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GROUND-WIND RESTRICTIONS
PROCEDURE FOR
ATLAS/CENTAUR/SURVEYOR
AC-6 AND AC-7

Report Number GD/C-BTD65-061
1 June 1965

Contract Number NAS3-3232

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"The winds in the East . . . I am always conscious of an uncomfortable sensation now and then when the wind is blowing in the East."

– Dickens, Bleak House.

"Ill blows the wind that profits nobody."

– Shakespeare, Henry VI, Act ii.

The following persons and their engineering groups have also been instrumental in preparing the information in this document. It is published with their concurrence; and any questions concerning it should be directed to them.

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FOREWORD

This report has been prepared and published in compliance with the provisions of Contract NAS3-3232 which specify structural dynamic-loads and design-determination requirements as outlined in Item 147 of the Centaur Documentation Requirements Plan, Report Number 55-00207E, dated 11 January 1965 (General Dynamics/Astronautics). This report supersedes Report Number GD/A-BTD65-024, dated 8 February 1965 (Reference 1). Its purpose is to present ground-wind restrictions and associated information for Atlas/Centaur/Surveyor Vehicles AC-6 and AC-7, consistent with the most recent ground-wind loads study.

The assumptions and limitations implicit in the information presented herein are essentially those associated with the generation of the corresponding ground loads and are described in References 2 through 9.

The inclusion of a separate set of wind restrictions and minimum pressure requirements for certain wind-direction "sectors" should be noted. This necessary complication has evolved from wind tunnel studies at Ames Research Center (ARC) and from configuration changes.

SUMMARY

This report contains ground-wind restrictions and associated information for the Atlas/Centaur/Surveyor, vehicles AC-6 and AC-7, at the Eastern Test Range (ETR) while erected on the launcher pad at Complex 36A or 36B. Limiting wind speeds for the Atlas/Centaur vehicle while on automatic pressure regulation – both free-standing and with tower in place – are presented in tabular form for normal launch sequence tanking conditions. For certain wind directions there are limiting wind speeds based on launcher capability, and these are denoted as such. Recommended courses of action are contained in this report in the event that wind speeds and/or vehicle pitch and yaw rate gyro responses exceed the specified allowable values during normal sequence tanking.

Maximum allowable recorded wind speeds and rate gyro responses for other possible tanking conditions are presented in graphical form for Atlas Step I, II, and III pressures in Appendix B. These data are presented for special tanking tests, as well as to cover conditions which could occur due to some malfunction.

The introduction of the wind direction and structural capability as controlling parameters is explained and illustrated. Also discussed at some length are the minimum differential pressures required across both the Atlas and Centaur intermediate bulkheads.

Appendix A is furnished primarily for use by those persons directly concerned with the launch, in the event that the Bendix Aerovane Anemometer becomes inoperative. Included in Appendix A is a normalized wind profile which can be used should the aforementioned situation occur.

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SECTION I

INTRODUCTION

1.1 CONTENTS

This report contains the results of a study of nearly all possible tanking conditions for the erected, free-standing Atlas/Centaur/Surveyor vehicles AC-6 and AC-7. The minimum pressures of Reference 1-1 and the equivalent of Reference 1-2 for AC-6 and AC-7 have been used to determine allowable wind speeds while tanking, or holding, under automatic pressure control. Also presented are procedures to be followed in the event that maximum recorded wind speeds and Centaur or Atlas rate gyro responses should exceed the allowable values.

1.2 CHANGES FROM AC-5

The following significant differences exist between the AC-5 and AC-6, -7 ground-wind analyses and Eastern Test Range (ETR) operational procedures:

a. A refined statistical method is used for combining individual steady-state, gust, and vortex-shedding bending moments (see References 6, 7, and 8).

b. Vehicle stiffness has changed somewhat, due to differences in Centaur skin gauges and use of the operational interstage adapter. The stiffness changes have, in most cases, reduced the Centaur rate gyro response allowable curves to values close to the Atlas rate gyro response allowable curves. For this reason, only Atlas curves (zero to peak) have been presented in this report. If for some reason Centaur rate gyro response allowable curves become necessary, the Atlas curves as herein presented can be used conservatively in their stead.

c. Atlas pitch and yaw rate gyro response and wind speed* and direction* are now recorded on a single strip-chart recorder. In addition, Atlas pitch or yaw rate gyro response is plotted versus wind speed on an X-Y plotter. This plotter plots wind speed on the X axis and is capable of switching from Atlas yaw rate response to pitch rate response on the Y-axis plot.

Non-external configuration changes such as changes in Surveyor payload weights create only minor differences in the loads analysis.

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*As recorded by the Bendix AN/GMQ-11 (Aerovane) anemometer located on a 90-foot mast northeast of the ETR Complex 36A blockhouse.

Since the Atlas vehicle skins, the minimum pressures, and the launcher have not changed since AC-5, the bending moment allowables for AC-6 and AC-7 are identical to those of References 3, 4, and 5.

1.3 GENERAL NOTES

1.3.1 MINIMUM PRESSURE QUALIFICATIONS. The minimum pressure requirements, which appear both in Table 2-1 and in Appendix B, represent recorded pressures and, as such, reflect corresponding instrumentation errors as indicated below:

a. Atlas fuel tank: +1.1 psi
b. Atlas LO_2 tank: +0.8 psi
c. Centaur LO_2 tank: +0.5 psi
d. Centaur LH_2 tank: +0.3 psi

The equivalent of Reference 1-2 for AC-6 and AC-7 should be consulted for the appropriate upper red-line values.

1.3.2 LIMITING WIND-SPEED QUALIFICATIONS. The Maximun Allowable Recorded Wind Speeds as denoted by MARWS in this report, make no allowance for the precision of the anemometer being used. It is therefore necessary to use an appropriate calibration curve in order to adjust the limiting wind speeds contained in this report. These limiting wind speeds do reflect, however, the inability of the anemometer to record the actual wind speed as stated in Appendix A, Paragraph A-1.

SECTION II

DISCUSSION

2.1 MAXIMUM ALLOWABLE RECORDED WIND SPEED

There are two major considerations which determine the magnitude of the Maximum Allowable Recorded Wind Speed (MARWS). These are the structural capability and the wind direction.

2.1.1 STRUCTURAL CAPABILITY. When the wind is blowing on the free standing Atlas/Centaur vehicle, bending moments are induced throughout the length of the vehicle.

2.1.1.1 Moments on Tank Skins. The bending moments which are induced on the vehicle skins must be reacted by sufficient internal tank pressure to ensure that skin compressive stability problems will not arise. Raising the internal tank pressure will increase the MARWS only if the tank skins are critical.

2.1.1.2 Moments on Station 1133 Latches. At vehicle Station 1133 the latches are located which join the Atlas booster section to the sustainer stage. The bending-moment capability of these latches is limited by the amount of tension that the latches can withstand. The latch allowables are independent of tank pressure. The more propellants that are tanked aboard, the less critical the latches become.

2.1.1.3 Moments on Launcher Supports. The bending moments about the pitch axis are reacted by the main launcher supports at vehicle Station 1191. Since the main launcher supports are extremely strong, Station 1191 never becomes critical for any tanking condition.

The bending moments about the yaw axis, however, must be reacted by the auxiliary launcher supports at vehicle Station 1206. Unfortunately, the strength of the auxiliary launcher supports is of such magnitude as to limit the value of the MARWS for many tanking conditions. Since internal tank pressure has no effect on the strength capability of the auxiliary launcher supports, raising the tank pressures in no way affects the MARWS when the launcher is critical.

2.1.1.4 Effect of Raising Tank Pressures. In some cases when the tank skins are initially critical, the MARWS may be increased by raising the tank pressures, but this increase is effective only up to a value limited by the capability of the Station 1133 latches or the Station 1206 auxiliary launcher support allowables. In other cases, when the latches or auxiliary supports are initially critical, raising the tank pressures will not increase the MARWS.

2.1.2 WIND DIRECTION. Reduction and correlation of the vortex-shedding coefficients generated at Ames Research Center (ARC) has revealed that, with the wind blowing from 15° east of north* for Eastern Test Range (ETR) Complex 36A (see Figure 2-1a) or from 25° east of north for ETR Complex 36B (see Figure 2-1b), vortex-shedding effects are produced which greatly exceed those produced at all other orientations. It is believed that

*True azimuth.

