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UNIT

48801

MATERIALS HANDLING EQUIPMENT STUDY

VOLUME II

APPENDIXES

PREPARED BY:

INGALLS SHIPBUILDING DIVISION

OF

LITTON SYSTEMS, INCORPORATED

UNDER

CONTRACT 1-36200

FOR

THE OFFICE OF ADVANCED SHIP DEVELOPMENT

MARITIME ADMINISTRATION

WASHINGTON, DC 20235

Transportation
Research Institute

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ENCLOSURE 1

ANNUAL OPERATING COSTS

MATERIAL HANDLING EQUIPMENT

**ANNUAL OPERATING COSTS
MATERIAL HANDLING EQUIPMENT**

TABULATION SHEET

	CAPY	QTY	UNIT COST	AMORTIZ ATION SCHED	DEPREC COST /YR		UNIT LABOR COST	UNIT MNTCE COST	UNIT FUEL COST		UNIT TOTAL COST		TOTAL COST
Truck Crane	140T	1	Rental	Rental/Yr	81600		83200	4500	430		169730		169730
Crawler Crane	18.5T	2	50000	12	4165		62400	1400	430		68395		136790
Speeder Crane	25-30T	3	70000	12	5835		62400	1050	430		69715		209145
Whirley Crane	33-75T	18	336000	12	28000		104000	5500	N/A		137500		2475000
Slewing Crane	16T	1	300000	12	25000		62400	11500	650		99550		99550
Bridge Crane	1T	10	2000	12	165		N/A	275	N/A		440		4400
	5-100T	28	41000	12	3415		41600	900	N/A		45915		1285620
Jib Crane		78	600	12	50		N/A	100	N/A		150		11700
Monorail Crane		45	780	12	65		N/A	100	N/A		165		7425
Rail Crane	18T	5	115400	12	9615		62400	4750	1210		77974		389875
	38T	1	155000	12	12925		62400	4750	1210		81285		81285
Roller Conveyor	517-172	2	184000	12	15300		N/A	3000	N/A		18300		18300
Hydraulic Boom Crane	5-7.5T	3	23200	12	1935		41600	975	480		44990		134970
Gantry Crane	2T	1	1440	12	120		N/A	225	N/A		345		345
Hydraulic Boom Crane	3/4T	1	420	12	35		N/A	50	N/A		85		85
Barge		2	21750	18	1210		N/A	500	N/A		1710		3420
Tug (Sea Mule)		1	15000	18	835		41600	600	430		43465		43465
Semi Tractor		2	12500	6	2085		41600	1600	430		45715		91430
Lo-Boy Trailer	100T	1	100000	12	8335		20800	850	N/A		29985		29985
Flatbed Railcars	30-60T	87	900	14	65		N/A	350	N/A		415		36105
Box Car		7	1200	14	85		N/A	100	N/A		185		1295
Locomotive		3	100000	14	7140		41600	3500	1210		53450		169350
Flatbed Wagon	5T	50	3600	12	300		N/A	150	N/A		450		22500
Lo-Boy Wagon	30T	1	6500	12	540		N/A	700	N/A		1240		1240
Forklift (Powered)		25	10750	6	1800		20800	975	825		24400		610000
Tractor (Farm)		2	8500	4	2125		20800	800	370		24095		48190
Dempster Dumpster		3	18500	4	4625		41600	2000	650		48875		146625
Truck (Jeeps, Van													
P/U)	¼-3/4T	36	2750	3	920		20800	740	550		23010		828360
Truck (Flatbeds,													
Stakebody)	1-3T	26	5800	4	1450		20800	870	840		23960		622960
Scooter (3 Wheel)		15	1900	3	630		N/A	375	270		1275		19125
Stationwagon		4	5800	3	1935		20800	500	570		23805		95220
Front End Loader/													
Back Hoe		1	6000	6	2665		20800	550	500		24515		24515
Sweeper (3 Cu Y/D)		1	14500	4	3625		20800	3000	1150		28575		28575

ENCLOSURE 2

PALLET HANDLING VEHICLES COST COMPARISON

ENCLOSURE 2

PALLET HANDLING VEHICLES COST COMPARISON

For a cost comparison of the number of man minutes for the various methods of moving pallets 6 pallets are to be moved from a location in a rack to another location 1/2 mile away. All equipment is assumed to be in a central location at the start and is to be returned there at the end. The central location is 1/2 mile from the pick-up location and 1/4 mile from the destination.

<u>Equipment</u>	<u>Assumed Travel Speeds</u>
Fork Lift	Loaded -4 Mi/Hr
Truck, Semitractor	Loaded & Empty -15 Mi/Hr
Tractor with Wagon	Loaded -10 Mi/Hr
	Empty -15 Mi/Hr
Fork Lift With Wagon	Loaded -8 Mi/Hr
	Empty -10 Mi/Hr
Straddle Carrier	Loaded -10 Mi/Hr
	Empty -15 Mi/Hr
Railroad	Loaded and Empty - 15 Mi/Hr
Side Loader	Loaded -10 Mi/Hr
	Empty -15 Mi /Hr

PALLET MOVING EQUIPMENT ASSUMPTIONS

- a. Fork lift moves 1 pallet at a time.**
- b. Straddle carrier moves 3 pallets at a time on a platform.**
Platform is loaded with a fork lift.
- c. Side loader moves 3 pallets at a time on a platform.**
Side loader services its platform.
- d. Flat bed truck moves 6 pallets at a time.**
Truck is loaded with a fork lift or side loader.
- e. Semitrailer with semitractor moves 6 pallets at a time.**
Semitrailer is loaded with a fork lift or side loader.
- f. Semitrailer with fork lift fitted with fifth wheel moves 6 pallets at a time.**
- g. 4-wheeled wagon with tractor moves 6 pallets at a time.**
Wagons loaded with a fork lift or side loader.
- h. 4-wheeled wagon with fork lift moves 6 pallets at a time.**
Fork lift services its wagon.

- i. Railroad used only for special large movements.**
- j Crane used only for special movements.**
- k. Proposed vehicle with 3 sets of independently controlled forks.**

STEPS PERFORMED IN MOVING SIX PALLETS 100 FEET

The following steps were performed when applicable in the movement of the six pallets a distance of 100 feet.

1. With all equipment at a central location the prime mover hooks onto its trailer or platform.
2. The equipment moves 1/2 mile to pick-up location.
3. Prime mover unhooks.
4. Prime mover returns 1/2 mile to central if not needed for loading.
5. There is waiting time for the prime mover if it can not be unhooked and it is dependent on others for assistance.
6. Pick up 6 pallets out of a rack, move 50 ft. and load pallets onto moving equipment. With the truck there are 2 men present for this operation. A fork lift is the service vehicle for loading.
7. Prime mover moves 1/2 mile from central to pick-up location.
8. Prime mover hooks onto its piece of moving equipment.

9. The equipment moves 100 feet to destination.
10. Prime mover. unhooks.
11. The prime mover returns 1/2 mile to central if not needed for unloading at destination.
12. There is waiting time for the prime mover if it can not be unhooked and it is dependent on others for assistance.
13. Unload 6 pallets off the moving equipment, move 50 ft. and place pallets on the ground. With the truck 2 men are present for this operation. A fork lift is the service vehicle for unloading.
14. Prime mover moves 1/2 mile from central to destination location.
15. Prime mover hooks onto its piece of moving equipment.
16. The equipment moves 1/2 mile to central.
17. The prime mover unhooks.
18. For those pieces of equipment that cannot carry the 6 pallets at one time the prime mover must move 100 feet from destination to pick up for the additional moves.

9. **The equipment moves 1 mile to destination.**
10. **Prime mover unhooks.**
11. **The prime mover returns 3/4 mile to central if not needed for unloading at destination.**
12. **There is waiting time for the prime mover if it can not be unhooked and it is dependent on others for assistance.**
13. **Unload 6 pallets off the moving equipment, move 50 ft. and place pallets on the ground. With the truck 2 men are present for this operation. A fork lift is the service vehicle for unloading.**
14. **Prime mover moves 3/4 mile from central to destination location.**
15. **Prime mover hooks onto its piece of moving equipment.**
16. **The equipment moves 3/4 mile to central.**
17. **The prime mover unhooks.**
18. **For those pieces of equipment that cannot carry the 6 pallets at one time the prime mover must move 1 mile from destination to pick up for the additional moves.**

**PALLET HANDLING VEHICLES
COST COMPARISON**

4-7-72

TABULATION SHEET

based on using prime mover for 1 year (2080 hr.)

Equipment (see page 3)	Fork Lift a	Strad dle b	Side loader c	Truck d	Semi- trailer e	Semi- trailer f	Wagon- tractor g	Wagon- fork h	Rail- road i	Crane j	Pro- posed k	SL-3	AA1
TO MOVE PALLETS 100 FEET													
Number of pallets prime mover will move in 2080 hours	41,600	34,036	28,800	29,952	24,154	18,720	32,556	23,400	-	39,410	62,400	37,440	37,440
Operating cost per year													
Prime Mover	24,400	27,400	30,500	23,960	45,715	24,400	24,095	24,400	-	45,915	33,375	27,400	29,800
Carrying Vehicle	-	-	-	-	6,387	550	7,043	450	-	-	-		
Service Vehicle	-	16,636	-	14,640	11,806	-	15,913	-	-	-	-		
Total	24,400	44,036	30,500	38,600	63,908	24,950	47,051	24,850	-	45,915	33,375	27,400	29,800
Cost to move													
100 pallets	58	129	105	128	264	133	144	106	N/A	116	53	73	79
TO MOVE PALLETS 1/2 MILE													
Number of pallets prime mover will move in 2080 hours	9,984	24,960	24,154	18,720	21,394	17,413	34,036	22,686	44,047	-	44,047	28,800	28,800
Operating cost per year													
Prime Mover	24,400	27,400	30,500	23,960	45,715	24,400	24,095	24,400	53,450	-	33,375	27,400	29,800
Carrying Vehicle	-	-	-	-	5,657	550	7,363	450	8,788	-	-		
Service Vehicle	-	12,200	-	9,150	10,457	-	16,636	-	21,529	-	-		
R.R. track maint.	-	-	-	-	-	-	-	-	17,562	-	-		
Total	24,400	39,600	30,500	33,110	61,829	24,950	48,094	24,850	101,329	-	33,375	27,400	29,800
Cost to move													
100 pallets	244	158	126	177	288	143	141	109	230	N/A	75	95	103
TO MOVE PALLETS 1 MILE													
Number of pallets prime mover will move in 2080 hours	5,465	17,018	18,263	17,018	17,413	14,976	24,154	19,200	29,952	-	27,732	20,800	20,800
Operating cost per year													
Prime mover	24,400	27,400	30,500	23,960	45,715	24,400	24,095	24,400	53,450	-	33,375	27,400	29,800
Carrying Vehicle	-	-	-	-	4,604	550	5,225	450	5,976	-	-		
Service Vehicle	-	8,318	-	8,318	8,511	-	11,806	-	14,640	-	-		
R.R. track maint.	-	-	-	-	-	-	-	-	17,562	-	-		
Total	24,400	35,718	30,500	32,278	58,830	24,950	41,126	24,850	91,628	-	33,375	27,400	29,800
Cost to move													
100 pallets	443	204	167	189	338	166	169	129	305	N/A	120	131	143

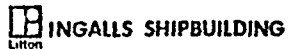
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TABULATION SHEET

cost	I	I 16,636	I	I 14,640	]11,806	I	115,913				
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PALLET HANDLING VEHICLES COST COMPARISON

4-4-72



Man Minutes to Move 6 Pallets 1/2 Mile

TABULATION SHEET

Equipment Steps (see page 4)	Fork Lift a	Strad- dle b	Side- Loader c	Truck d	Semi- Trailer e	Semi- Trailer f	Wagon g	Wagon h	Rail- road i	Crane j	Pro- posed k	SL-3	AAI
1.		2	1		5	3	2	2	2				
2.	3	4	3	2	2	3	2	3	4		2	2	2
3.		1			3	3	1	1	2				
4.		4			2		2		4				
5.				5									
6.	6	9	9	18	9	9	9	9	9		4	9	9
7.		2			2		2		4				
8.		2	1		5	3	2	2	2				
9.	45	6	6	2	2	4	3	4	4		6	6	6
10.		1	1		3	3	1	1	2				
11.		1			1		1		2				
12.				15									
13.	5	6	6	12	6	6	6	6	6		2	6	6
14.		1			1		1		2				
15.		2	1		5	3	2	2	2				
16.	1	1	1	1	1	3	1	1	2		1	1	1
17.		1			3	3	2	2	2				
18.	15	2	2								2	2	2
TOTAL	75	45	31	55	50	43	37	33	49	N/A	17	26	26
Total Prime Mover Use	75	30	31	40	35	43	22	33	17		17	26	26
Number of pallets prime mover will move in 2080 hr.	9984	24,960	24,154	18,720	21,394	17,413	34,036	22,686	44,047		44,047	28,800	28,800
Operating cost for the percentage of time in use during one year of prime mover time													
Carrying Vehicle					6 x 60	x	6 x 60	x	6 x 60	x			
					35		22		17				
					550=		450=		415=				
Cost					5,657		7,363		8,788				
Service Vehicle		15		15	15	x	15	x	15	x			
		30		40	35		22		17				
		24,400=		24,400=	24,400=		24,400=		24,400=				
Cost		12,200		9,150	10,457		16,636		21,529				

