Hence, the geometry of the ship and anchor handling system must be carefully reviewed to ensure that a heel angle of greater than 5 degrees (away from the side on which the anchor is being handled) can be accommodated when handling the anchor; the heel angle (which could be accommodated) should exceed 5 degrees by at least the list angle which is anticipated or which can be tolerated by other subsystems and/or operations. The chain locker is provided with its own sump and drainage system; hence, large values of trim will not have any significant impact on the drainage of the chain locker.
583	Boat Handling and Stowage	In accordance with Section 583 of reference (a), boat davits are designed to raise and lower the boats when the ship has a adverse list of 10 degrees; a minimum of 6 inches of clearance is to be provided between the boats and the deck or deck-mounted items during boat handling operations. If however, the ship has an excessive permanent list, and if heeling (due to damage) should occur to the same side as the permanent list, this compounding of heel angles could result in damage to the boats being raised or lowered on the high side of the ship and/or to ineffective boat handling.

TABLE III. Considerations in determining effects of excessive list and trim on ship systems. - Continued

<u>ESWBS</u>	<u>SYSTEM</u>	<u>CONSIDERATION</u>
586	Aircraft Recovery Support	Currently on ships without Recover Assist Securing and Traversing Systems (RAST), helicopter operations can be conducted when the significant roll angle (single amplitude) is less than 4 degrees. Even moderate values of list could limit the allowable roll angle, especially if the landing area is wet. On ships fitted with RAST, helicopter operations are considered to be feasible at significant roll angles up to 8 degrees. Excessive values of trim, which could increase deck wetness due to spray and possibly cause helicopters to skid, could decrease air operations effectiveness. Aircraft carriers are required to meet restrictive list and trim limits for aircraft operations (see Table IV), which determine the capacity of the variable ballast tank system. Excessive values of list or trim at ship delivery can exceed the variable ballast tank system capacity and reduce aircraft operations safety.
587	Aircraft Launch Support	Same as ESWBS 586
588	Aircraft Handling, Servicing, and Stowage	Same as ESWBS 586
600	Outfit and Furnishings	Same as ESWBS 200
700	Armament	Same as ESWBS 200

TABLE IV. Aircraft carrier list and trim limits.

	Unrestricted Operations (Fixed-wing Aircraft <u>Take-off and Landing</u>)	Standard <u>Contractual</u>
List	0.50 Degrees	0.50 Degrees
Trim-Forward	4.00 Feet	2.00 Feet
Trim-Aft	4.00 Feet	2.00 Feet

a. Section 070 of publication, NAVSEA No. S9AAO.AA.SPN-010/Gen. Spec. requires that the shipbuilder deliver each ship to the Navy within the Full Load condition list and trim limits specified for each new ship design in the detailed ship specifications. These list and trim limits exclude the effects on list and trim of weight and moment changes in Government Furnished Material and those resulting from contract modifications. The values of list and trim which determine compliance with the limits are based on the Inclining Experiment with the corrections required to bring the ship to the Full Load condition. The installation of permanent ballast is not an acceptable means to correct the list or trim of the ship to satisfy the limits.

b. The list and trim limits will be set for each ship class on the basis of their effects on hydrostatic stability, hydrodynamic performance, machinery and equipment performance, and ship operations. The required minimum freeboard in the intact and damaged stability calculations of Design Data Sheet DDS 079-1 determines the maximum list and trim for hydrostatic stability. The required powering, seakeeping and directional stability performance of the ship determine the maximum list and trim for hydrodynamic performance according to Design Data Sheet DDS 070-1. Those pieces of machinery and equipment which are most sensitive to the effects of list and trim determine the maximum list and trim limits for machinery and equipment performance. The operation of aircraft, replenishment-at-sea, stores strikedown, or other operations set the maximum list and trim limits for ship operations. The lowest values of list and trim limits determined above become the maximum acceptable list and trim values from a ship design standpoint. The list and trim limits specified in the ship specifications are to ensure that the shipbuilder delivers an essentially level ship. If the governing design list and trim values are higher than those given in the following table, the design values will be used in the specifications, otherwise the following standard values will be used.

Ship Type	List, deg	Trim, ft by the	
		Bow	Stern
Carriers	0.50	2.00	2.00
Combatants	0.50	0.50	1.50
Amphibious	0.50	1.00	2.00
Auxiliaries (< 400 ft)	0.50	1.00	2.00
Auxiliaries (400-600 ft)	0.50	1.00	3.00
Auxiliaries (> 600 ft)	0.50	1.00	4.00

If a more stringent list or trim value is required to meet design requirements, then this more restrictive value is specified. At the end of contract design the calculated list and trim shall be less than the limits to allow for changes during detail design and construction, otherwise corrective action shall be taken.