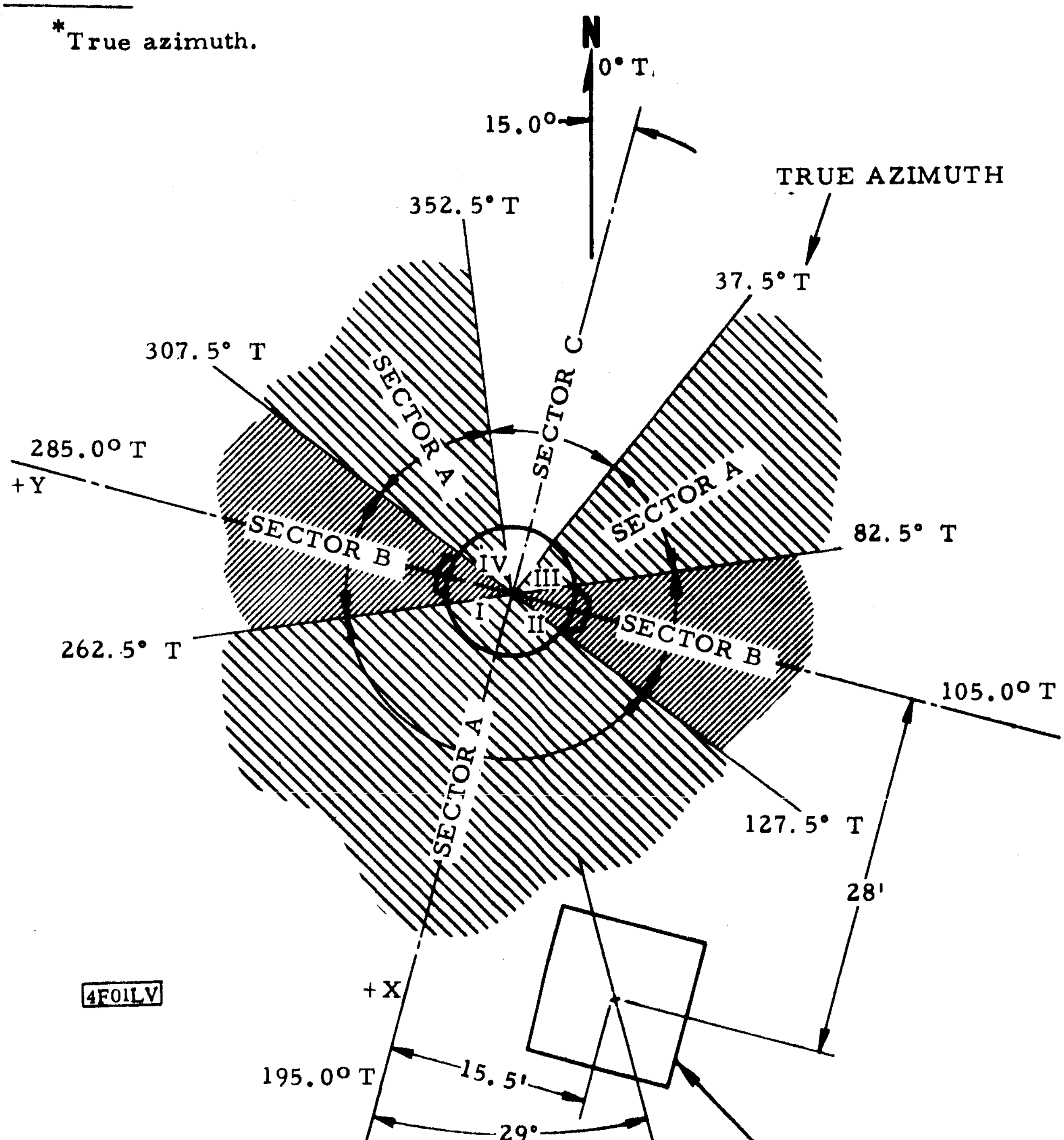


Figure 2-1a. Vehicle Orientation – Eastern Test Range Launch Complex 36A

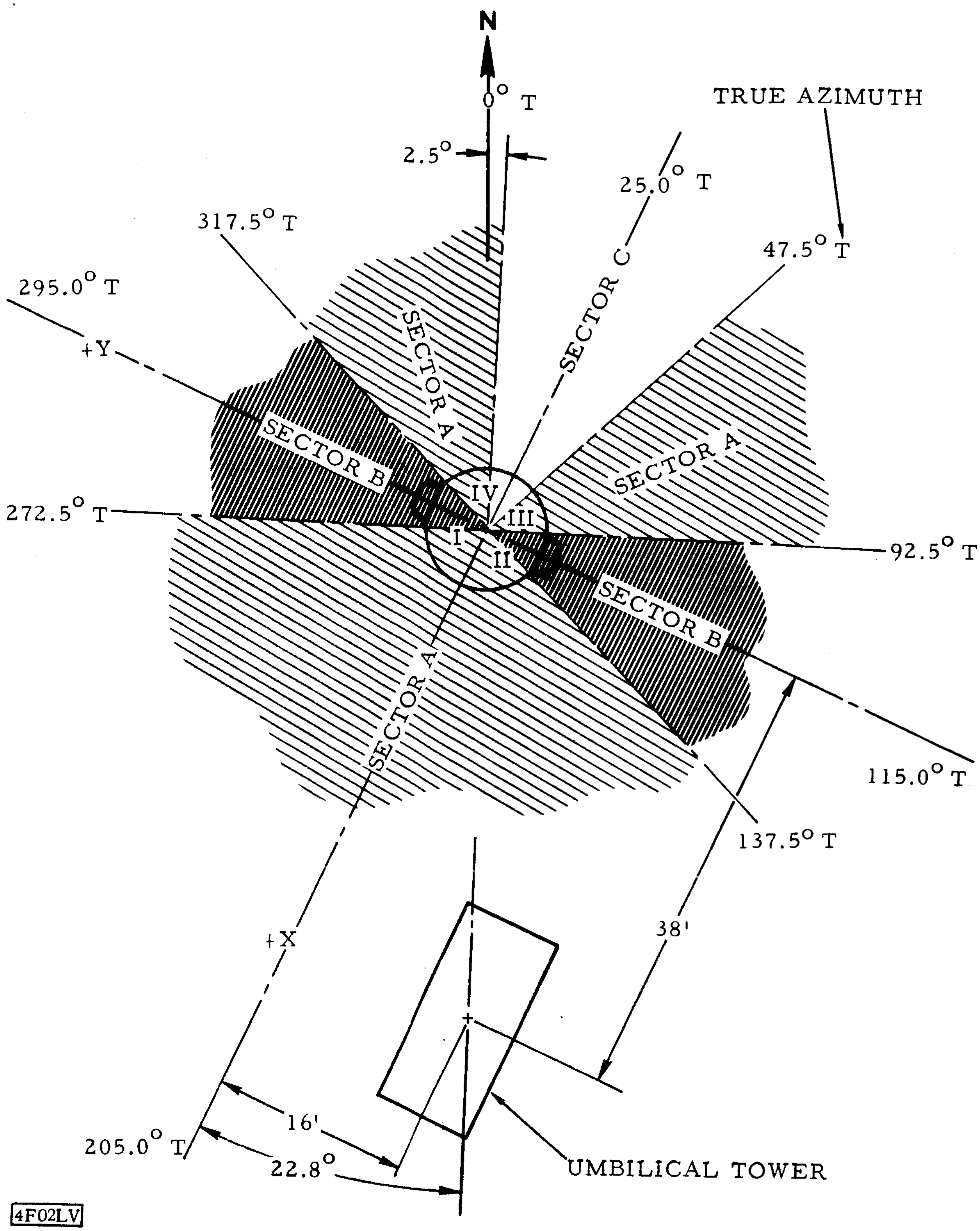


Figure 2-1b. Vehicle Orientation - Eastern Test Range Launch Complex 36B

these vortex-shedding effects were induced by the Centaur insulation panel antenna tunnels located on the Y-Y axis. With the addition of a dummy antenna tunnel on the -X axis insulation panel of vehicles AC-3 and on, it is also believed that large vortex-shedding effects may occur with winds blowing in the 105° T and 285° T orientations for Complex 36A and in the 115° T and 295° T orientations for Complex 36B.

In order to fully ensure the safety of the vehicle, the wind restrictions are given for three sectors.

2.1.2.1 Wind from Sector B. For Sector B (see Figure 2-1a when referring to Complex 36A or Figure 2-1b for Complex 36B), the vortex-shedding phenomenon causes severe oscillations in a direction perpendicular to the wind. Since the auxiliary launcher support, which is relatively weak, must react the entire lateral bending moment, it becomes the critical item for most conditions regardless of Atlas or Centaur tank pressures.

2.1.2.2 Wind from Sector C. For Sector C (see Figure 2-1a when referring to Complex 36A or Figure 2-1b for Complex 36B), severe lateral oscillations may likewise exist due to vortex shedding. However, in this plane, the main launcher supports, which are extremely strong, react all bending moments. The vehicle tank skins then become critical for Sector C winds.

2.1.2.3 Wind from Sector A. For Sector A (see Figure 2-1a when referring to Complex 36A or Figure 2-1b for Complex 36B), wind tunnel tests have shown that the induced lateral oscillations are substantially smaller than those which may occur in Sectors B and C. In most cases, the critical item again becomes the auxiliary launcher supports.

2.2 USE OF RATE GYROS

2.2.1 VEHICLE PITCH AND YAW RATE GYRO RESPONSE. The limitations, as explained above, are based upon the assumption that random vortex-shedding effects exist and that the magnitudes of the induced loads can reach the three-sigma value defined by the ARC wind-tunnel tests. Since these vortex-shedding loads are based upon data from a wind-tunnel model of slightly different configuration, the actual magnitudes arising during any time period may be considerably less than the ARC data indicate.

To evaluate these random effects, vehicle rate gyros (which measure the vehicle dynamic response) can be monitored and used as a means of determining the actual dynamic response of the erected Atlas/Centaur vehicle. When this procedure is followed, the recorded wind speed and both pitch and yaw rate gyro outputs (either Atlas or Centaur) must be monitored simultaneously. It is strongly recommended that the past history (from 15 to 30 minutes) of the gyro outputs be used as a partial basis for determining whether a dangerous condition is likely to occur.

2.2.2 VEHICLE RATE GYRO GROUNDING. During the tanking sequence, rate gyros may be grounded for certain short periods of time in order to provide for prelaunch checkouts. During those times when the gyros are grounded, it is mandatory that the following procedure be pursued:

a. Obtain at least four (4) minutes of wind-speed and wind-direction traces taken at the tanking condition that will exist while the gyros are grounded. This four-minute sample is to be obtained at a time immediately preceding that during which the gyros are to be grounded.

b. Ground the gyros while continuously monitoring the Maximum Recorded Wind Speed (MRWS).

c. Determine the safety of the vehicle as follows:

(1) If the MRWS, during the gyro-grounded time periods, does not exceed three (3) knots above the MRWS as obtained from the four-minute sample traces,

AND

(2) If the wind direction does not shift farther than ten (10) degrees beyond the four-minute sample trace envelope,

then the vehicle may be assumed to be in a safe condition and checkout tests can continue.

d. However, if either variation or both are greater than allowed above, take action to end checkout and immediately begin to monitor vehicle rate gyro outputs.

2.3 MINIMUM ULLAGE PRESSURE DIFFERENCES

The minimum differential pressure required across the intermediate bulkhead of the Atlas vehicle is 3.0 psi. This corresponds to a difference in ullage pressure of 3.0 psi when the liquid-oxygen tank is empty and 21.5 psi when the liquid-oxygen tank is full. The higher pressure is required in the RP-1 tank.

The minimum differential pressure required across the intermediate bulkhead of the Centaur vehicle is 2.6 psi. This corresponds to a difference in ullage pressure of 2.6 psi when the liquid-hydrogen tank is empty and 3.2 psi when the liquid-hydrogen tank is full. The higher pressure is required in the liquid-oxygen tank.

The minimum ullage pressures specified above are sufficient only to prevent reversal of the intermediate bulkheads. For some tanking conditions, however, the pressure differential required for the Atlas may be more than this minimum in order to maintain structural capability of the Atlas RP-1 tank.

2.4 WIND RESTRICTIONS FOR VARIOUS TANKING CONDITIONS

2.4.1 SPECIFIED WIND SPEEDS. Wind speeds specified herein are as recorded by the Bendix AN/GMQ-11 (Aerovane) anemometer at ETR Complex 36A, located on a 90-foot mast northeast of the blockhouse. Figure A-2 of Appendix A is to be used in the event of failure of this anemometer. It is most strongly recommended that Appendix A be read by those persons concerned with these wind restrictions.

2.4.2 ENVELOPE OF RESTRICTIONS FOR ANY FREE-STANDING TANKING CONDITION. In most cases the condition occurring when all tanks are full of propellants is the most critical for ground winds. Figure 2-2 presents a curve, based upon the all-full condition, which depicts the envelope of all critical conditions which may arise due to any of the normal sequence or

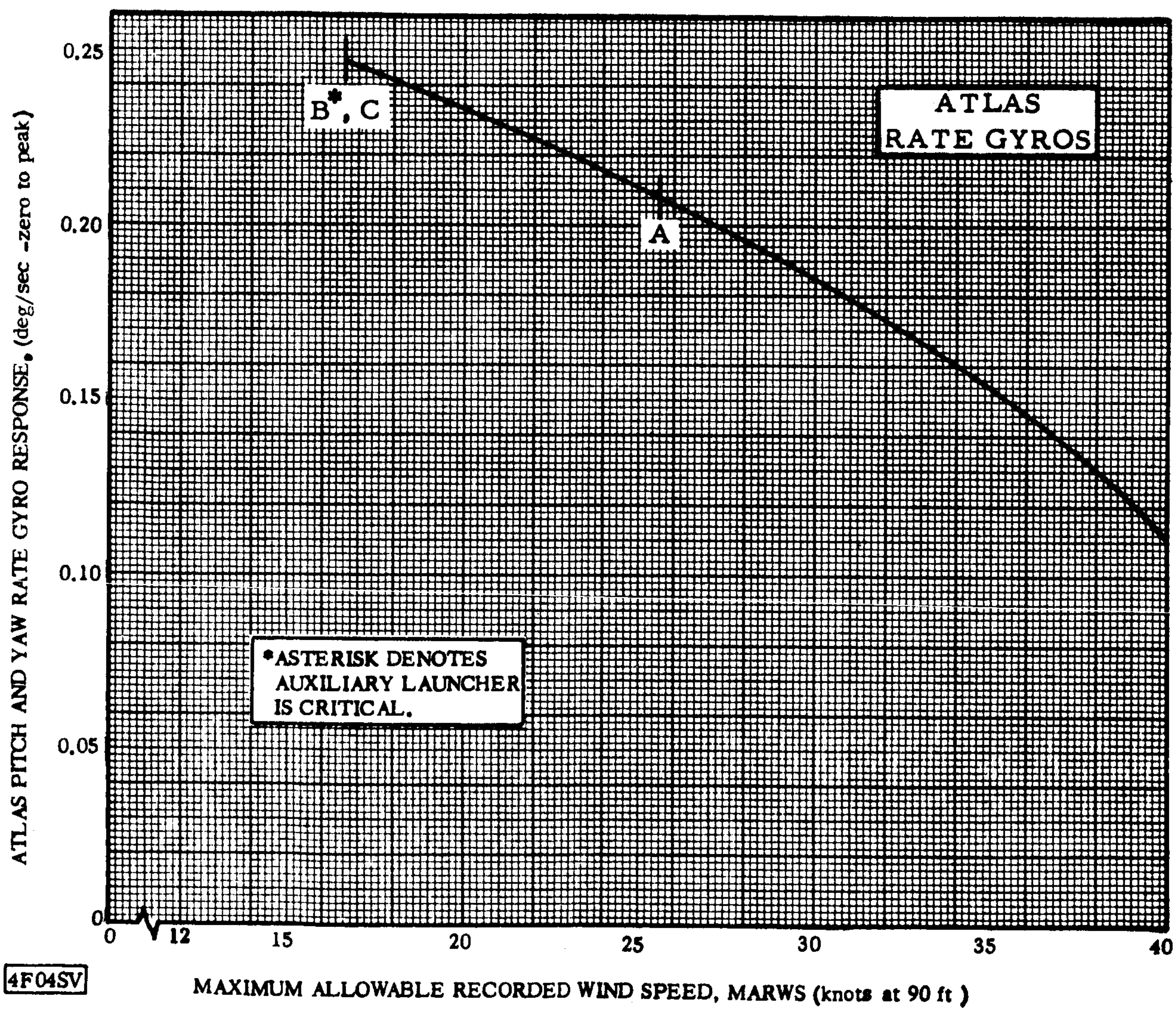


Figure 2-2. Envelope of Wind Restrictions to be Used when Monitoring Atlas Rate Gyros

malfunction configurations except Step I pressures with cryogenics tanked. Therefore, as long as the rate gyro response remains within the allowable limits of Figure 2-2, the structural integrity of the free-standing Atlas/Centaur vehicle will be ensured for all configurations except Step I pressures with cryogenics tanked. For any MRWS below 16.5 knots, it is not required to monitor the rate gyro response regardless of wind direction. This point is designated by B, C in Figure 2-2.