PALLET HANDLING VEHICLES COST COMPARISON

4-4-72



INGALLS SHIPBUILDING

Man Minutes to Move 6 Pallets 1 Mile

TABULATION SHEET

Equipment Steps (see page 4)	Fork- Lift a	Strad- dle b	Side- loader c	Truck d	Semi- trailer e	Semi- trailer f	Wagon g	Wagon h	Rail- road i	Crane j	Pro- posed k	SL-3	AAI
1.		2	1		5	3	2	2	2				
2.	3	4	3	2	2	3	2	3	4		2	2	2
3.		1			3	3	1	1	2				
4.		4			2		2		4				
5.				5									
6.	6	9	9	18	9	9	9	9	9		4	9	9
7.		2			2		2		4				
8.		2	1		5	3	2	2	2				
9.	90	12	12	4	4	8	6	8	8		12	12	12
10.		1	1		3	3	1	1	2				
11.		3			3		3		6				
12.				15									
13.	5	6	6	12	6	6	6	6	6		2	6	6
14.		3			3		3		6				
15.		2	1		5	3	2	2	2				
16.	3	3	3	3	3	6	3	3	6		3	3	3
17.		1			3	3	2	2	2				
18.	30	4	4								4	4	4
TOTAL	137	59	41	59	58	50	46	39	65	N/A	27	36	36
Total prime mover use	137	44	41	44	43	50	31	39	25		27	36	36
Number of pallets prime mover will move in 2080 hrs.	5,465	17,018	18,263	17,018	17,413	14,976	24,154	19,200	29,952		27,732	20,800	20,800
Operating cost for the percentage of time in use during one year of prime mover time.													
Carrying Vehicle					6 x 60 43	x	6 x 60 31	x	6 x 60 25	x			
Cost					550= 4,604		450= 5,225		415= 5,976				
Service Vehicle		15 44	x	15 44	x	15 43	x	15 31	x	15 25			
Cost		24,400= 8,318		24,400= 8,318	24,400= 8,511		24,400= 11,805		24,400= 14,640				

ENCLOSURE 3
REPRESENTATIVE EQUIPMENT
USED TO MOVE
STRUCTURAL STEEL IN SHIPYARDS

Maximum traversable grade (loaded):	3 percent
Turning radius:	30 ft. (all wheels turn)

c. Comments. A complete operator's cab at each end of the transporter renders the transporter extremely maneuverable. A crew of two men can load a unit on the transporter from pedestals in 15 minutes and unload onto pedestals in 20 minutes. Reasonable care must be exercised in uniformly loading the transporter and operating over reasonably even surfaces. Maintenance experience with this equipment has been generally satisfactory.

3. TRAILERS WITH ELEVATING PLATFORMS

a. General. Structural units up to 100 tons in weight are moved on trailers, either wagon type or lowboy, with elevating platforms. Special high-powered tractors are normally used with these heavy-duty trailers. The elevating feature of the platforms permits loading or unloading without assistance from other equipment.

b. Operational Characteristics.

(1) Trailer:

Load capacity:	100 tons
Platform size: (Platform is supported by 8 hydraulic cylinders.)	12 ft by 40 ft
Platform elevation:	6 ft (max.) 5 ft (min.)
Number of wheels:	32 on 8 axles

Maximum speed:	
Empty:	12.0 mph
Loaded:	5.0 mph
Turning radius:	40 ft (all wheels turn)

(2) Tractor:

Power:	247 HP diesel engine
Number of wheels:	4 on 2 axles
Maximum traversable grade (loaded)	2 percent

c. Comments. A crew of two men is required to operate these units. Maneuverability of these units is somewhat less than that of the transporters covered in Paragraph 2. Maintenance costs and downtime for these units are considered to be excessive, If, after use, employment of the units is anticipated in the near future, the tractors are seldom disconnected from the trailer.

4. LOWBOY TRAILERS

a. General. Structural units weighing up to 100 tons are moved on lowboy trailers towed by low speed semitractors.

b. Operational Characteristics.

(1) Lowboy trailer

Load capacity:	100 tons
Platform size:	12 ft by 33 ft
Number of wheels:	16 on 4 axles

(2) Semitractor:

Number of wheels:	10 on 3 axles
Maximum speed:	25 mph

c. Comments. A crew of two men are required to operate the lowboy trailer/semitractor combination. The semitractor is seldom disconnected from the lowboy trailer. Loading and unloading the lowboy trailer must be done by a crane, which can lead to excessive waiting time unless excellent coordination is achieved. Experience has shown that maintenance costs and downtime are minimal with this type of equipment.

5. RAILROAD CARS

a. General. When structural units weighing up to 500 tons must be moved over some distance railroad cars are used. For this purpose, special framing is added to the car to make a 40 ft by 60 ft plattform.

b. Operational Characteristics.

Load capacity: 500 tons

Plattform dimensions:

Normal : 9 ft by 60 ft

With framing: 40 ft by 60 ft

Tractive power: Diesel locomotive
or trackmobile

Maximum speed (loaded): 15 mph

c. Comments. With the tractive power, a crew of three men is required to move units by this method. Loading and unloading requires the use of a crane, adding to the number of personnel required. This method is characterized by restricted flexibility of movement because the load can be transported only where tracks exist and there is adequate clearance. In addition, with wide loads on the car movement on other trackage is necessarily restricted until the unit has been moved to the destination. Maintenance records show that initial costs and upkeep on this equipment is expensive.

6. GANTRY CRANES

a. General. Structural units of not more than 340 tons weight may be moved in and along the ship assembly area by gantry cranes. These units span the shipway and an assembly area on each side and at the head of the shipway. The gantry cranes are primarily intended for movement of structural units in the immediate area of the ship and for installation purposes.

b. Operational Characteristics.

Load capacity:	340 tons (4 hooks on 2 trolleys)
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Maximum speed (loaded):	100 fpm
-------------------------	---------

c. Comments. A crew of 7 men is required to move structural units. Movement of these units is restricted to that area between installed trackage.

7. WHIRLEY CRANES

a. General. When units weighing up to 700 tons must be moved a combination of 200-ton capacity Whirley cranes may be used. Such uses are dependent upon whether the crane trackage is laid so that such combinations are possible.

b. Operational Characteristics.

Load capacity:	200 tons
----------------	----------

Maximum speed (loaded):	250 fpm
-------------------------	---------

c. Comments. A crew of 4 men is required for each crane. Movement of individual cranes is restricted to areas in which there is installed trackage. Combinations of cranes for use in moving large units is dependent on availability of cranes in the desired area, either by permanent installation

or by interconnecting trackage. Because of the multiplicity of equipment involved in combination movements extremely close coordination of the movement must be exercised at all times.

8. TRANSLATIONAL SYSTEMS

Structural units up to 9, 000 tons in weight are moved on Ship Transfer Systems. The Ship Transfer System consists of power units, pallet cars, transfer cars, strongbacks and a rail system. The ship module is erected on blocking on a group of strongback assemblies. The strongback assemblies are supported on a series of driven and nondriven pallet cars which are positioned so that power distribution is balanced. The completed ship module is moved in an athwart ship direction by means of a self-contained power unit driving the pallet cars along rails. Some of the pallet cars are freewheeling and serve only as support and truckage, but all of the pallet cars are chained to the strongbacks. When the ship module reaches the final assembly area, the transfer cars are run under the strongback assemblies, and positioned so that power distribution is balanced. The transfer cars incorporate hydraulic actuators which then lift the ship module along with the strongbacks and pallet cars and move the module to an interface point with the adjoining module. Some of the transfer cars are freewheeling and serve only as support and truckage, but all of the transfer cars incorporate hydraulic actuators for lifting. After final assembly the hydraulic actuators on the transfer cars are lowered so that the strongbacks rest on shims on top of the pallet cars, which are engaged into the atwartship rails. The completed ship is carried, by the pallet cars, to the launching drydock.

APPENDIX B

VISITS TO SHIPYARDS

APPENDIX B
VISITS TO SHIPYARDS

During the course of the investigation of the movement of large structural units in American shipyards, Ingalls representatives visited the following shipyards. During each visit conferences were held with material movement personnel at the host shipyard and tours were made of shipyard facilities to observe the material movement equipment and techniques at first hand.

SHIPYARDS VISITED

Newport News Shipbuilding & Drydock Co. Newport News, Va. 23607	Lockheed Shipbuilding and Construction Co. Seattle, Wa. 98134
Sun Shipbuilding and Drydock Co. Chester, Pa. 19013	Seatrail Lines Inc. 1 Chase Manhattan Plaza New York, N. Y. 11205 (Brooklyn Navy Yard) (Building-292) (Brooklyn, N. Y. 11205)
Bath Iron Works Bath, Me 04530	Puget Sound Naval Shipyard Bremerton, Wa. 98314
American Shipbuilding Co. Investment Plaza Cleveland, Ohio 44114	Mare Island Naval Shipyard Vallejo, Ca. 94592
National Steel and Shipbuilding Co. 28th and Harbor San Diego, Ca. 92112	Bethlehem Steel Corporation Sparrows Point, Md. 21219
General Dynamics Quincy Shipbuilding Division Quincy Mass. 02169	Todd Shipyards, Inc. Seattle Division Seattle, Wa. 98134
General Dynamics Electric Boat Division Groton, Ct 06340	Sun Shipbuilding and Drydock Co. Chester, Pa. 19013
Todd Shipyards Inc. P. O. Box 231 San Pedro, Ca. 90733	Long Beach Naval Shipyard Long Beach, Ca. 90733

APPENDIX C
QUESTIONNAIRE
SENT TO
MAJOR SHIPYARDS

APPENDIX C
QUESTIONNAIRE S

To provide a basis from which factual conclusions could be drawn regardtig the efficiency of shipyard material movement the questionnaire attached hereto as enclosure 1 was developed and submitted to 10 shipyards and 13 other industrial concerns that fabricate equipment to move structural steel of various sizes and configurations. The questionnaire was based on module shapes and sizes already determined by Ingalls personnel as being representative of typical shipyard loads.

Although response to the questionnaire was not as great as had been hoped, it was sufficient to provide the basis for the data included in Appendix A.

The shipyards and industrial firms to which the questionnaire was addressed are as follows:

Shipyards

**Quincy Shipbuilding Division
General Dynamics**

**Newport News Shipbuilding and
Drydock**

Litton Ship Systems

**Todd Shipyards Corporation
Los Angeles Division**

Industrial Firms

Elkton Car and Construction Co.

L. B. Smith, Incorporated

Eldal International Corporation

Fruehauf Corporation

Talbert Trailers, Incorporated

**Lockheed Shipbuilding and
Construction Co.**

**Todd Shipyards Corporation
Los Angeles Division**

Seatrail Shipbuilding Corporation

Sparrow Point Shipyard

National Steel and Shipbuilding Co.

**Electric Boat Division
General Dynamics**

Hyster Company

Birmingham Manufacturing Co.

Lawless Industries

Ohio Valley Fabricating Company

**Hydronautics Division
Cosmodyne Corporation**

Western Gear Corporation

Truck Engineering, Limited

Boeing Vertol Company

ENCLOSURE
TO
APPENDIX C

Subject: Maritime Administration Material Handling Research
and Development Program

Dear Sir:

The Maritime Administration with industry assistance has initiated a research and development program to improve the productivity of the shipbuilding industry. Under this program the Maritime Administration has awarded Ingalls Nuclear Shipbuilding, a Division of Litton Systems, a contract to administer the research and development program in the area of material handling.

One of the projects in this program is a study of the methods of transporting large structural units about a shipyard. We are requesting your assistance in developing data for moving typical large structural units with your equipment.

The typical structural sections listed below and defined by the attached sketches are assumed to be moved 100 feet, 1/4 mile and 1 mile for this study.

Plate blanket	20T
Flat panel	40T, 80T, 150T
Box section	50T, 200T
Stern section	80T, 300T
Bow section	50T, 100T, 200T
Deckhouse	30T, 80T, 200T, 500T
Mast	20T
Ship module	1500T, 3000T, 8000T

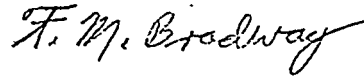
Would you kindly furnish data from which operating cost and characteristics can be determined for each of your vehicles or transporting devices which will move one or more of the typical structural units any & the specified distances in a shipyard.

In addition to the above equipment which is presently available, do you have any suggestions which would make the moving of the large structural units about a shipyard more economical?

Do you have any ideas which you or others could develop under this research and development program which would result in more economical movement of the large sections?

Thank you for your help in making this information available so that shipyard managers may make better informed decisions on moving large structural units.

Very truly yours,

A handwritten signature in cursive script, reading "F. M. Bradway".

F. M. Bradway
Program Manager

hw

The following outline, as applicable, is offered as a guide to the information that is desired.

Transporting Large Structural Units

1. Type of equipment: _____
2. Sections moved:
 - Plate blanket: 20T ☐ _____
 - Flat panel: 40T ☐ , 80T ☐ , 150T ☐ _____
 - Box section: 50T ☐ , 200T ☐ _____
 - Stern section: 80T ☐ , 300T ☐ _____
 - Bow section: 50T ☐ , 100T ☐ , 200T ☐ _____
 - Deckhouse: 30T ☐ , 80T ☐ , 200T ☐ , 500T ☐ _____
 - Mast: 20T ☐ _____
 - Ship module: 1500T ☐ , 3000T ☐ , 8000T ☐ _____
3. Load capacity: _____
4. Size of load supports or platform: _____
5. Number of load supports: _____
6. Method of supporting load: _____
7. Power source for movement: _____
8. Method of directional control: _____
9. Turning radius: _____
10. Maximum speed:
 - Empty: _____
 - Loaded: _____
11. Maximum grade:
 - Loaded: _____
12. Type of surface required for movement: _____
13. Assistance needed for loading and unloading: _____

14. Brief description of any unique features of operation: _____

15. Cost of equipment: _____
16. Cost and description of required support facilities: _____
17. Down time for maintenance in a year: _____
18. Cost of parts for maintenance for a year: _____
19. Fuel or power required for 8 hours of operation: _____
20. Number of men used to move the units: _____
21. Amount of time necessary to move each of a representative number of the typical units, that the equipment will handle, the different distances. Give the loading, unloading and traveling time separately: _____
22. Estimated number of mixed typical units that can be moved in a 40 hour week for each of the assumed distances up to the capacity of the equipment: _____
23. Remarks:

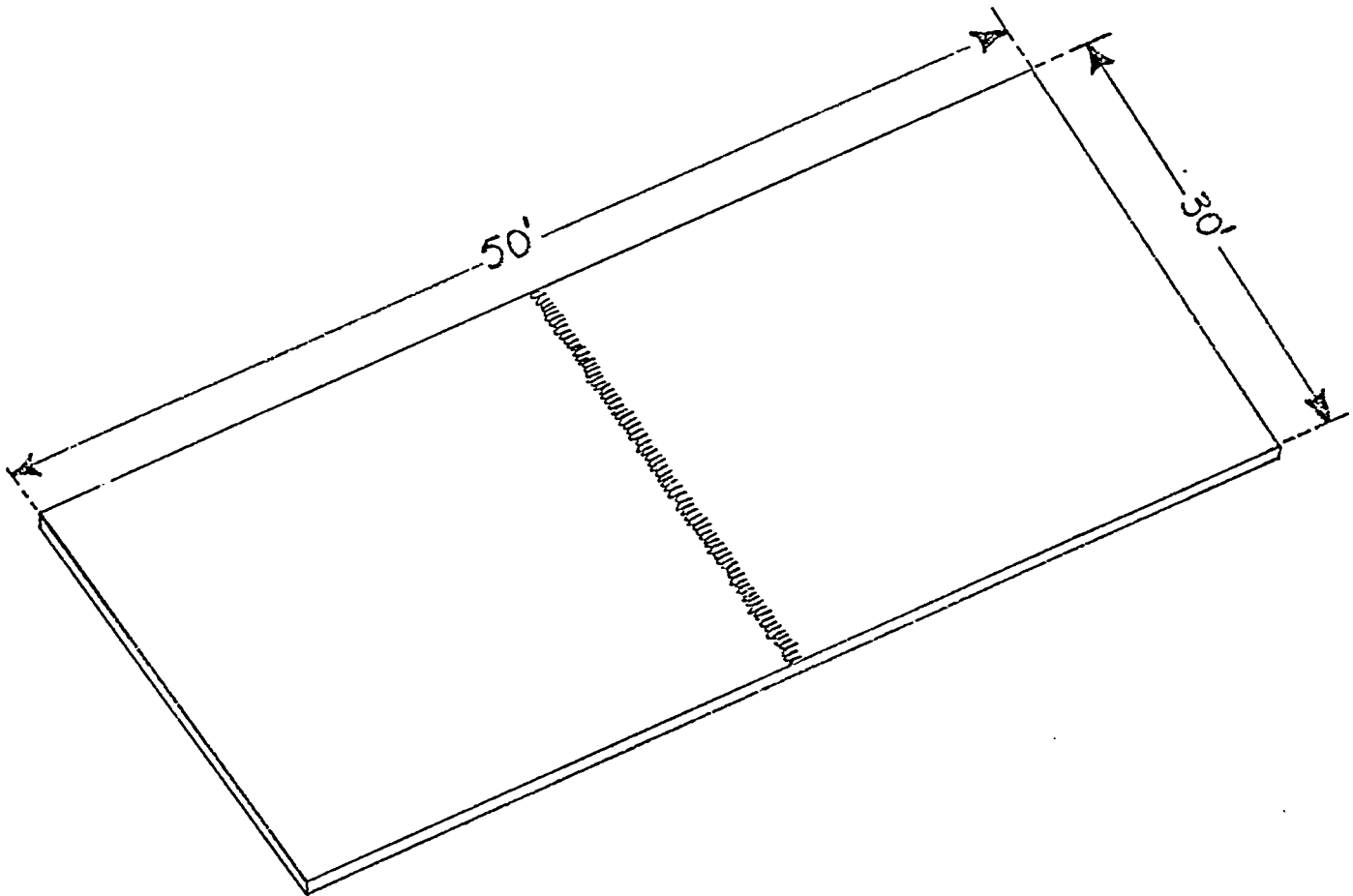
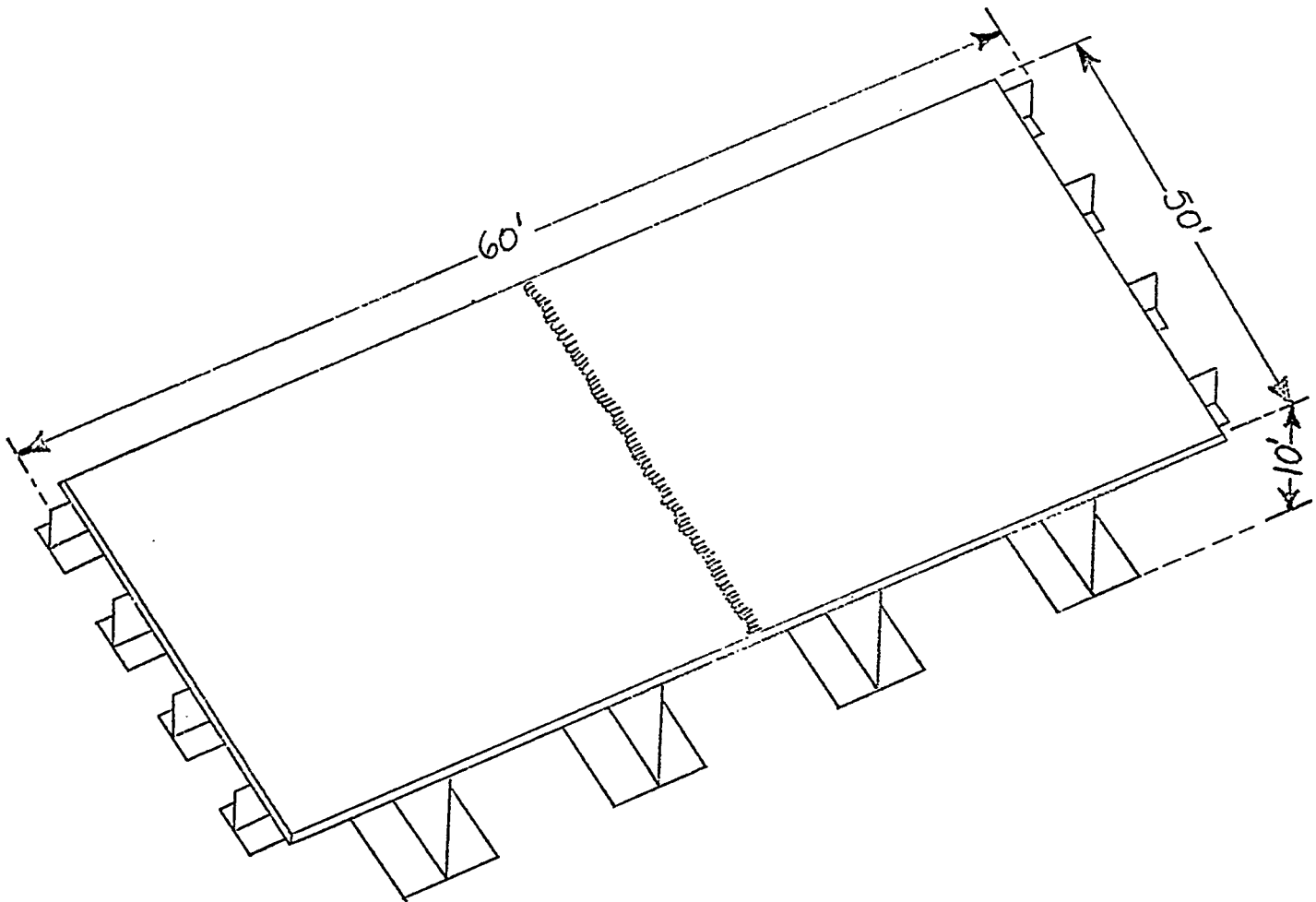