If the MRWS is from 16.5 to 25.7 knots and the wind is blowing in Sectors B or C, the rate gyros must be monitored along with wind speed. In Figure 2-2 this region is bounded by the points B, C and A. If the MRWS exceeds 25.7 knots, as designated by Point A, rate gyro response must be monitored regardless of wind direction. It should be noted that the shape of the rate gyro response curve is independent of wind direction.

2.4.3 RESTRICTIONS FOR NORMAL-SEQUENCE TANKING. The procedure for determining ground-wind restrictions under normal-sequence tanking conditions is given in the following paragraphs.

2.4.3.1 <u>Tanking and Detanking Procedures.</u> The normal tanking sequence for AC-6 and AC-7 is as follows:

a.	Tank Atlas RP-1	100 percent full
b.	Tank Centaur LO_2	50 percent full
c.	Tank Atlas LO_2	100 percent full
d.	Tank Centaur LH_2	100 percent full
e.	Tank Centaur LO_2	100 percent full

The flow chart of Figure 2-3 contains tanking and recommended detanking procedures. The dotted arrows and boxes are presented to account for possible special tanking tests or malfunctions, either of which may require complete or partial detanking of the erected Atlas/Centaur vehicle. The procedures shown in dotted boxes and lines should be used only if the normal procedures (as shown by solid boxes and flow lines) cannot be followed.

2.4.3.2 <u>Table of Wind Restrictions.</u> Table 2-1 contains limiting wind speeds for normal-sequence tanking. In order to determine corresponding Maximum Allowable Recorded Wind Speeds for tanking sequences other than that specified in Table 2-1, refer to Paragraph 2.4.4.

It should be noted that the pressures listed in Column C of Table 2-1 represent in each case the minimum pressure as it appears on the recorder and not the pressure existing in the tank. The pressure corrections of Paragraph 1.3.1 were applied to the design minimums.

TABLE 2-1. GROUND-WIND RESTRI

A				B	C		
VEHICLE CONDITION (See Section 2.4.4 for other conditions)				COND No.	MINIMUM TANK PRESSURES		
					Centaur		At
					LH_2	LO_2	LO_2
In Process of Erection or Removal	Erection or Removal of Atlas First Stage			1		N. A.	6.3
In Process of Erection or Removal	Erection and Mating and/or Removal of Centaur Second Stage from First Stage		Without Stabilizer	2	4.5	7.5	6.2
In Process of Erection or Removal	Erection and Mating and/or Removal of Centaur Second Stage from First Stage		With Stabilizer and Tag Lines	3	4.5	7.5	6.2
In Process of Erection or Removal	Mating Payload			4	4.5	7.5	6.2
Atlas with Centaur Mounted	Vehicles in Tower, All Tanks Empty	Curtains and Windows Closed	Vehicles in Stretch, 13,500 ± 500 lb	5	0.0 (in stretch)	0.0 (in stretch)	0.0 (in stretch)
Atlas with Centaur Mounted	Vehicles in Tower, All Tanks Empty	Curtains and Windows Closed	No Stretch	6	4.0	9.6	6.2
Atlas with Centaur Mounted	Vehicles in Tower, All Tanks Empty	Curtains and Windows Open (5)		7	4.0	9.6	6.2
Atlas with Centaur Mounted	Vehicles on Launcher, Tower Removed (free-standing)	Atlas RP-1 Only	Atlas Step I Pressures (5)	8	4.0	9.6	6.2
Atlas with Centaur Mounted	Vehicles on Launcher, Tower Removed (free-standing)	Atlas RP-1 Only	Atlas Step II Pressures (5)	9	4.0	14.0	9.3
Atlas with Centaur Mounted	Vehicles on Launcher, Tower Removed (free-standing)	Half Empty Centaur LO_2, Atlas RP-1 (5)		10	4.0	14.0	9.3
Atlas with Centaur Mounted	Vehicles on Launcher, Tower Removed (free-standing)	Half Empty Centaur LO_2, Atlas LO_2, Atlas RP-1 (5)		11	4.0	14.0	9.3
Atlas with Centaur Mounted	Vehicles on Launcher, Tower Removed (free-standing)	Centaur LH_2, Half Empty Centaur LO_2, Atlas LO_2, Atlas RP-1 (5)		12	4.0	14.0	9.3
Atlas with Centaur Mounted	Vehicles on Launcher, Tower Removed (free-standing)	All Tanks Full	Atlas Step II Pressures (5)	13	4.0	14.0	9.3
Atlas with Centaur Mounted	Vehicles on Launcher, Tower Removed (free-standing)	All Tanks Full	Atlas Step III Pressures (5)	14	4.0	14.0	24.3

*For notes referenced by numbers in parentheses, see Paragraph 2.4.3.3.

 (1)

	D	E	F
sig) (1)* / RP-1	WIND FROM SECTOR(S) (2) (See Fig. 2-1a and 2-1b)	MAXIMUM ALLOWABLE RECORDED WIND SPEED (knots) (3)	RECOMMENDED ACTION WHEN WIND IS PREDICTED TO EXCEED MAXIMUM ALLOWABLE SPEED (4)
13.6	A		a. Delay erection until winds recede.
	B	28.9	b. Accomplish removal (for hurricanes) prior to reaching MARWS.
12.1	A		
	B	10.7	Same as above.
	C		
12.1	A		
	B	25.0	Same as above.
	C		
12.1	A		
	B	10.7	Same as above.
	C		
0.0 (in stretch)	A		(Will only be exceeded during hurricane or
	B	43.4	extreme storm conditions.) Proceed with
	C		removal.
12.1	A		
	B	43.4	Same as above.
	C		
12.1	A		
	B	28.8	Return to condition 6. (6)
	C		
12.1	A	27.9	Do not remove service tower; or return
	B	23.8	service tower if removed.
	C	23.8	(6)
58.1	A	35.3 (7)	
	B	28.7 (7)	Same as above. (6)
	C	28.7	
58.1	A	31.4 (7)	
	B	23.5 (7)	Return to condition 9. (6)
	C	23.5	
58.1	A	27.7 (7)	
	B	* 17.7 (7)	Return to condition 10. (6)
	C	18.9	
58.1	A	27.7 (7)	
	B	17.3 (7)	See Figure 2-4. (6)
	C	17.3	
58.1	A	27.7 (7)	
	B	16.5 (7)	See Figure 2-4. (6)
	C	16.5	
58.1	A	27.7 (7)	
	B	16.5 (7)	See Figure 2-4. (6)
	C	27.7 (7)	

*For alternative recommended procedures, see Paragraph 2.4.3.4 and Figure 2-4.

While tanking or detanking a particular tank, the more severe wind restriction should be imposed for that condition, whether it corresponds to the inception or the completion of the tanking. For a simultaneous tanking, the more severe wind restriction of the possible combinations should be employed. Paragraph 2.4.4 and associated figures of Appendix B are to be consulted as required.

If the test conductor believes that the Maximum Recorded Wind Speed will exceed the values indicated in Column E of Table 2-1, he should take the recommended action described in Column F of the table, corresponding to the configuration and wind direction noted, i.e., the direction from which the wind is blowing. The intent of the course of action recommended in Column F is to outline a logical and effective procedure for returning the vehicle to a condition capable of withstanding excessive winds, when they do occur, for normal sequence tanking conditions. These procedures are identical to those of Figure 2-3 and are based on the information contained in Column E, as well as on ETR range-safety requirements. Thus, in the event that excessive winds occur for some tanking condition not specified in the table, the allowable wind speeds specified in Appendix B and the flow diagram of Figure 2-3 will enable an appropriate procedure to be developed to ensure the safety of the vehicle.

Due to the significant amount of time involved in performing the operations outlined in the recommendations, it is necessary that such action anticipate, rather than follow, the occurrence of excessive winds.

2.4.3.3. Notes for Wind Restriction Table. The following notes apply to Table 2-1. When any number in Table 2-1 appears in parentheses, the applicable note should be consulted for further information.

(1) See "General Notes," Paragraph 1.3.1.

(2) The wind speeds are applicable to a given sector whenever the wind is blowing from an azimuth within that sector.

(3) The Maximum Allowable Recorded Wind Speed (MARWS) is the peak recorded wind speed producing loads equal to the allowable stress level. Values given are for the AN/GMQ-11 (Aerovane) anemometer on a 90-foot mast located northeast of the blockhouse. Also see "General Notes," Paragraph 1.3.2.

(4) Action should be taken before the wind speed reaches the MARWS, not afterwards.

(5) The tanks must not be depressurized under these conditions.

(6) Return to the indicated condition only if the predicted (forecast) wind speed fails to exceed the MARWS for that condition; otherwise, return to a condition for which the MARWS will not be exceeded.

(7) The launcher is critical in this condition and the MARWS should not be exceeded regardless of tank pressures.

LEGEND:

E = EMPTY

F = FULL

F/E = FULL OR EMPTY

E/2 = 50 PERCENT FULL

1 = RECOMMENDED DETANKING PROCEDURE.
2 = PROCEDURE IF (1) CANNOT BE FOLLOWED.
3 = PROCEDURE IF NEITHER (1) NOR (2) CAN BE FOLLOWED.
4 = PROCEDURE IF NEITHER (1), (2), NOR (3) CAN BE FOLLOWED.