PLATE BLANKET

3/8" TO 1 1/4" THICK

MAXIMUM DIMENSIONS

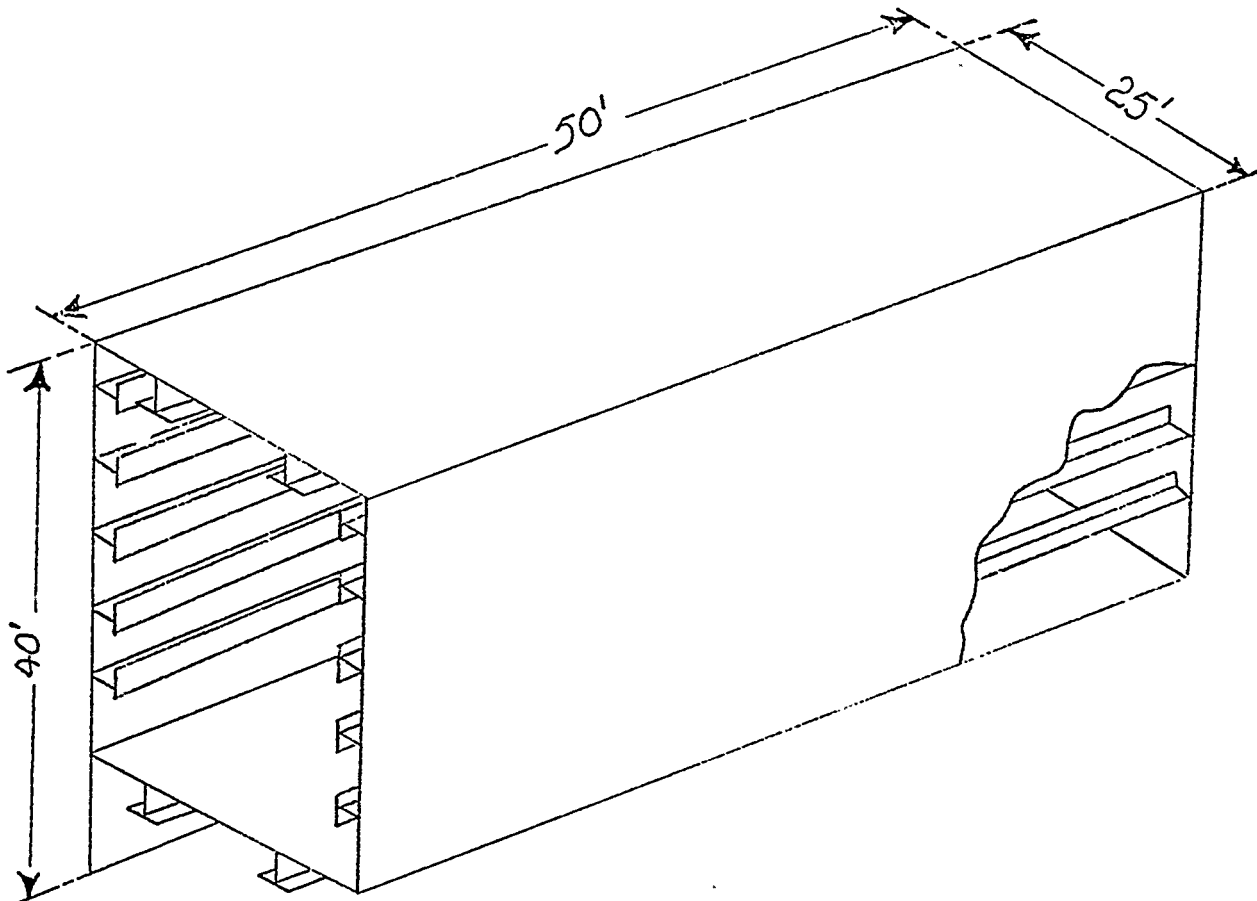
WEIGHT RANGE 3—50T



FLAT PANEL

MAXIMUM DIMENSIONS

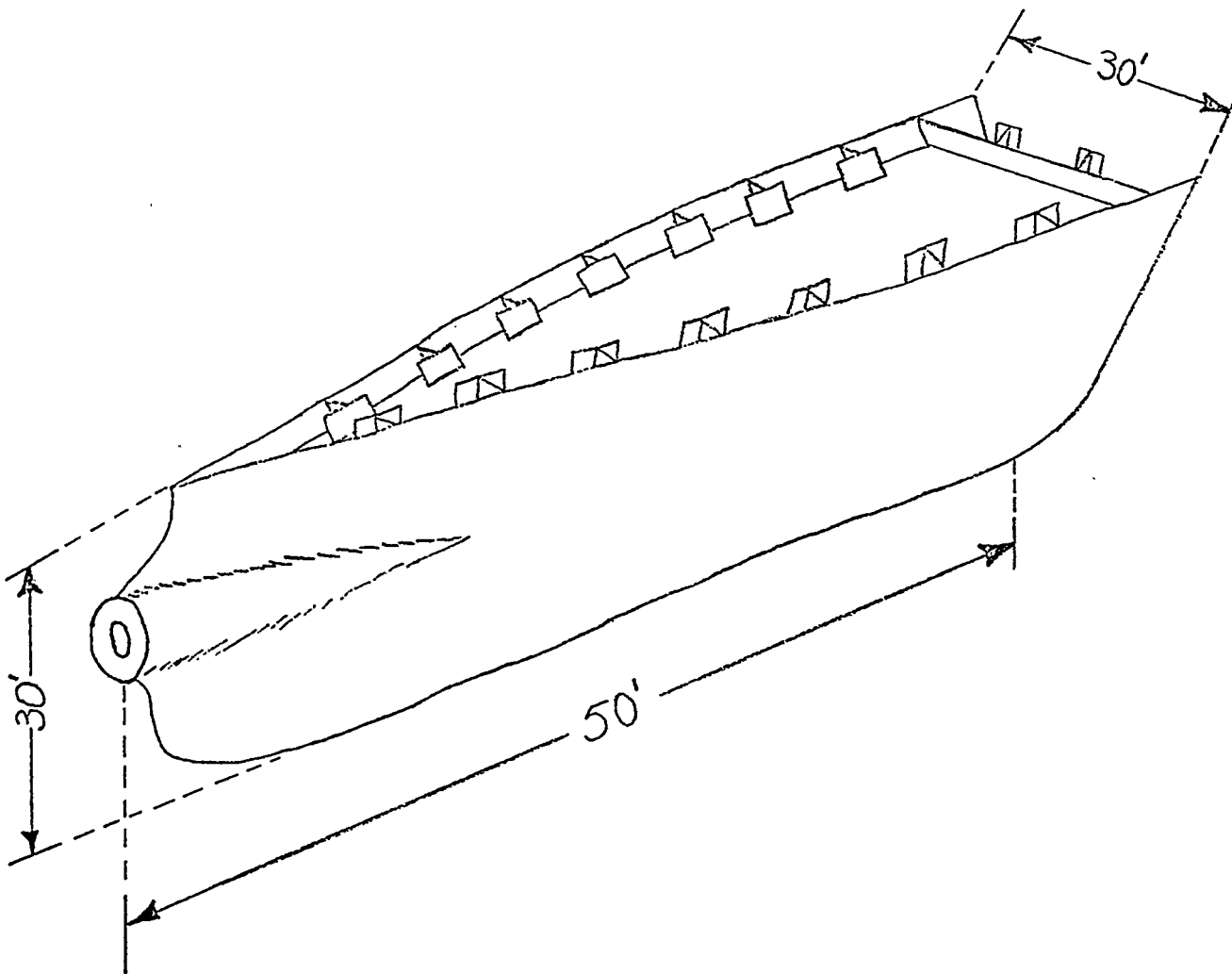
WEIGHT RANGE 5-200T



BOX SECTION

MAXIMUM DIMENSIONS

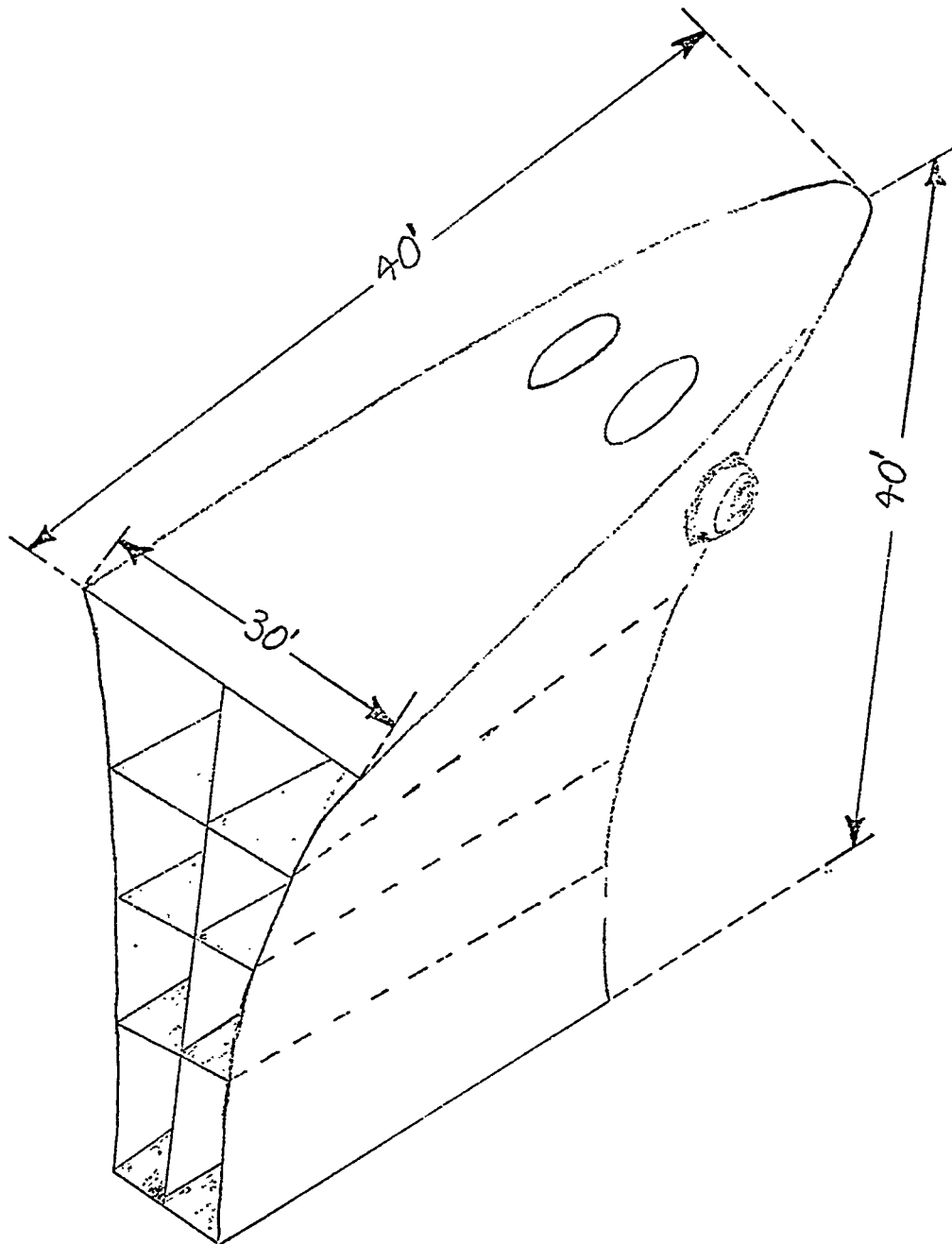
WEIGHT RANGE 20-200T



STERN SECTION

MAXIMUM DIMENSIONS

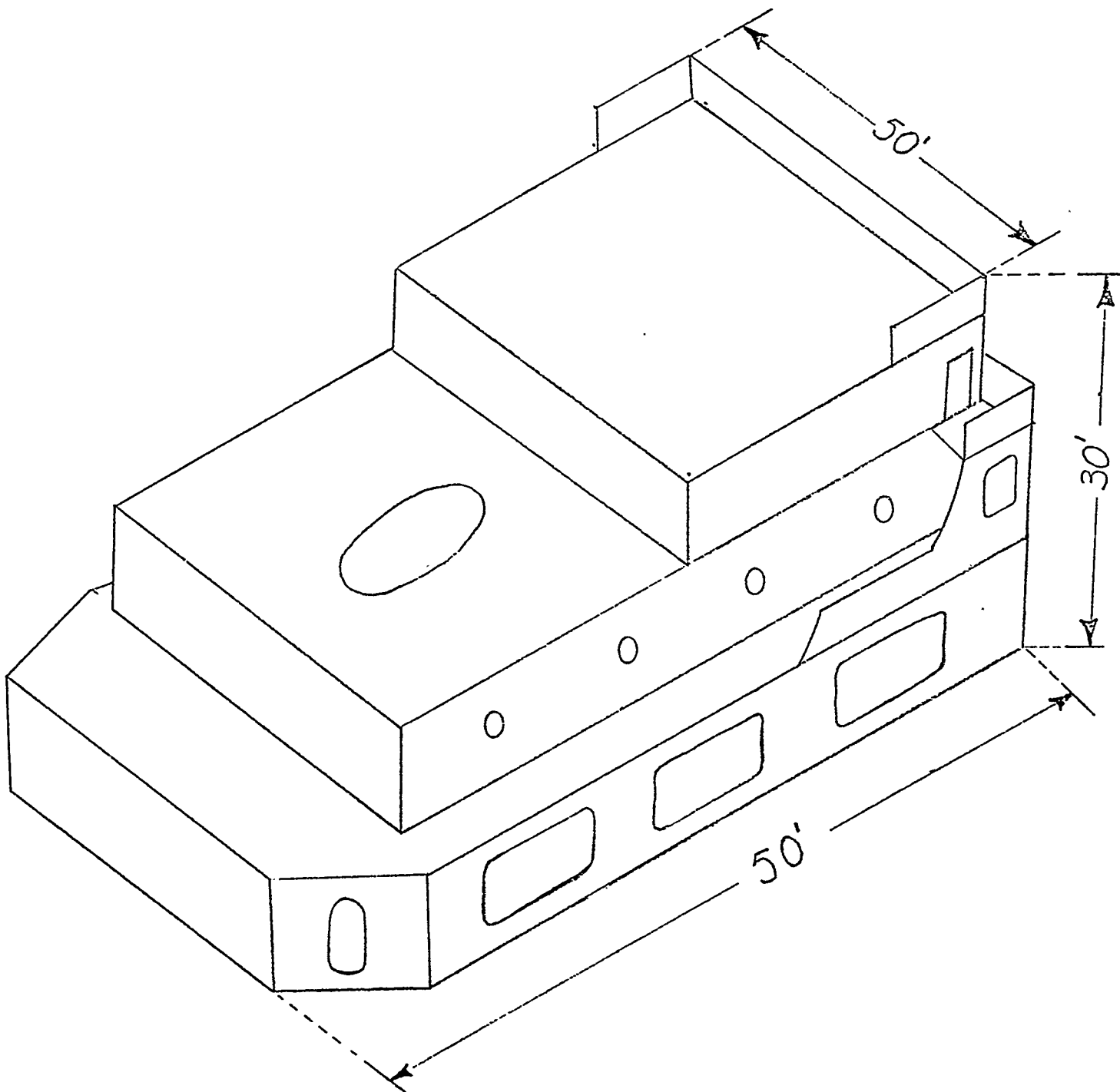
WEIGHT RANGE 30 – 300T



BOW SECTION

MAXIMUM DIMENSIONS

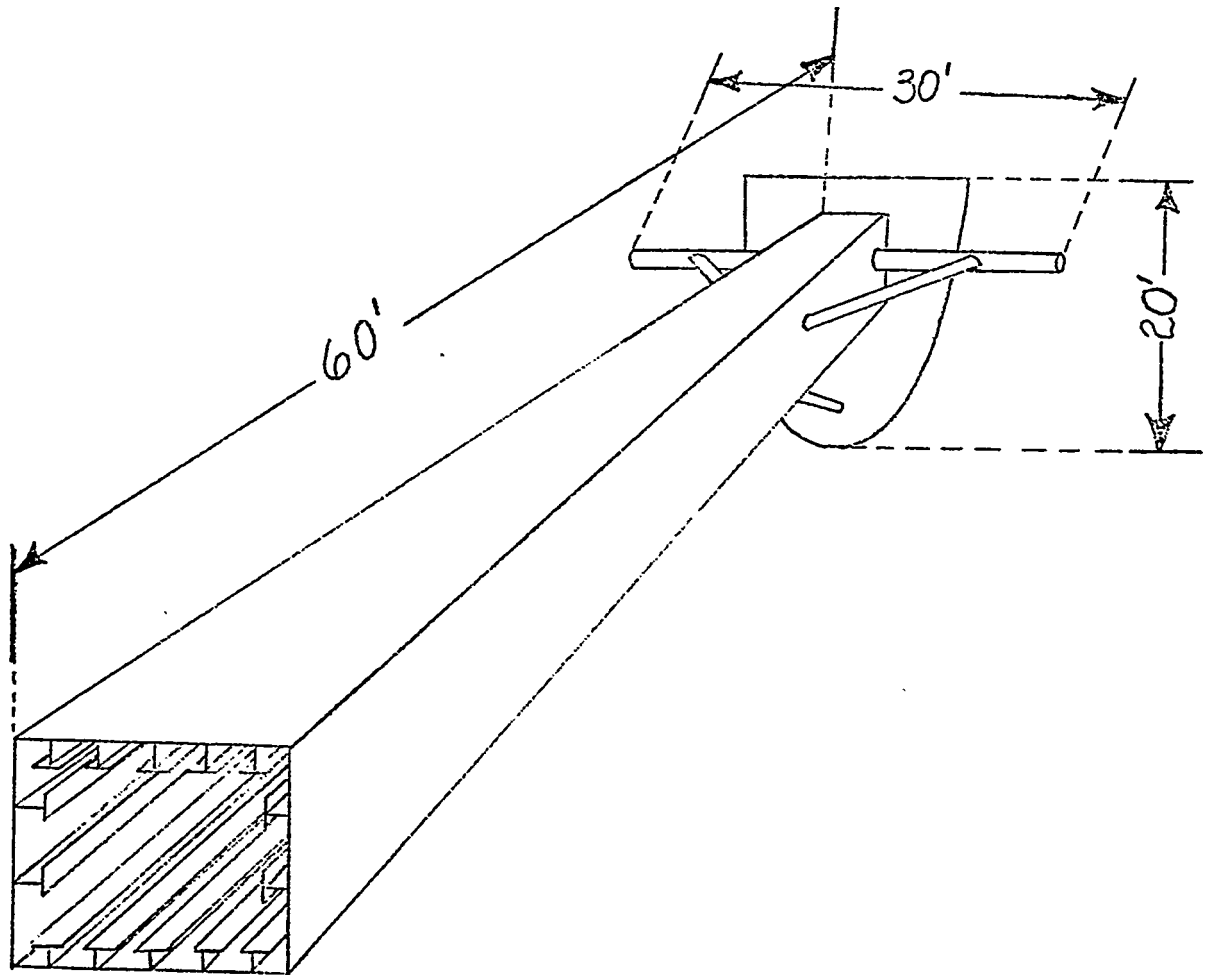
WEIGHT RANGE 30-200T



DECKHOUSE

MAXIMUM DIMENSIONS

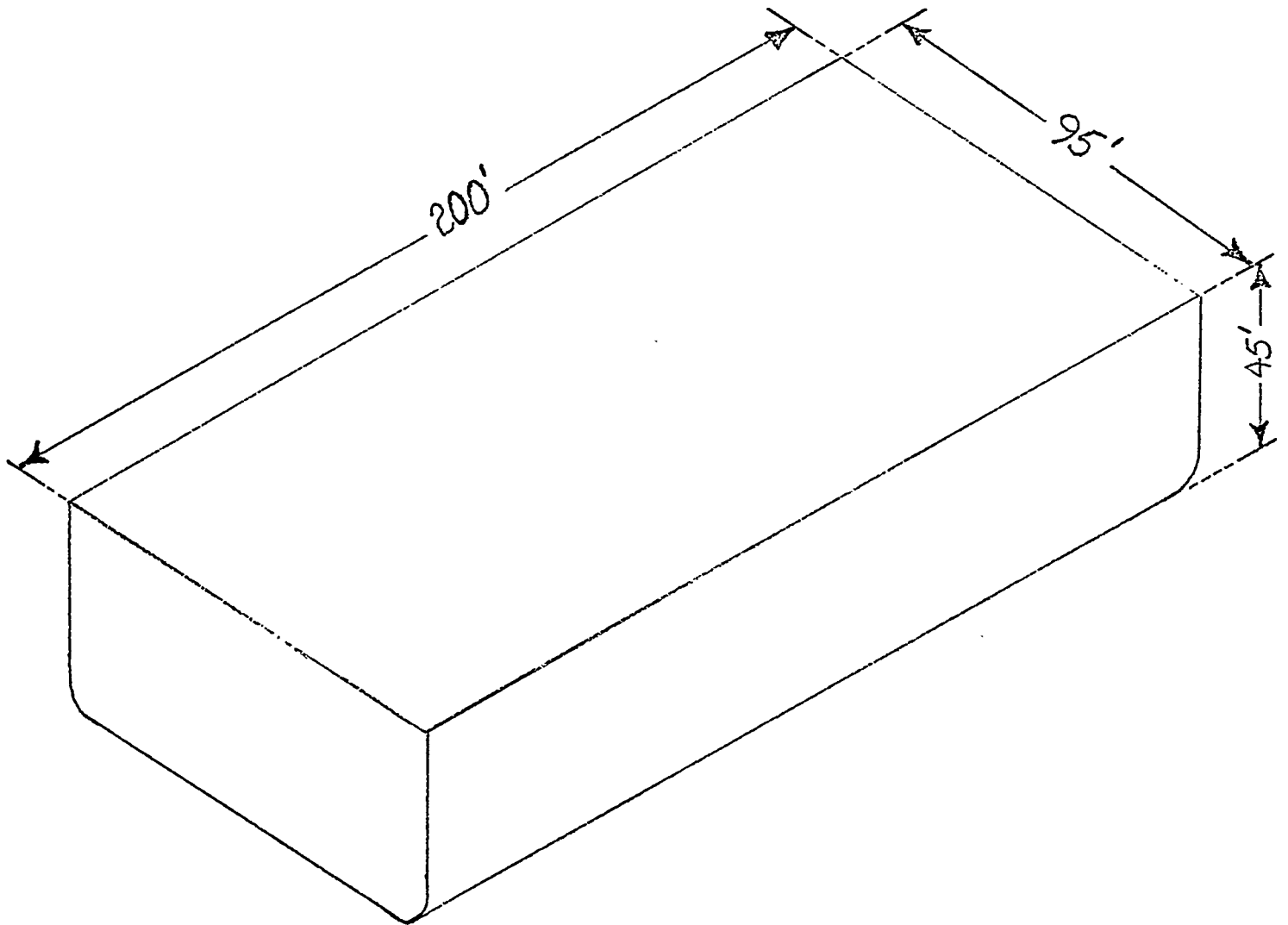
WEIGHT RANGE 10-500T



MAST

MAXIMUM DIMENSIONS

WEIGHT RANGE 1-50T



SHIP MODULE

MAXIMUM DIMENSIONS

WEIGHT RANGE 1000— 8000T

APPENDIX D

REPORT ON TESTS

CONDUCTED

ON A

10 -TON OVER -THE -ROAD AIR LIFT TRANSPORTER

UNDER

CONTRACT 1-36200

APPENDIX D

10 -TON OVER -THE -ROAD AIR LIFT TRANSPORTER

This appendix includes a description of the 10-ton air lift platform developed under Contract 1-36200, the conditions under which required tests were performed and the results of the tests. Sufficient detail has been included in each section to permit a complete understanding of the physical construction of the vehicle, operating characteristics, test conditions, and the technical data accumulated during the tests.

As a part of the subcontract, the vendor was asked to project the design features for air lift platforms with the capacity to transport large typical structural loads as defined in appendix C. These projections are given in the final section of this appendix.

Section I
DESCRIPTION OF EQUIPMENT

1. GENERAL.

The Air Barge system (Figure 1) tested under the provision of the Ingalls subcontract consists of an LP 8X20-8-36 load bearing platform and an electrically driven truck which carries on Model ASU - 1 power unit as the air source and also serves as a tractive source for the load-bearing air lift platform.

2. MODEL LP 8X20-8-36 AIR3ARGE.

a. Model Number Significance. The model number of the LP 8X20- 8-36 AirBarge (Figure 1) denotes a load bearing plattform 8 feet wide by 20 feet long fitted with eight model S-36 casters, or air cushion units. The S-36 designation denotes a caster 36 inches in diameter. Each of the casters has a circular flexible brush seal which interacts with the road surface and retains the flotation air inside the air cushion.

b. Lateral Stabilization. One of the characteristics of an air cushion load bearing platform is a tendency of the aft end to drift in the direction of a downward slope. To overcome this, AirBarge incorporated a set of anti-drift wheels (Figure 1) at the aft end to prevent either downward drift or lateral "fish-tailing" resulting from other causes. The se wheels do not interfere with the normal jacking action of the platform because of a hinged action of the wheel mountings.