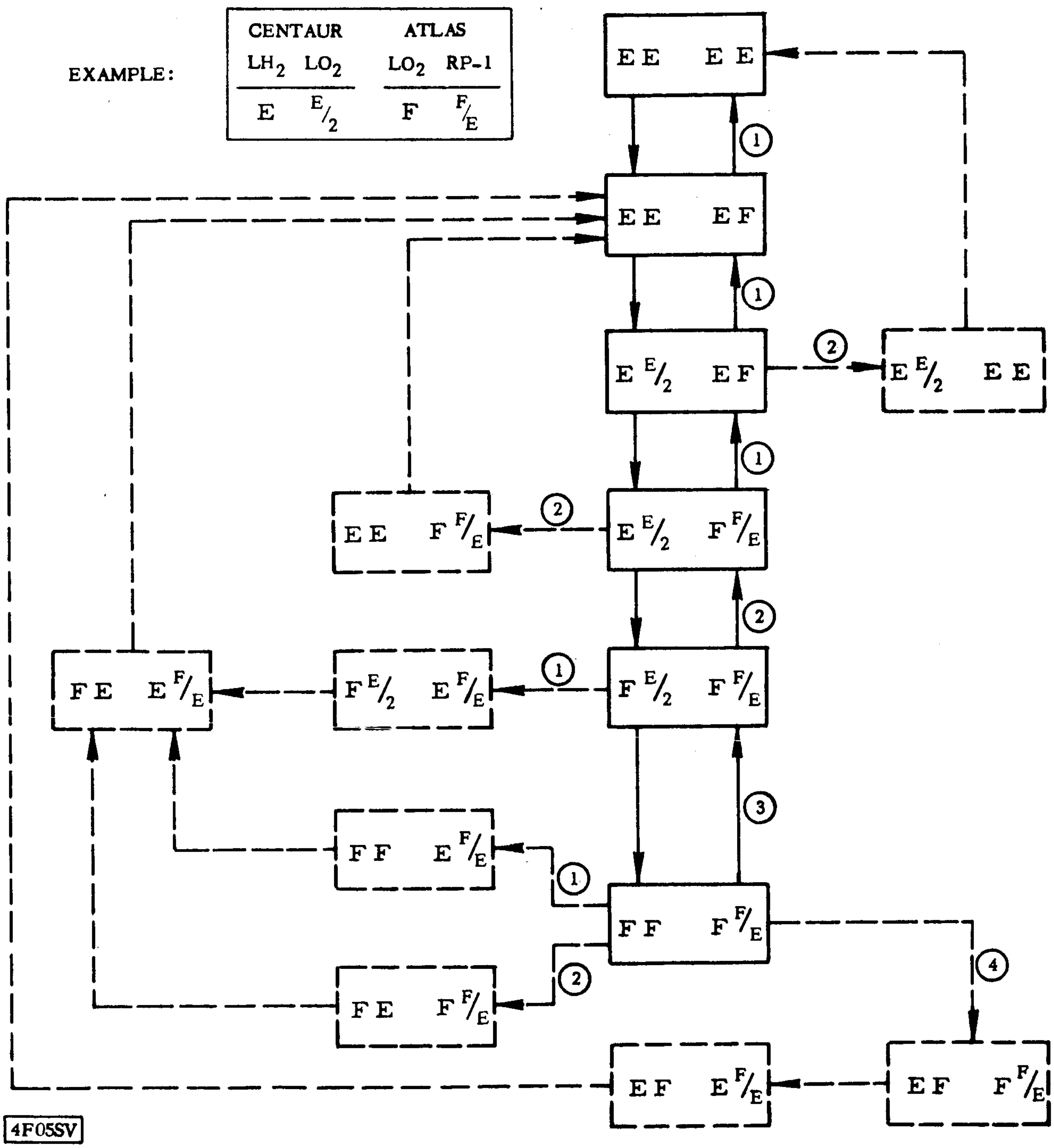


Figure 2-3. Tanking and Detanking Procedures

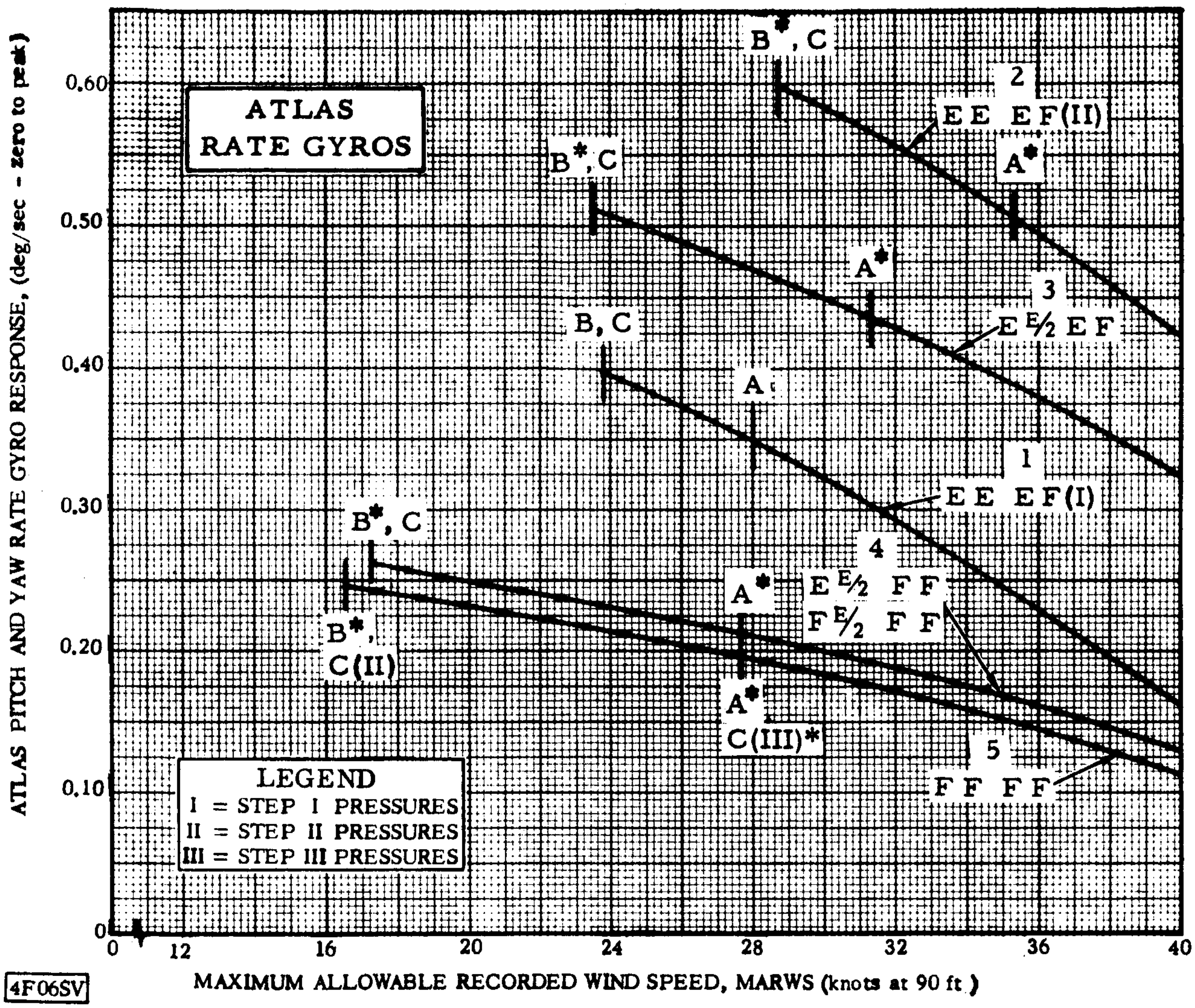
2.4.3.4 Allowable Rate Gyro Response. The curves in Figure 2-4 represent the critical limits for five normal sequence tanking conditions. As in Figure 2-3, the tanking conditions (E = empty, E/2 = half full, F = full) are cited in order from top to bottom (LH_2 to RP-1). This figure is similar to Figure 2-2, except that individual tanking operations are presented. When using these curves, BOTH pitch and yaw rate gyro responses must be below the allowable curve. The meanings of Point B, C, of the region from B, C to A, and of Point A are explained in Paragraph 2.4.2. Where asterisks are shown, the launcher is critical.

For emergency conditions during which the allowable limits are exceeded, in addition to detanking, it may be beneficial to pressurize propellant tanks to Step III pressures.

Note that the allowable rate gyro response curves are extremely dependent on tanking condition. This is primarily due to the fact that, as more propellants are tanked aboard, the first mode frequency of the erected Atlas/Centaur vehicle decreases. Since allowable gyro response is directly proportional to frequency, the curves drop sharply when the vehicle becomes heavier. Therefore, when proceeding from one detanking condition to another, there should be no cause for alarm if the gyro rates begin to increase slowly. The difference between Curves 1 and 2 is due to the change in propellant tank pressures which occurs when going from Step I to Step II pressures.

To prevent possible launch drift problems (collision of vehicle with umbilical tower or booms), the MRWS should be limited to 40 knots per Reference 10.

2.4.4 MAXIMUM ALLOWABLE RECORDED WIND SPEEDS FOR TANKING CONDITIONS OTHER THAN THOSE NORMALLY ENCOUNTERED. To cover tanking conditions which might occur during a special tanking test or due to some malfunction, Maximum Allowable Recorded Wind Speeds and associated minimum pressure requirements are presented in the figures of Appendix B. It is considered that the cases presented in these figures will cover most, if not all, emergency cases. In the event that these figures do not cover the case at hand, it is recommended that the author, or those persons listed on page ii, be contacted.



NOTES:

The following notes present the conditions for monitoring Atlas rate gyros, under normal sequence tanking, as given in the above figure.

a. *Condition* EE EF, *Atlas Step I Pressures*
Removing Service Tower

i. If MRWS is less than 23.8 knots, ignore rate gyros.
ii. If MRWS is greater than 23.8 knots, rate gyro monitoring is required when wind is in Sectors B or C (see Curve 1).
iii. If MRWS is greater than 27.9 knots, rate gyro monitoring is required for all wind directions (see Curve 1).

Figure 2-4. Wind Restrictions to be Used when Monitoring Atlas Rate Gyros, for Five Normal Sequence Tanking Conditions

NOTES (Continued):

b. *Condition* E E E F, *Atlas Step II Pressures*
No Cryogenics Tanked
- i. If MRWS is less than 28.7 knots, ignore rate gyros.
- ii. If MRWS is greater than 28.7 knots, rate gyro monitoring is required when wind is in Sector B or C (see Curve 2).
- iii. If MRWS is greater than 35.3 knots, rate gyro monitoring is required for all wind directions (see Curve 2).

c. *Condition* E E E F *to* E E/2 E F, *Atlas Step II Pressures*
Tanking Centaur LO_2
- i. If MRWS is less than 23.5 knots, ignore rate gyros.
- ii. If MRWS is greater than 23.5 knots, rate gyro monitoring is required when wind is in Sector B or C (see Curve 3).
- iii. If MRWS is greater than 31.4 knots, rate gyro monitoring is required for all wind directions (see Curve 3).

d. *Conditions* E E/2 E F *to* E E/2 F F, *Atlas Step II Pressures*
Tanking Atlas LO_2
- i. If MRWS is less than 17.3 knots, ignore rate gyros.
- ii. If MRWS is greater than 17.3 knots, rate gyro monitoring is required when wind is in Sector B or C (see Curve 4).
- iii. If MRWS is greater than 27.7 knots, rate gyro monitoring is required for all wind directions (see Curve 4).

e. *Conditions* E E/2 F F *to* F E/2 F F, *Atlas Step II Pressures, and Conditions* F E/2 F F *to* F F F F, *Atlas Step II Pressures*
Tanking Centaur LH_2 or Completing Centaur LO_2 Tanking
- i. If MRWS is less than 16.5 knots, ignore rate gyros.
- ii. If MRWS is greater than 16.5 knots, rate gyro monitoring is required when wind is in Sector B or C (see Curve 5).
- iii. If MRWS is greater than 27.7 knots, rate gyro monitoring is required for all wind directions (see Curve 5).

f. *Condition* F F F F, *Atlas Step III Pressures*
Preparing to Launch
- i. If MRWS is less than 16.5 knots, ignore rate gyros.
- ii. If MRWS is greater than 16.5 knots, rate gyro monitoring is required when wind is in Sector B (see Curve 5).
- iii. If MRWS is greater than 27.7 knots, rate gyro monitoring is required for all wind directions (see Curve 5).

Figure 2-4. Wind Restrictions to be Used when Monitoring Atlas Rate Gyros for Five Normal Sequence Tanking Conditions (Continued)

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

The ground-wind restrictions, with their associated requirements, set forth in this report are intended to cover the Atlas/Centaur/Surveyor AC-6 and AC-7 vehicles. Ground-wind restrictions for subsequent vehicles will be published at a later date. Only those persons listed on the distribution list at the close of this report will be notified in the event that changes to the report become necessary.

The procedures and/or ground-wind restrictions of Table 2-1 should be incorporated in the following documents:

1. Program Requirements Document.

2. Unified Test Plan.

3. Centaur Redline Document.

It is recommended that the scale for the wind-speed recorder in the blockhouse at ETR Complex 36 be reset. The current full-scale range extends from 0 to 120 knots in 4-1/2 inches, allowing less than 1-1/8 inches for the range of interest (0 to 30 knots); and each scale division is equal to 2 knots so that the magnitude of the wind speed cannot be read closer than approximately ± 0.2 knots — the width of the trace. The recorder/amplifier should be modified or replaced so that two ranges, 0-30 and 0-120 knots, are available.

It is also recommended that the anemometer/amplifier/recorder system be calibrated to determine systematic and random errors. The systematic errors should then be compensated for, by either changing the recorder scale or applying the appropriate correction to the Maximum Allowable Recorded Wind Speeds. Random errors should be combined with other random variables in the ground-wind loads so that the MARWS is not unduly reduced.

SECTION IV

REFERENCES

4.1 REFERENCE NUMBERING

Each reference is assigned a number, in the same sequence as it first appears in the report, by section and order. The same number is then maintained throughout the report on all subsequent referrals to the previously cited document, regardless of the section in which the referral appears.

4.2 SOURCES CITED

1. Ground-Wind Restrictions Procedure for Atlas/Centaur, AC-5, M. I. Kestenbaum. Report No. GD/A-BTD 65-024, 8 February 1965 (General Dynamics/Astronautics).

2. The Response of an Atlas/Centaur Vehicle Exposed to Ground Winds, Including the Effects of Weight Offset, J.D. Martin. Dynamics Memo No. CD62-42, Rev. A, 9 January 1964 (General Dynamics/ Astronautics).

3. Determination of Bending Moment Allowables for Centaur AC-5 to be Used in Preparation of Ground Wind Restriction Procedure, J. Jenness. Centaur Stress Group Memo ACS-65-01, 4 January 1965 (General Dynamics/Astronautics).

4. Allowable Bending Moments for Atlas Booster Station 1133 and Launcher for the Atlas/Centaur AC-5 Configuration while Erected on the Launch Pad at Complex 36A ETR, J. H. Baker. SLV Stress Group Memo 663-4-64-91, 16 December 1964 (General Dynamics/ Astronautics).

5. Ground Wind Restrictions for the LV-3C/AC-5 Vehicle Propellant Tanks, G. Harrison. SLV Stress Group Memo 663-4-64-92, 17 December 1964 (General Dynamics/Astronautics).

6. Proposed Changes to GLASS Digital Computer Program No. 3229, M. Kestenbaum. Structural Dynamics Memo SD-65-12 CEN, 21 January 1965 (General Dynamics/Astronautics).

7. Method for Combining Random Loads, M. Kestenbaum. Structural Dynamics Memo SD-65-59 CEN, 9 February 1965 (General Dynamics/Astronautics).

8. Probability Study for Combining Random and Steady State Bending Moments on the Erected Atlas/Centaur Vehicle Subjected to Ground Winds, M. Kestenbaum. Structural Dynamics Memo SD-65-79 CEN, Revision A, 30 March 1965 (General Dynamics/Convair).

9. Ground-Wind Loads for Atlas/Centaur, M. Kestenbaum. Structural Dynamics Memo SD-65-103 CEN, Revision A, 13 May 1965 (General Dynamics/Convair).

10. Flight Dynamics and Control Analyses of the LV-3C Launch Vehicle (Atlas/Centaur AC-6 and AC-7), P.R. McGowan. Report No. GD/C-DDE65-021, April 1965 (General Dynamics/Convair).

1-1. External Design Loads - Operational Centaur Vehicles (AC-6 through AC-15), J. Hogan. Report No. GD/C-BTD65-017, 1 May 1965 (General Dynamics/Convair).

1-2. Atlas/Centaur Redlines for AC-5, Tabulation No. 961-5-116-AC-5, 2 February 1965 (General Dynamics/Astronautics).

1.3. Ground Wind Loads Wind Tunnel Tests on Several Atlas Vehicles (U) (Confidential), E.F. Gaffney. Report No. GD/A63-0999, April 1964 (General Dynamics/Astronautics).

APPENDIX A
DEFINITIONS AND WIND-SPEED VARIATIONS

A.1 TERMINOLOGY AND DEFINITIONS FOR GROUND WINDS AND GROUND-WIND LOADS

In the past, there has been some confusion over the usage and definition of the design terminology "equivalent steady-state wind." When wind loads for missiles were first calculated, it was assumed that loads imposed on the missile by some square-profile steady wind would be an adequate criterion for a good missile design, an assumption which has since been modified. As more knowledge has been gained of the real loads due to an "actual wind," (refer to Table A-1 and Figure A-1) the terminology "equivalent steady-state wind" has come into use, but it only has meaning for design purposes in that it is a uniform steady wind which produces the same loads as the peak loads due to an "actual wind."

This Appendix shall attempt to clear up any remaining confusion by presenting the terminology to be used when referring to winds and wind loads and giving explanatory examples. Hereafter, terminology defined in this Appendix shall be used and the expression "equivalent steady-state wind" avoided when referring to wind restrictions.

TABLE A-1. DEFINITIONS OF GROUND-WIND TERMS

Actual Wind: The wind actually blowing, which is a function of position and time. (See Figure A-1.)
Maximum Actual Wind Speed: The instantaneous peak actual wind speed occurring during any period that is of interest, such as when a vehicle is exposed to ground winds. (See Figure A-1.)
Maximum Allowable Actual Wind: The peak speed of the actual wind which produces limit-allowable loads. NOTE: The actual load which will cause a failure is the limit load multiplied by the factor of safety.
Recorded Wind: That wind recorded by an anemometer. The recorded wind speed usually varies from the actual wind speed. (See Figure A-1.)
Maximum Recorded Wind Speed: The instantaneous peak wind speed recorded during any period of interest, such as when a vehicle is exposed to ground winds. (See Figure A-1.) This is equal to five-sixths of the peak actual wind speed, or one-and-a-quarter times the average wind speed.
Maximum Allowable Recorded Wind Speed (MARWS): That peak wind speed, recorded by a particular anemometer, corresponding to an actual wind which produces limit-allowable loads. The particular anemometer used and its location must be specified.

TABLE A-1. DEFINITION OF GROUND-WIND TERMS (Continued)

Average Wind:	(Sometimes called the mean-wind speed.) The average wind speed over a five-minute period. The actual and recorded average winds ordinarily coincide. (See Figure A-1.)
Gust Wind:	The difference between the actual and the average winds. Gusts vary both in magnitude and duration. (See Figure A-1.)

A.2 WIND-SPEED VARIATION

Figure A-1 illustrates a typical plot of wind-speed variation with respect to time and is to be used in conjunction with the definitions given in Table A-1. Note that the magnitude and time of peaking of the recorded wind vary from the actual wind. This variation is caused by the response lag of the anemometer, which may change for different types of anemometers. The wind direction also varies, but this factor is not discussed here. Reference A-1 does give the directional distribution of the wind.

Figure A-2 is the profile of Reference A-2 and is applicable to ETR. This wind speed profile is a statistical average, and hence the instantaneous wind profile may vary considerably from this smooth profile. However, Figure A-2 can be used as a reference to predict wind speeds at a given elevation when the speed is known at some other elevation. This profile correction applies only to anemometers which are relatively far from any obstruction. It specifically does not apply to the anemometer mounted on top of the ETR Complex 36A blockhouse. If this anemometer is used, the 50-foot elevation profile correction should be employed.

To help define these terms and the use of Figure A-2, an example is presented. The case presented is a hypothetical one and hence is not to be considered as a ground-wind load criterion.

> Assume that the Atlas/Centaur vehicle was designed to withstand a maximum-allowable actual wind of 40 mph at 90 feet above ground. This corresponds to a 33-1/3 mph Maximum Allowable Recorded Wind Speed at 90 feet, measured with an AN/GMQ-11 Anemometer. For this condition, the average wind speed would be 26-2/3 mph at 90 feet. To determine the Maximum Allowable Recorded Wind Speed if the anemometer at the launch site is placed at 70 feet instead of 90 feet, refer to Figure A-2. From the profile of Figure A-2 it can be determined that the Maximum Allowable Recorded Wind Speed at 70 feet is 0.952 times that at 90 feet, or 31.7 mph. If the anemometer is different than type AN/GMQ-11, the Maximum Allowable Recorded Wind Speed must also be adjusted according to the response curve of that particular anemometer.

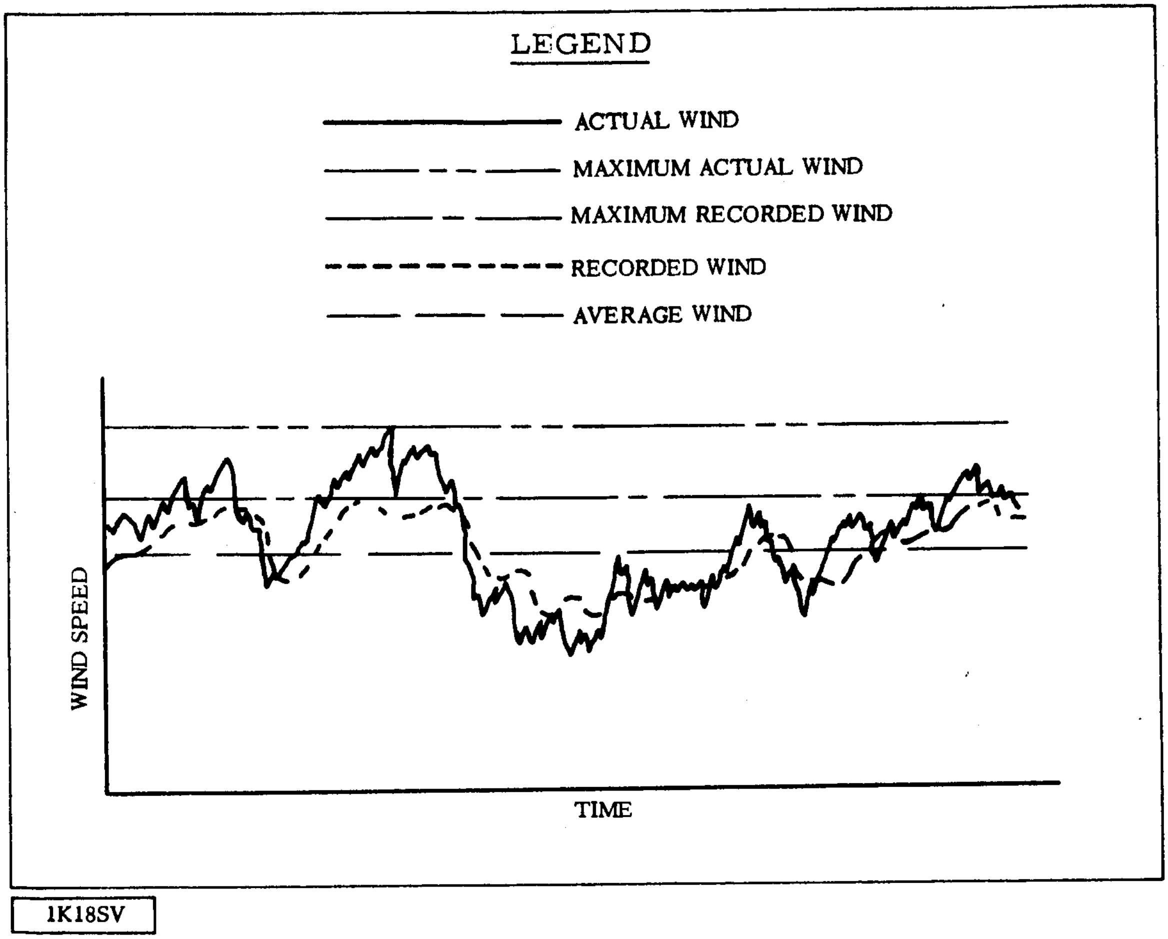


Figure A-1. **Wind-Speed** Variation with Time

A. 3 REFERENCES

A-1 Surface Wind Statistics for Patrick AFB (Cape Canaveral), Florida, Report No. MSP-AERO-61-78, 10 October 1961 (George C. Marshall Space Flight Center).

A-2 Ground Wind Criteria for Atlas/Centaur 95% Launch Capability, J. D. Martin. Report No. GD/A63-0445, 15 July 1963 (General Dynamics/Astronautics).