c. Casters. The air bearing casters are simply constructed units requiring a minimum of maintenance and incorporating some innovations not found in other similar equipment. The caster is circular and is separately remountable for maintenance or replacement purposes. The essential physical components of the caster are a housing, a circular plate, an inflatable inner tube-like jacking pad, and a flexible fabric flotation skirt terminated at the lower periphery by a brush air seal. A summarized description of the operation of the caster is given in paragraph e.

d. Towing. The forward end of the AirBarge is fitted with a towing hitch with a swivel fitting. The hitch is designed so as to permit maximum maneuverability of the towing vehicle within the limits imposed by the towed load.

e. Operating Characteristics. Air flow from the model ASU- 1 power unit is ducted to the AirBarge through a flexible duct, is piped to each caster through rigid integral ducting and is vented at the caster through internal ducting to inflatable inner tube-like jacking hangers. This causes the hanger to press the floating brushes firmly against the ground to trap flotation air inside the air cushions. The flotation air is retained by a flexible fabric skirt which has semirigid bristles installed vertically around the lower periphery. When the flotation air pressure has reached the pressure at which it becomes load bearing the air escapes under the brush thus providing the air cushion effect.

D-4

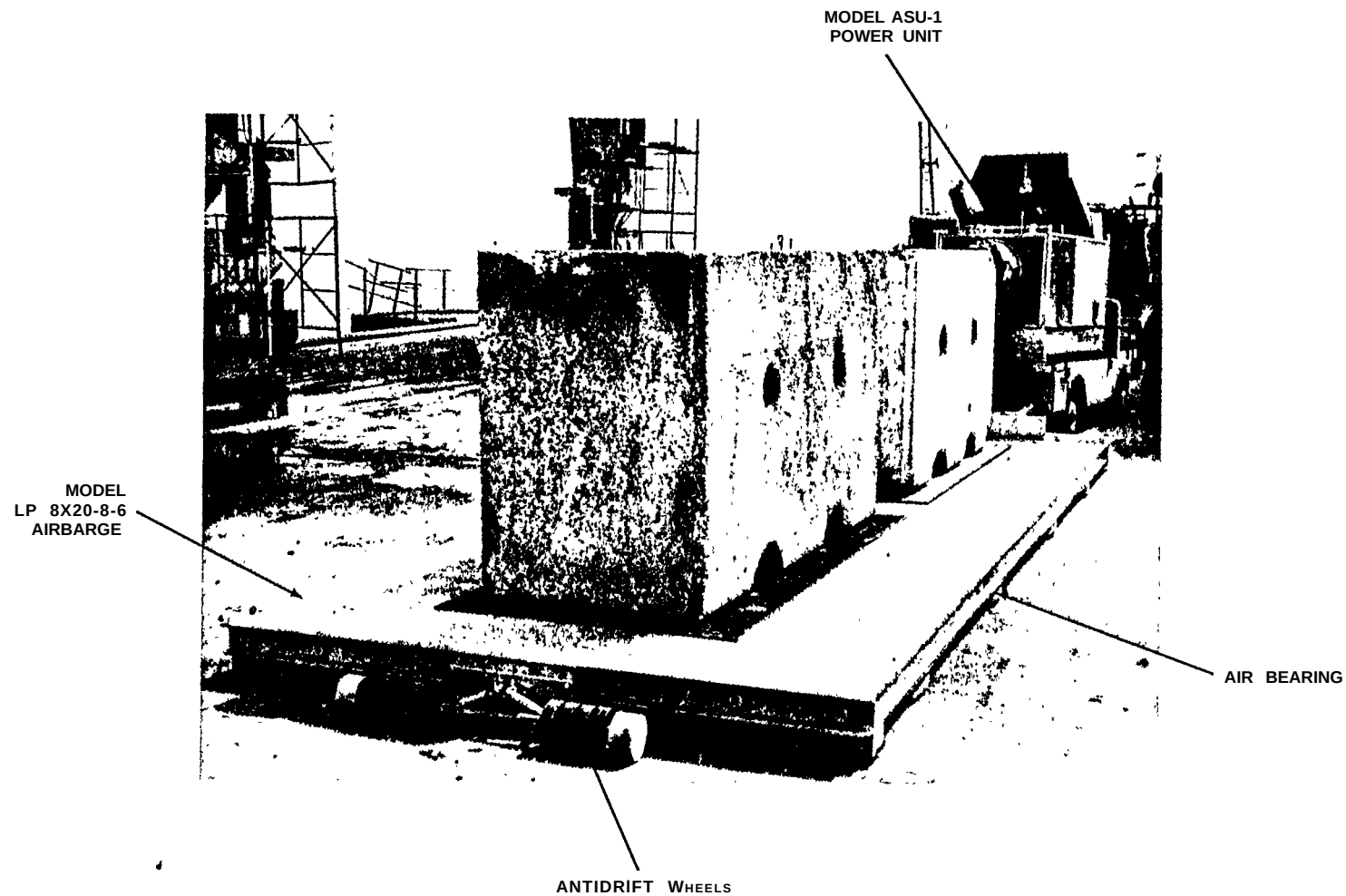


Figure 1 Model LP 8 x 20-8-6 AirBarge Air Lift Transporter

3. MODEL ASU- 1 POWER UNIT

a. **General.** The Model ASU -1 Power Unit (Figure 2) is a self-contained, more-or-less conventional source of air flow designed to provide a large flow of air (12,500 cfm at rated load) at low to moderate pressures (3 psi). Basically, the unit consists of a air source and a towing unit.

b. **Air Source.** The air source of the model ASU- 1 unit is powered by a "souped-up" Oldsmobile Toronado 455- cubic inch engine. The air flow is provided by a Joy axial flow fan connected to the engine by a drive shaft acting through a speed change gear and flexible coupling. To provide maximum reliability to the unit, separate cooling systems are provided for the engine and the gearbox lubricating oil. Cooling capacity for the engine is provided by an oversize radiator utilizing water as a coolant medium. The gearbox lubricating oil is maintained at operational temperature by the use of four special radiators. Flexible ducting, connected to the forward end of the AirBarge when in use, directs the air flow into the AirBarge internal ducting.

c. **Tow Capability.** Tow power for the Model ASU- 1 is provided by a 2,500 pound Taylor-Dunn Model 1248B 5-horsepower electric cart powered by internally contained batteries.

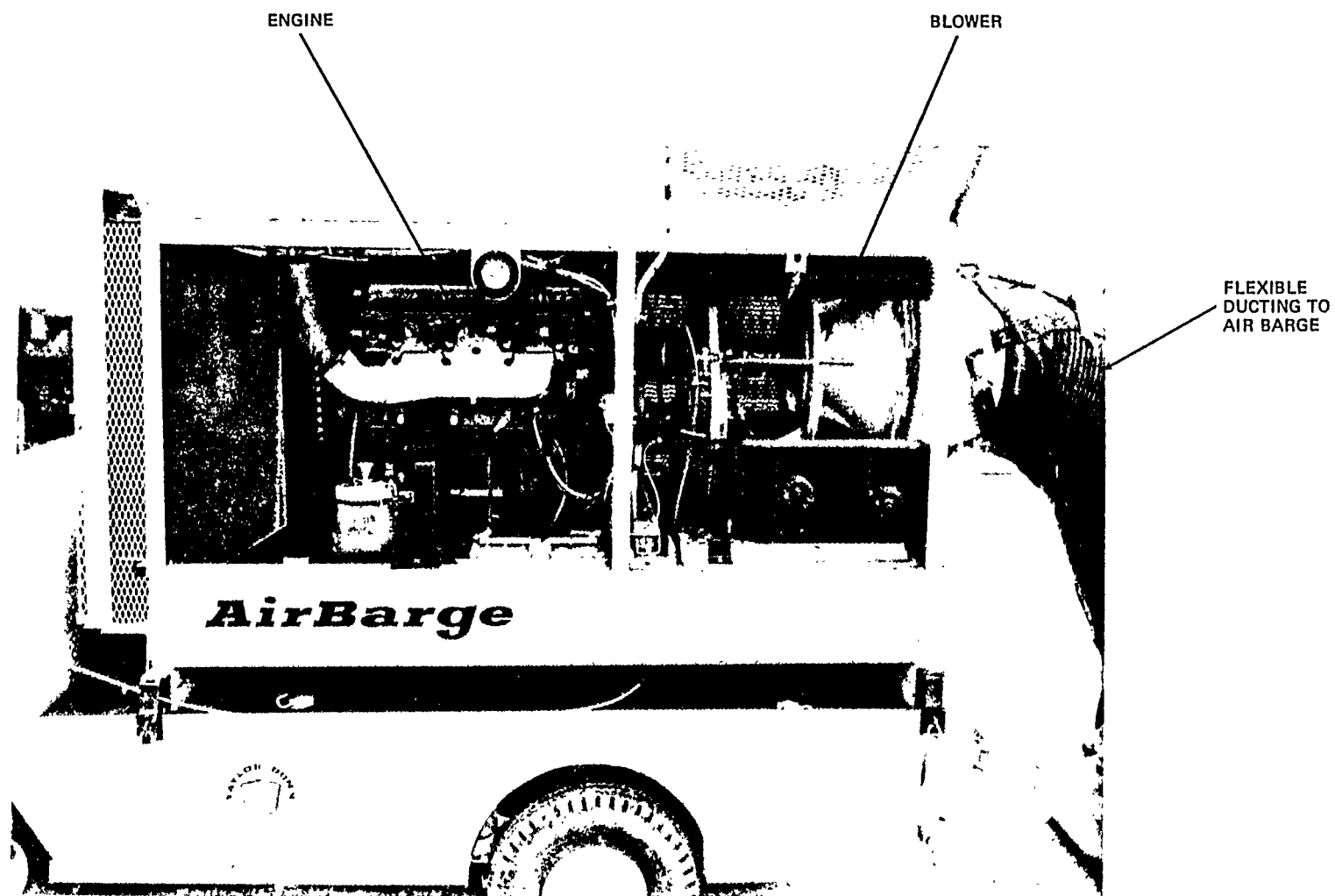


Figure 2 Model ASU-1 Power Unit

d. Instrumentation. The instrumentation (Figure 3) listed below is provided to permit monitoring of the operation of the model ASU- 1 unit:

- (1) Gear box oil temperature gage.
- (2) Gear box oil pressure gage.
- (3) Engine temperature gage.
- (4) Engine oil temperature gage.
- (5) Engine speed tachometer.
- (6) Manifold intake vacuum gage.
- (7) Fuel gage.
- (8) Generator ammeter.

4. OPERATING PROCEDURES

a. Model ASU- 1 Power Unit.

(1) Controls and Instrumentation. The controls and instrumentation for the model ASU- 1 power unit are so similar to that for other units constructed for the same purpose that no description of them other than that given in paragraph 3 is included in this report. It should be noted, however, that during the tests it was found that the gear box oil was overheating. To eliminate this problem, a separate cooling system providing a radiator flow through for the oil was installed. A gear box oil temperature gage is included in the instrumentation that is located on a forward facing panel immediately behind the operator's seat.

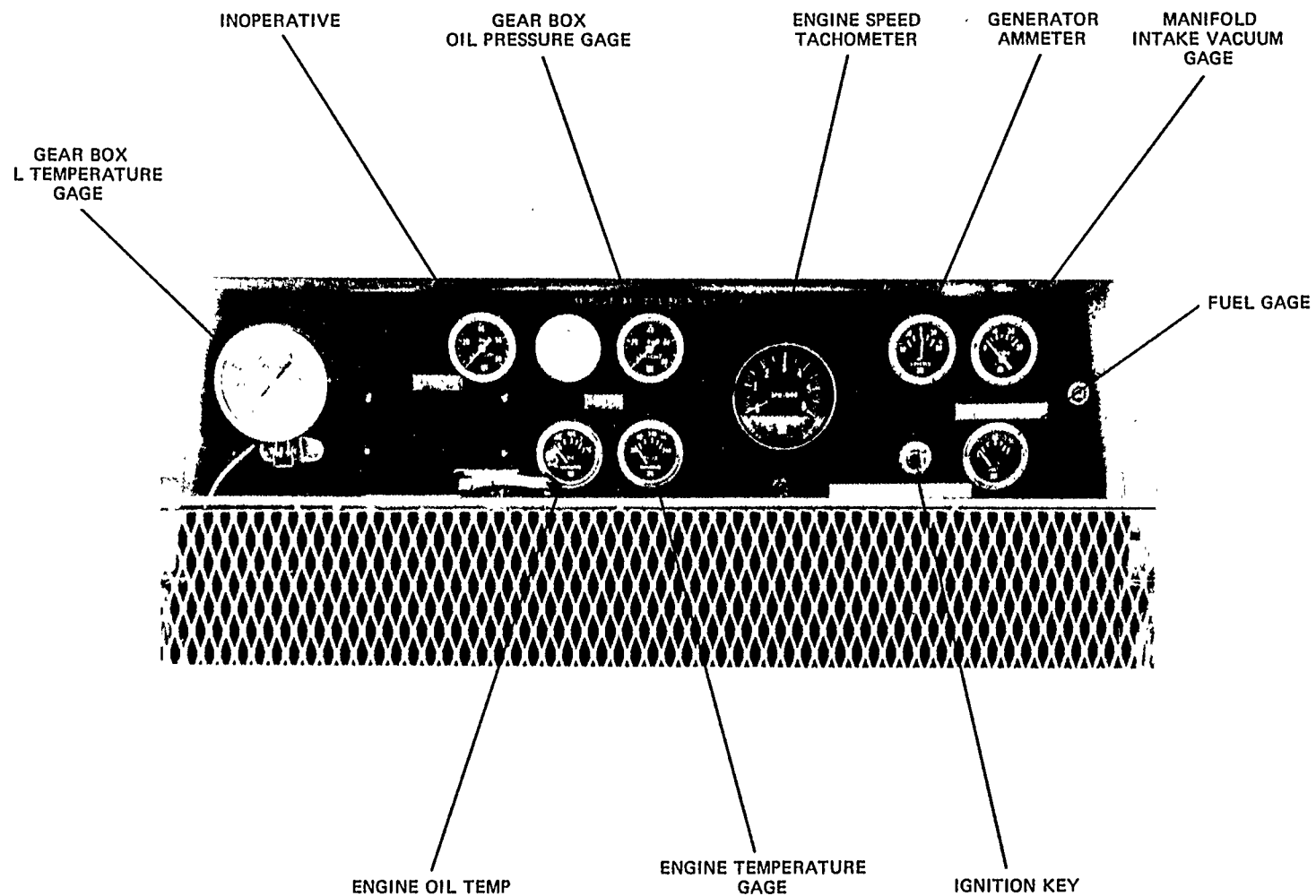


Figure 3 Model ASU-1 Power Unit Instrumentation

(2) Operation. Because of the similarity of the operating procedures for the model ASU- 1 power unit to those for a standard automobile, no description of these procedures is included in this report. It should be noted that the blower engine throttle, used to adjust the engine speed, is located adjacent to the operator's seat and can be easily adjusted to maintain optimum engine speed.

(3) Operational Precautions.

(a) Optimum Engine Speed. An air operating characteristics curve is mounted on a panel immediately in front of the driver's seat on the traction unit. Before starting movement operations the operator should ascertain the weight of the payload and consult the operating characteristics curve to determine the correct engine speed to be used and maintain that speed throughout the movement. Failure to do this will result in excessive brush seal wear if the speed is too low, and useless expenditure of power and fuel if the speed is too high.

(b) Fuel Supply. Prior to initiating a movement the operator should ensure that there is sufficient gasoline in the tank to allow completion of the run without interruption. If the fuel supply is depleted during movement, the engine will stop, the flotation air supply will cease and the Air-Barge will settle quickly to the operating surface and may crush the seals. This could result in permanent damage to the seals and cause the seals to be replaced.

b. Model LP 8x20-8-36 AirBarge.

(1) Controls. Five levers (Figure 4) are mounted side-by-side on the air manifold at the towing end of the AirBarge. A sixth is located to the right of these levers as viewed from the towing end of the Air Barge looking aft. The group of five consists of two black levers, two white, and one green. The two white levers control the flow of flotation air into the air cushions under the forward edge of the AirBarge and the black levers the flow into the air cushions under the aft end. The two levers on the right hand side control the flow of flotation air into the air cushions under the right hand side of the Air Barge and the two levers on the left hand side controls the air flow into the left hand air cushions. Positioning these levers toward the AirBarge allows flotation air to flow into the cushions while positioning them toward the tow truck restricts the flow of flotation air. The green lever at the center of the control levers admits air into the inflatable hangers of the air seals causing them to press the floating brushes firmly against the load bearing surface to trap the flotation air inside the air cushions. The sixth lever, painted red, is used to deflate the hangers of the air seals so the seals will not be crushed against the load bearing surface when flotation air is reduced to allow the AirBarge to settle to the ground.

(2) Start-up Procedure.

(a) Position all AirBarge control levers toward the AirBarge.

(b) Start blower engine and bring up to predetermined optimum speed rapidly to minimize blower surge.