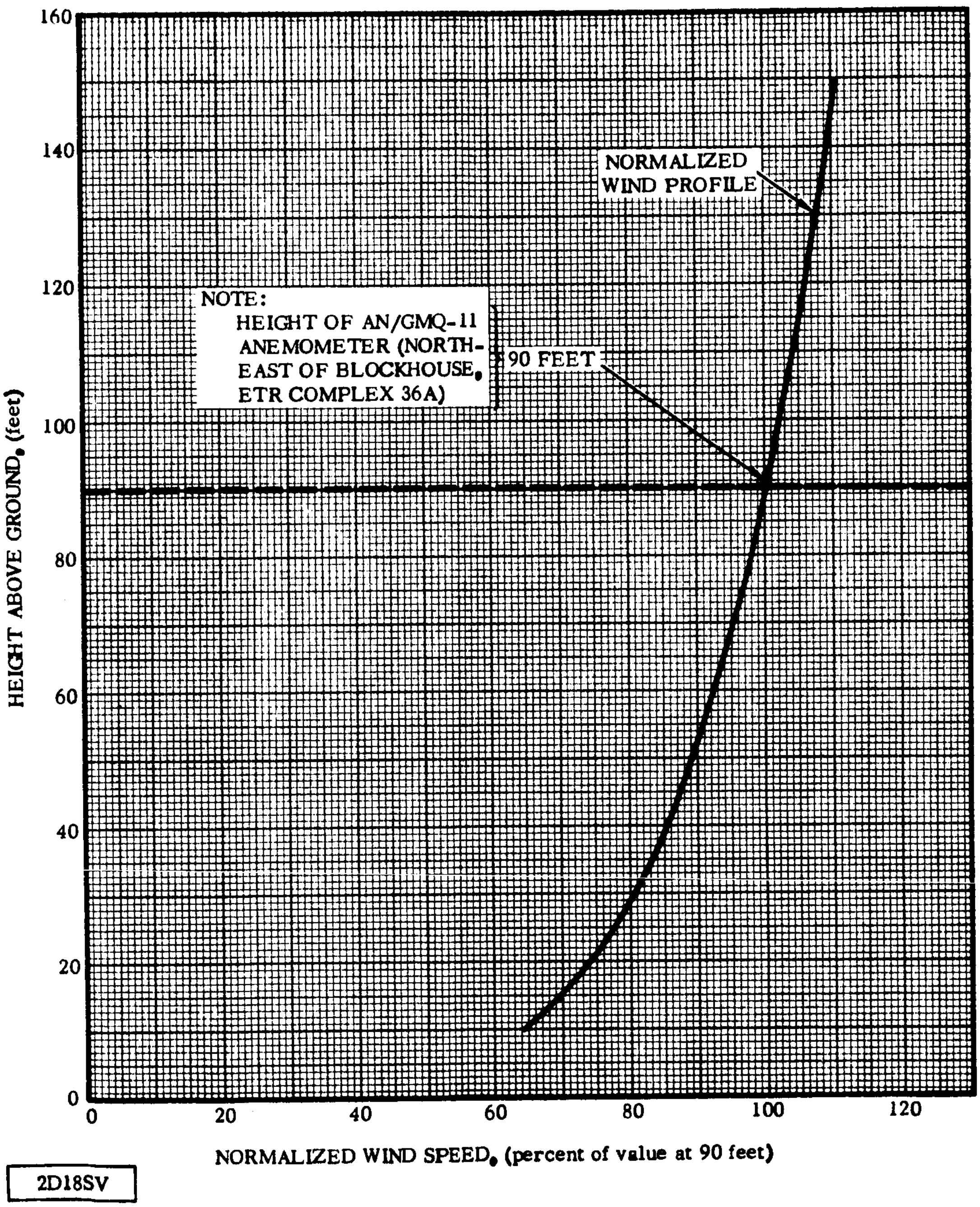


Figure A-2. Normalized Ground-Wind Profile

APPENDIX B

SPECIAL TANKING CONDITIONS

Figures B-1 to B-10 are presented to account for any non-normal tanking sequence configuration. The limitations and uses of these figures are identical to those of Figure 2-4. As in Figure 2-3, the tanking conditions (E = empty, E/2 = half full, F = full) are cited in order from top to bottom (LH_2 to RP-1).

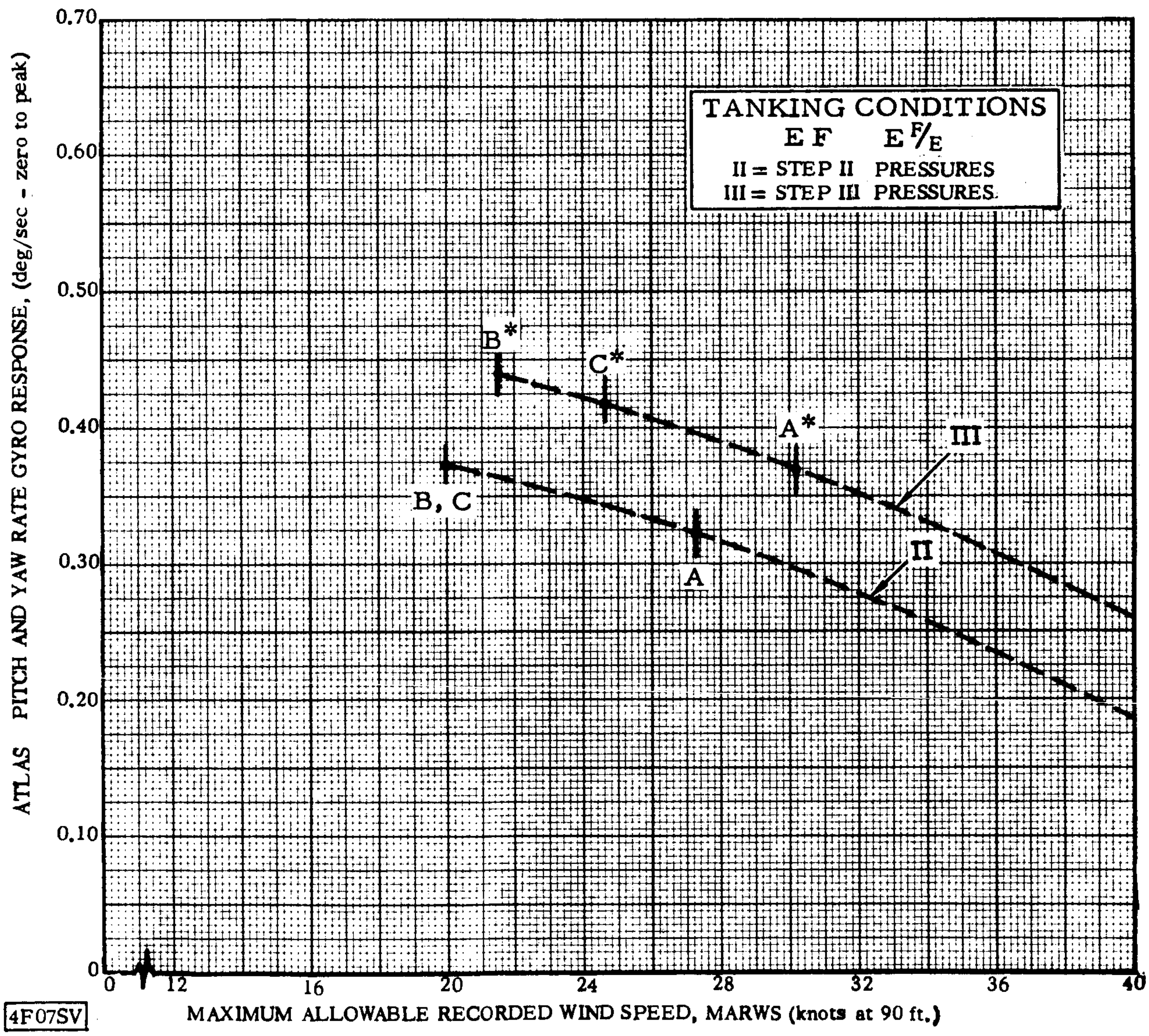


Figure B-1. Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition E F $E^F/_E$ (Step II and Step III Pressures)

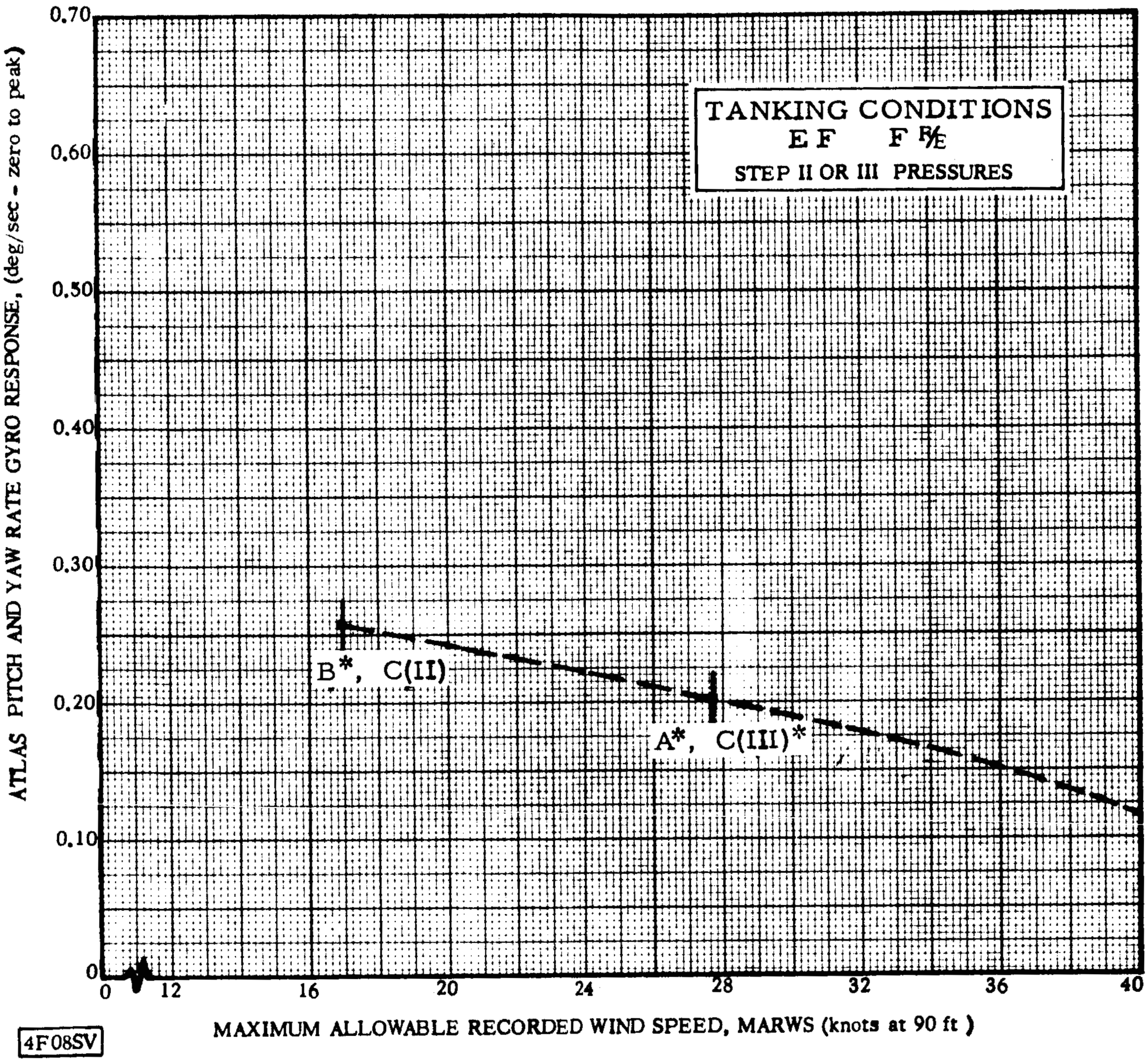


Figure B-2. Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition E F $F^F/_E$ (Step II or Step III Pressures)

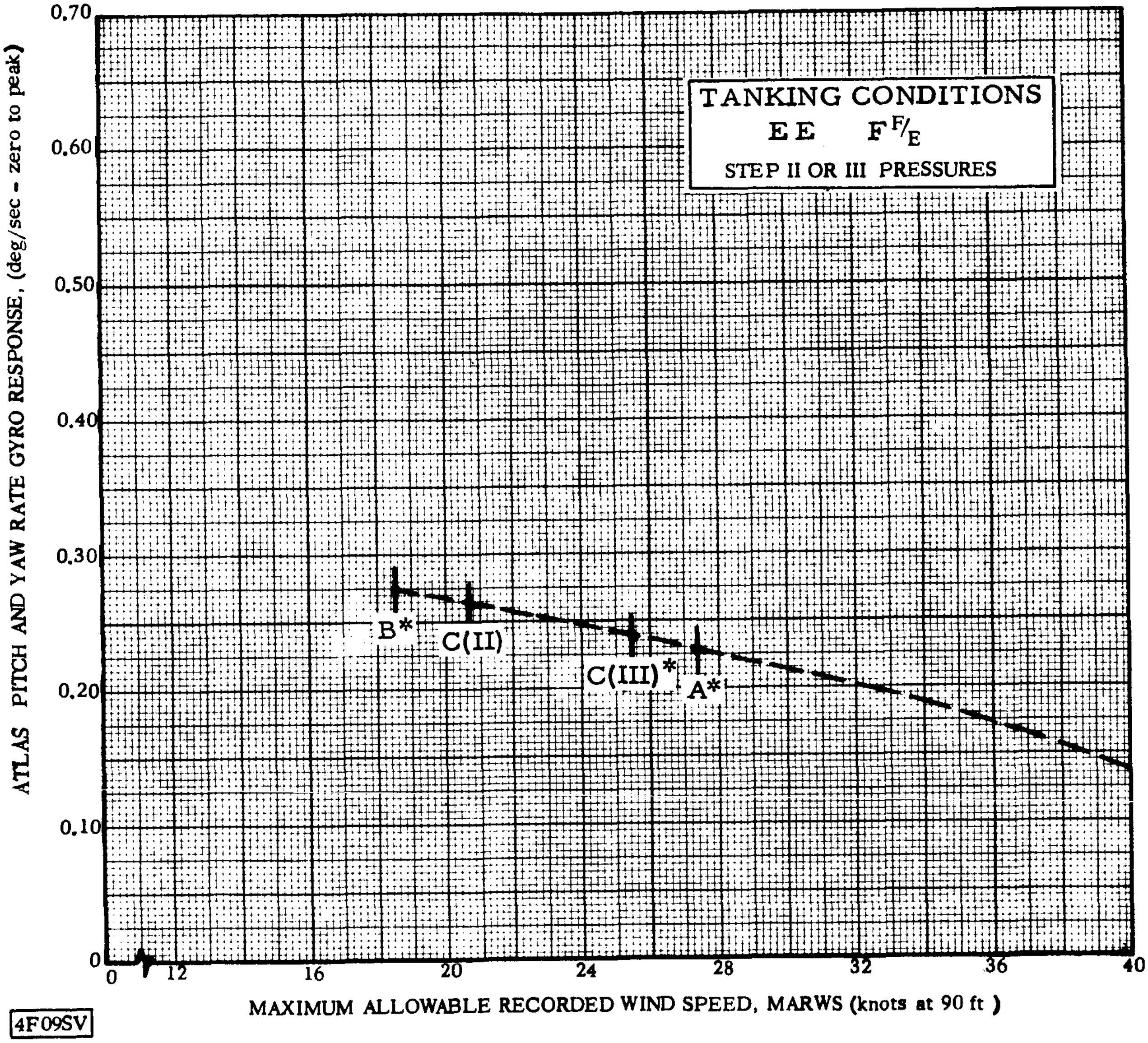


Figure B-3. Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition E E F F/E (Step II or Step III Pressures)

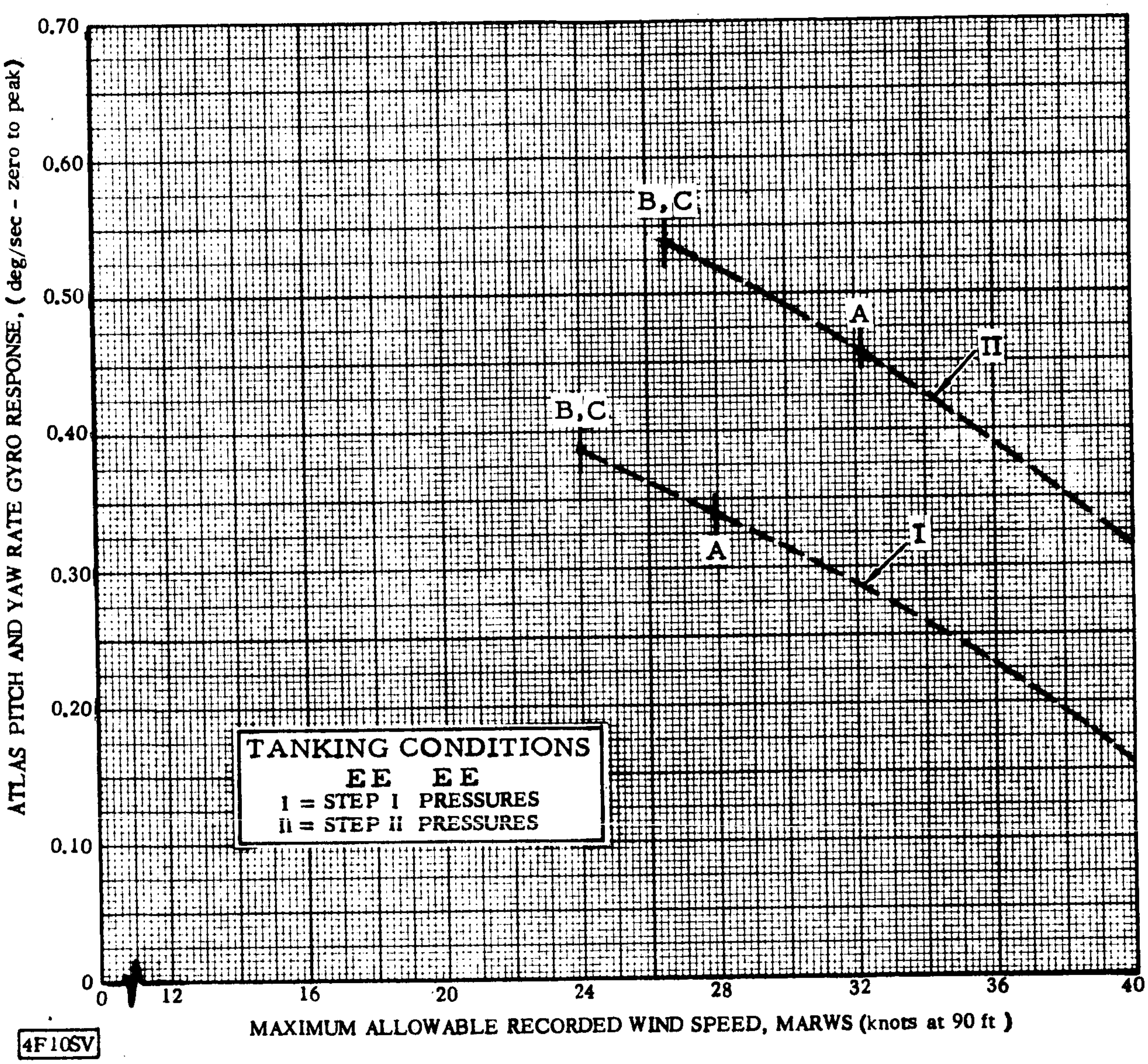


Figure B-4. Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition EE EE (Step I and Step II Pressures)

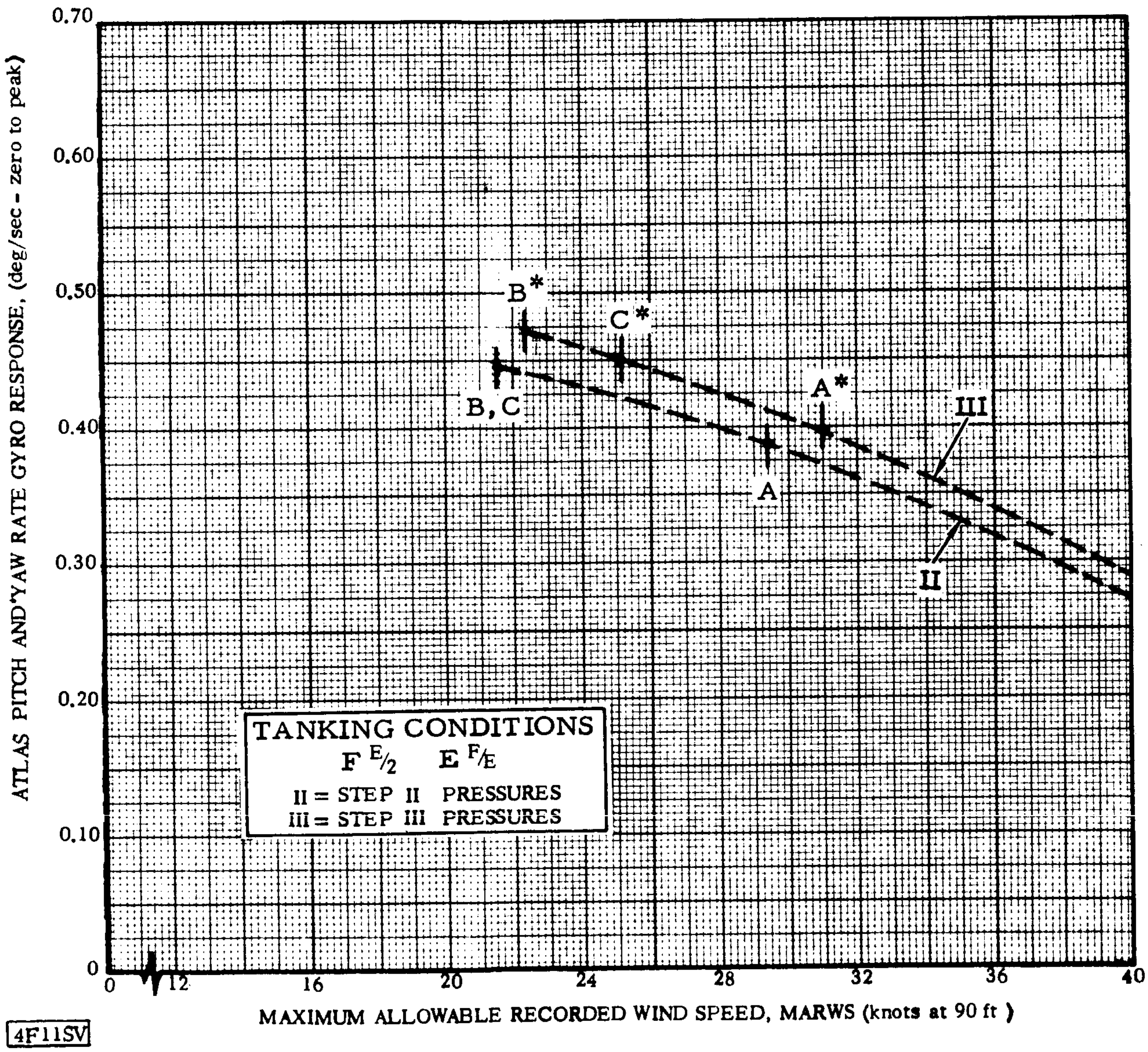


Figure B-5. Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition $F^{E/2}$ $E^{F/E}$ (Step II and Step III Pressures)

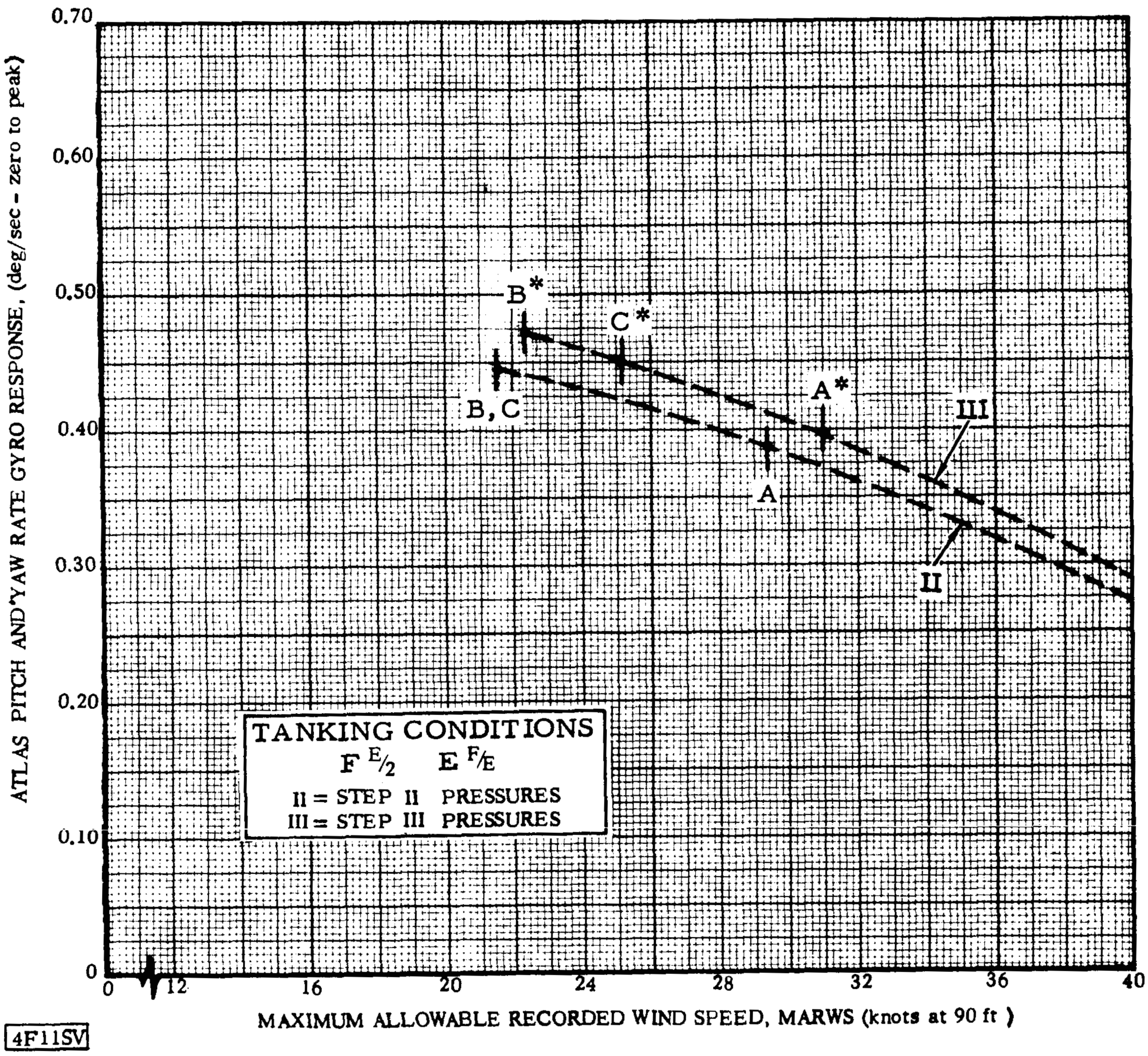


Figure B-5. Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition $F^{E/2}$ $E^{F/E}$ (Step II and Step III Pressures)