D-11

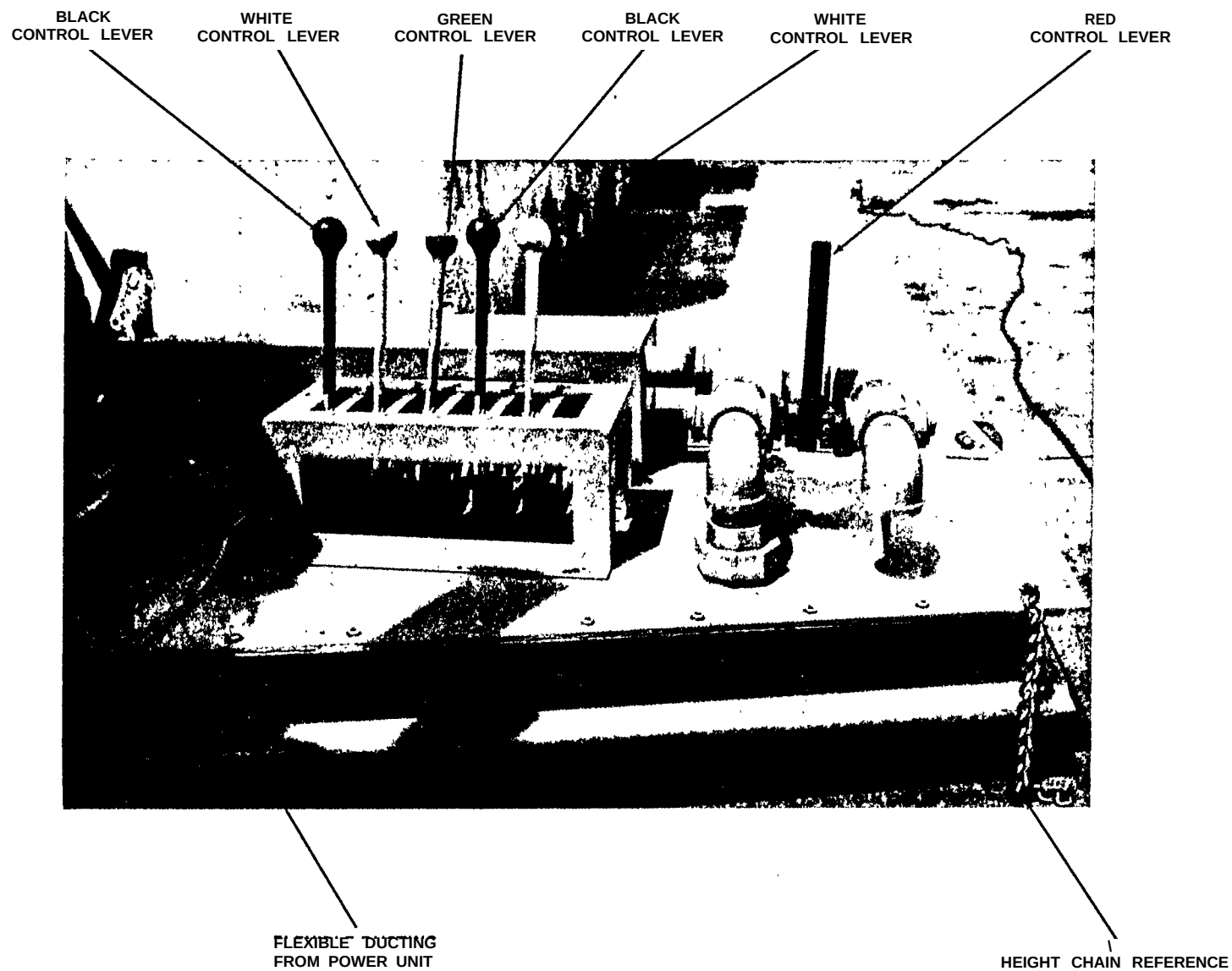


Figure 4 Model LP 8x 20-8-36 Air Lift Transporter Controls

(c) Move green lever toward the tow vehicle momentarily until the AirBarge raises and the reference chain (Figure 4) just clears the load bearing surface.

(d) Move the green lever toward the AirBarge as far as possible without allowing the AirBarge to lose height. This should be done immediately after operating height has been attained to prevent overinflation of the seal hangers and subsequent bouncing of the AirBarge.

(e) If the AirBarge displays a tendency to settle during operation move the green lever slightly toward the tow truck until the correct operating height is again reached.

(f) If the AirBarge has a tendency to ride high in any portion, this tendency can be corrected by manipulation of the appropriate black and white control levers.

(3) Shut-down Procedure.

(a) With the engine operating at optimum speed, move the red lever toward the tow truck and allow the Air Barge to settle to the operating surface.

(b) Reduce engine speed and shut down the engine.

(c) Move red lever as far as it will go toward the rear of the AirBarge.

(4) Emergency Shut-down Procedure. To shut down the AirBarge in an emergency, move the red control lever rapidly to the rear and allow the Air Barge to settle to the ground.

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Section II

TEST CONDITIONS

1. GENERAL

Observations of the AirBarge in operation were made under two circumstances, a formal test at the manufacturer's facility and working demonstrations conducted at Ingalls Shipbuilding. The conditions stated in this section apply only to the tests at the manufacturer's facility, since no formal documentation was made during the demonstrations. The test conditions were set up so as to ensure that the results would demonstrate whether the AirBarge could perform satisfactorily under simulated shipyard conditions. Detailed descriptions of test conditions are specified below.

2. OPERATING SURFACES

a. General. Tests were conducted on two load-bearing surfaces, the one a weathered concrete surface, the other an unsealed asphalt parking lot. The demonstration area at Ingalls was an unsealed asphalt road. These surfaces were chosen as being representative of the types of surfaced material movement routes generally found in most shipyards.

b. Concrete Surface. The first test surface was a weathered concrete driveway. Although the concrete was reasonably smooth, it had load cracks similar to those usually found in such surfaces and some expansion joints which had up to 1/4 inch vertical mismatch as well as horizontal gaps. This driveway could therefore be considered to be typical of concrete roadways encountered in industrial plants and shipyards.

c. Asphalt Surface. The second test surface was an unsealed asphalt parking lot similar to much hardtopping found in shipyards. This asphalt was much rougher than the concrete driveway. It was also much more porous since it was unsealed. Also present in the asphalt were cracks and cavities of varying magnitude.

3. AIRBARGE LOADING FOR TEST

The maximum load carried during the test consisted of eight circular and one rectangular steel plates making a total payload of 20, 346 pounds. With the added Air Barge tare weight of 6, 605 pounds the maximum test gross weight was 26, 951 pounds. The short lengths of chain (Figure 4) attached to the right-hand corners of the AirBarge are provided to assist the operator in adjusting the floating height as described in Section III, Paragraph 3g.

4. DURATION OF TESTS

During the test the AirBarge was moved forward and backward over both test surfaces. For the concrete surface the linear total of movement was 350 feet while for the asphalt surface the total was 640 feet. The distances and types of traverse to which the transporter was subjected during the load travel demonstrations at Ingalls are tabulated in Table I.

Table I. Distances Traversed During Working Demonstrations

Load (Tons)	Types of Traverse	Total Distance (Feet)
10	Forward and reverse	200
6 1/2	Varied	600
10	Circles to right and left	3 , 0 0 0
6 1/2	Circles to right and left	6,500
6 1/2	Forward and reverse	3,500
		Total: 13, 800

Section III

TEST RESULTS

1. GENERAL

Tests conducted on AirBarge equipment for which contracts were awarded under the project covered by this report had a two-fold purpose:

- a. Establishment of the feasibility of use of the contracted equipment in shipyards, and,
- b. Formulation of significant data upon which planning could be done on units capable of transporting the largest loads anticipated in ship construction. The material compiled in this section provided the basis for future planning. The material presented in this section has been divided into that which is applicable to the model ASU- 1 power unit and that which pertains to the AirBarge air lift transporter.

2. MODEL ASU- 1 POWER UNIT

a. Maximum Safe Engine Operating Speed. The blower installed in the model ASU- 1 power unit was thoroughly tested by the manufacturer prior to delivery. Tests and design data indicate that the maximum safe blower speed is 15,000 rpm and that this figure is reached at an engine speed of 3,460 rpm. Blower speed data at that and representative other lesser speeds are plotted in Figure 5.

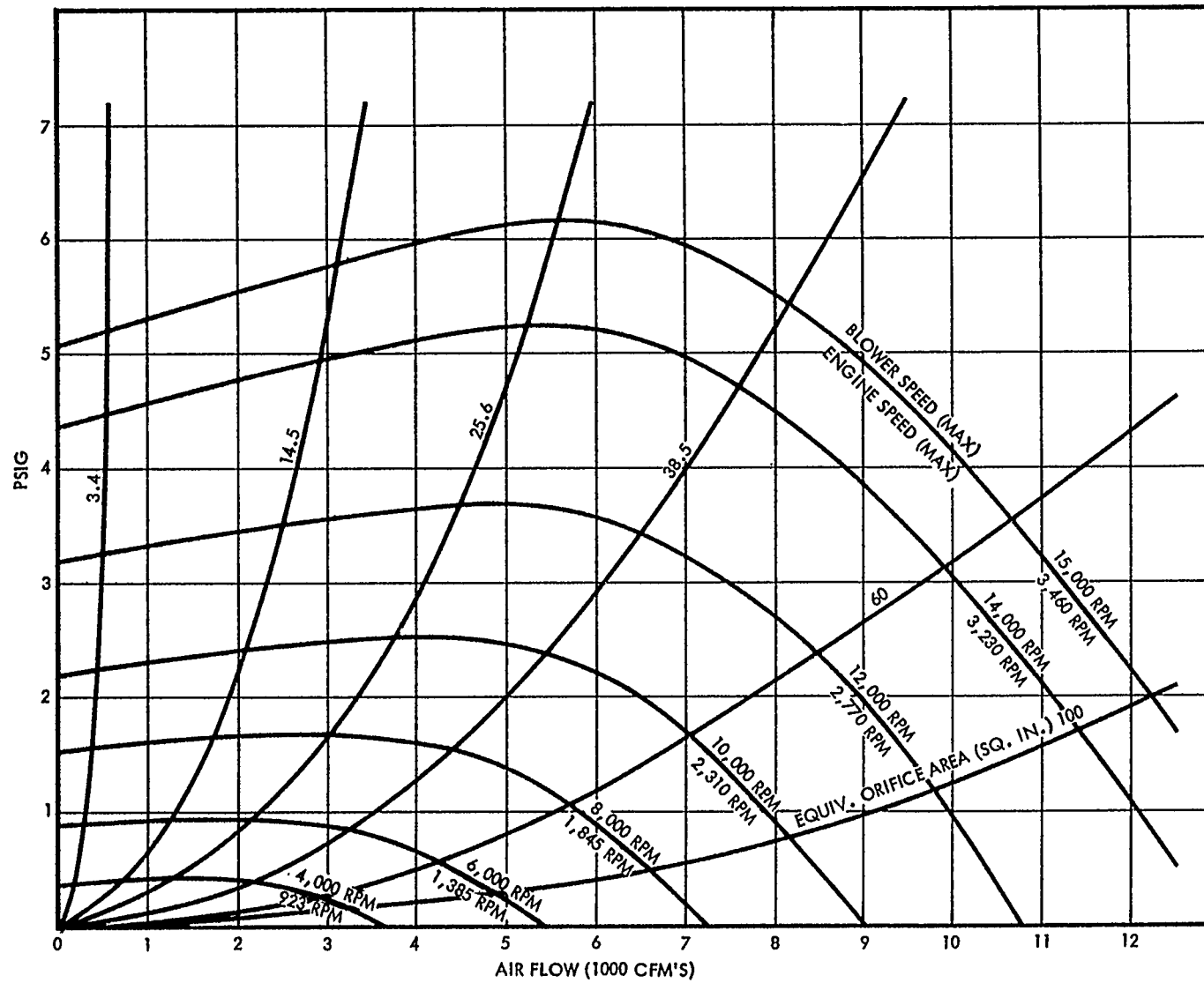


Figure 5 AirBarge Model ASU-1 Power Plant Blower Characteristics

b. Blower Brake Horsepower Requirements. Blower brake horsepower requirements at representative engine speeds are plotted in Figure 6.

c. Developed Engine Brake Horsepower. The curve shown in Figure 7 depicts engine brake horsepower developed at various engine speeds. The points plotted in the graph are actual test data measured during the Air Barge system tests. The curve therefore represents actual test experience with the engine and blower mounted in the model ASU- 1 power unit and ,supplying flotation air to the LP8X20-8-36 AirBarge platform.