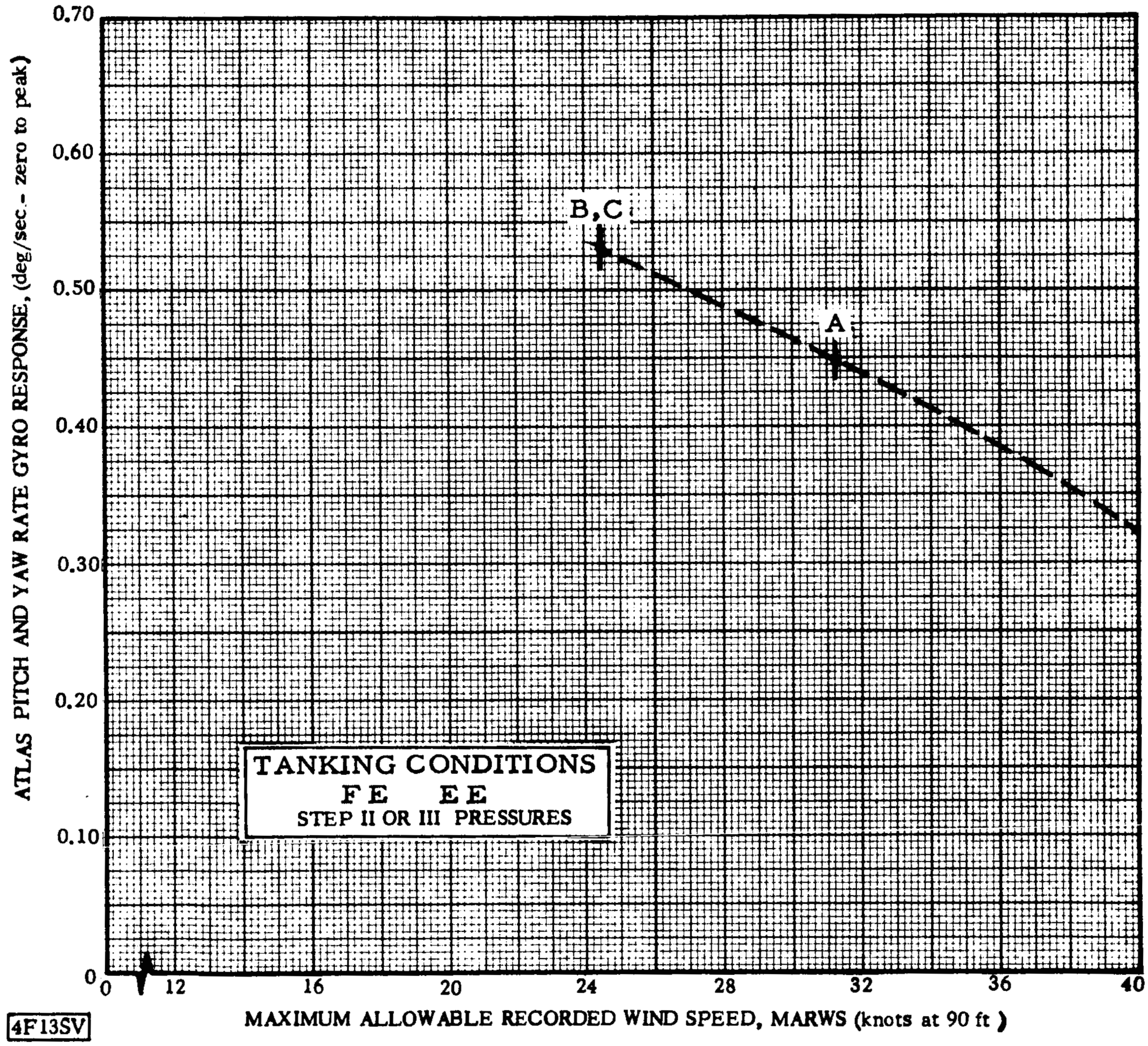


Figure B-7. Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition F E E E (Step II or Step III Pressures)

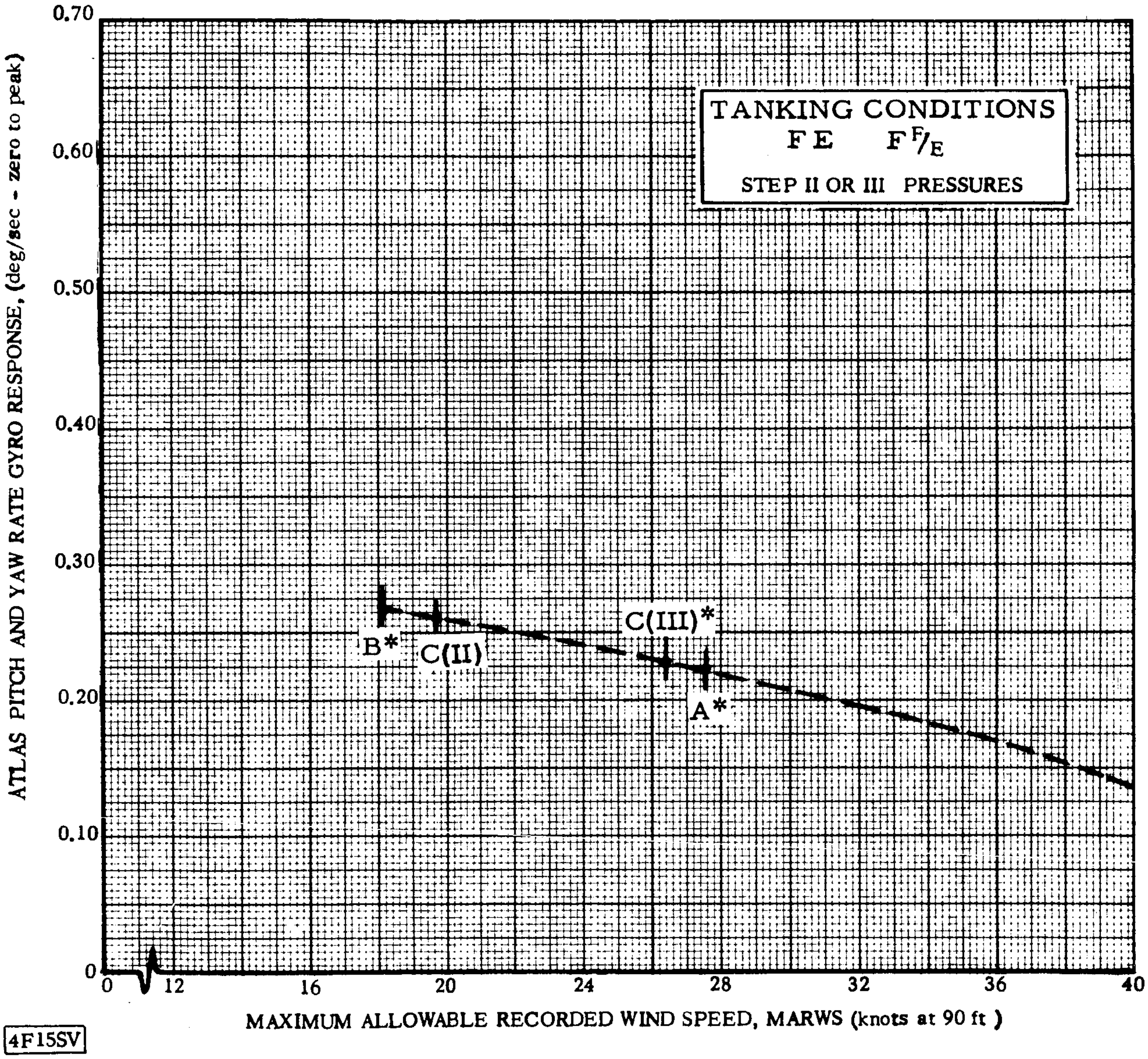


Figure B-9. Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition F E $F^F/_E$ (Step II or Step III Pressures)

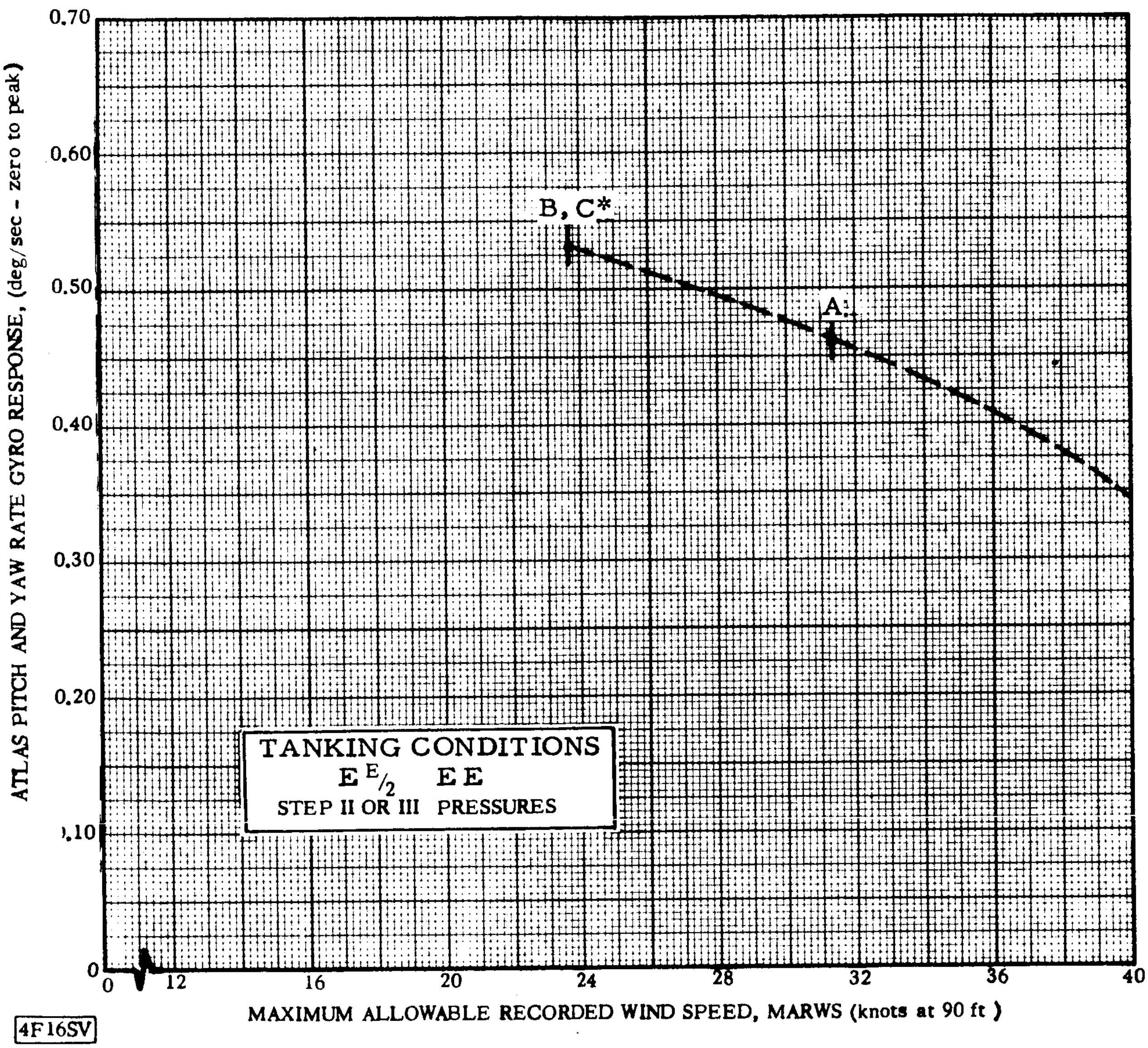


Figure B-10 Wind Restrictions to be Used when Monitoring Rate Gyros, for Condition $E^{E/2}$ E E (Step II or Step III Pressures)

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