3. MODEL LP 8X20-8-36 AIRBARGE LOAD BEARING PLATFORM

a. General. The most significant performance parameter in the design and operation of any air cushion vehicle is the equivalent gap, or the space between the load bearing surface and the air seal. This equivalent gap, symbolized "he", is measured in inches. It represents the average flotation gap which exists between the seal and the load bearing surface when the air cushion vehicle is floating. Equivalent gap varies widely with different types of seals and different load bearing surfaces. For example, air casters which have smooth faced seals designed for operation over smooth indoor surfaces may develop equivalent gaps as small as .002 inches to .005 inches. On the other hand, air cushion vehicles with flexible skirt type seals may develop equivalent gaps as large as 0.50 inches or more. Horsepower required to operate any air cushion vehicle is directly proportional to the air loss through the equivalent gap underneath the air seal. Therefore, for a given gross weight, an air cushion vehicle operating at an equivalent gap

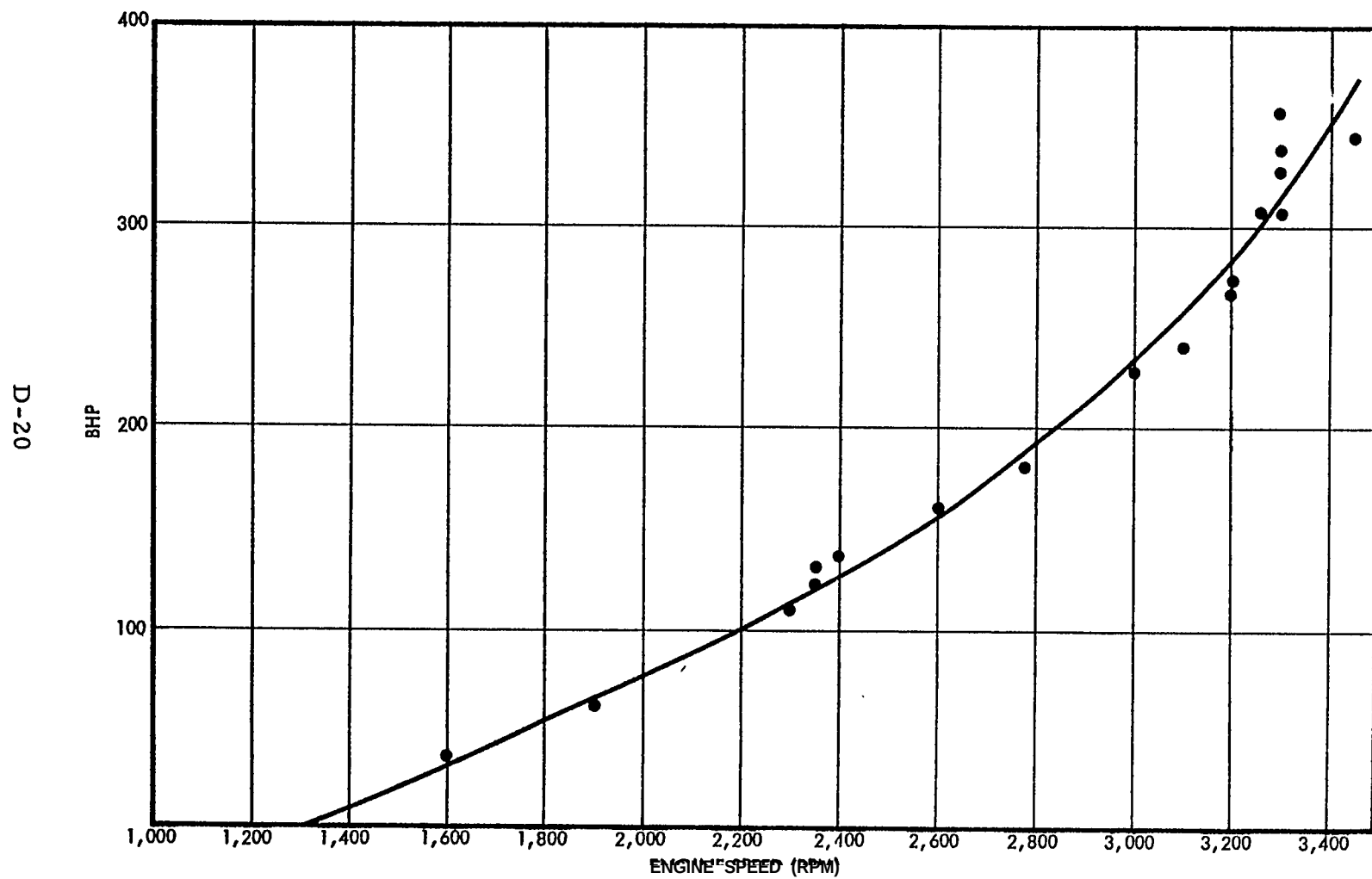


Figure 6. AirBarge Model ASU-1 Engine Horsepower

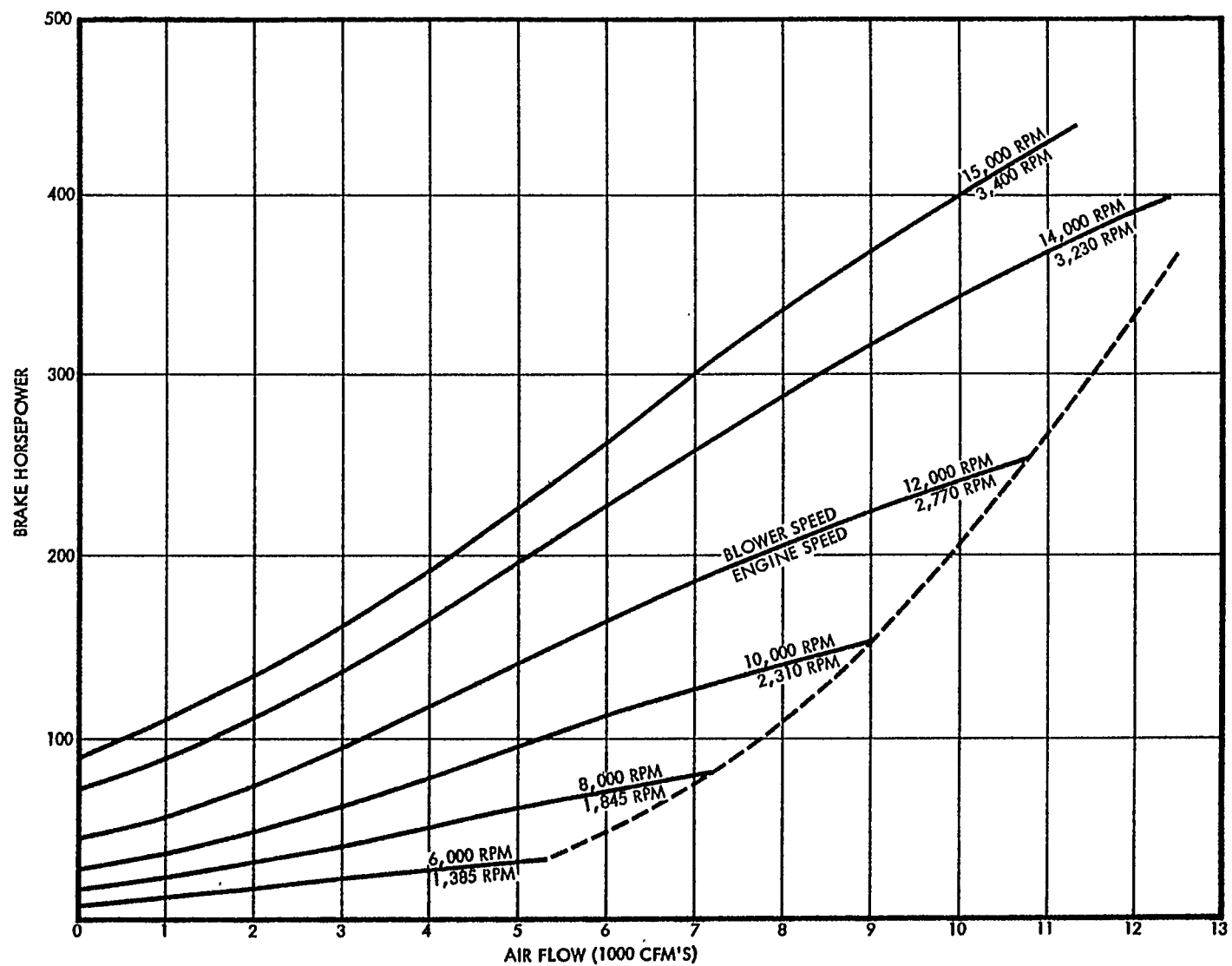


Figure 7 AirBarge Model ASU-1 Power Plant Blower Horsepower

of 0.50 inch, for example, will require 100 times as much air horsepower as an air cushion vehicle of the same weight operating at $h_e = .005$ inch. This comparison shows the dramatic reduction in required air horsepower which can be realized if the equivalent gap can be minimized. Ideal operating surfaces are rarely available in shipyard environments, however, particularly when long distance moves are to be made outdoors. Therefore, the practical lower limit to equivalent gap is often set by the given operating surface conditions and it is then necessary for the air cushion vehicle to have air seals which are compatible with this given surface. In industrial plants and shipyards, typical outdoor operating surfaces are weathered concrete and asphalt. The model LP8X20- 8-36 AirBarge is equipped with floating brush type air seals designed to be compatible with these typical surfaces.

b. Equivalent Gap at Various Engine Speeds. The curves shown in Figure 8 are plots of the equivalent gap at various engine speeds for eight representative gross weights (air cushion platform plus payload) used during the tests. Plotted data points shown in the graph are actual test measurements. Engine brake horsepower figures shown on the horizontal axis were determined from Figure 7.

c. Variations in Equivalent Gap. Study of the AirBarge performance curves in Figure 8 discloses that equivalent gap generally increases when engine speed is increased and diminishes when gross weight is increased. It is wasteful of power to run the engine faster than required to float any

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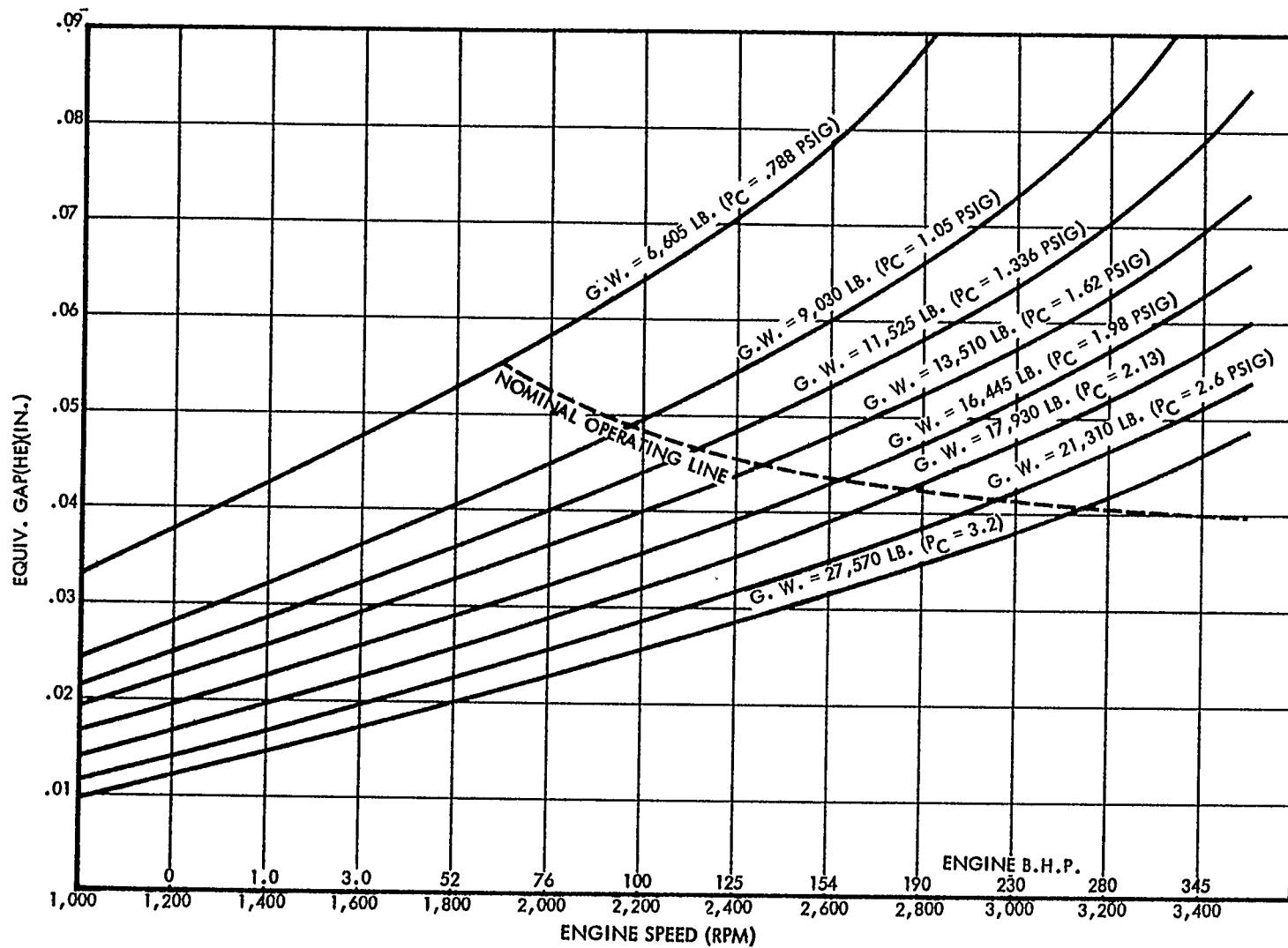


Figure 8 AirBarge Model LP 8 x 20-8-36 Pallet Performance

given load. On the other hand, if the engine is run too slow, seal friction will increase (See Section V, Paragraph 1e) and excessive seal wear will result.

d. Optimum Equivalent Gap. Based on the experience gained in the tests, the optimum range of equivalent gaps was found to be between .040 and .055 inches. From these operating results, a nominal operating line was defined as shown by the dashed line in the chart of Figure 8 with the AirBarge operating at the appropriate value given on the nominal operating line the average weight lifted per brake horsepower is approximately 104 lb/bhp. It should be noted that the nominal operating line requires the largest equivalent gaps at the smallest gross weights. This is because the seals tend to conform to the operating surface most efficiently when the AirBarge is loaded.

e. Optimum Engine Speeds for Various Payloads. Using the nominal operating line developed in Figure 8 as a basis, the optimum engine speeds to be employed for various payloads were plotted and are shown in Figure 9. This curve may be used by the operator to select the correct engine speed for any given load provided the weight of the payload (within reasonable limits) is known.

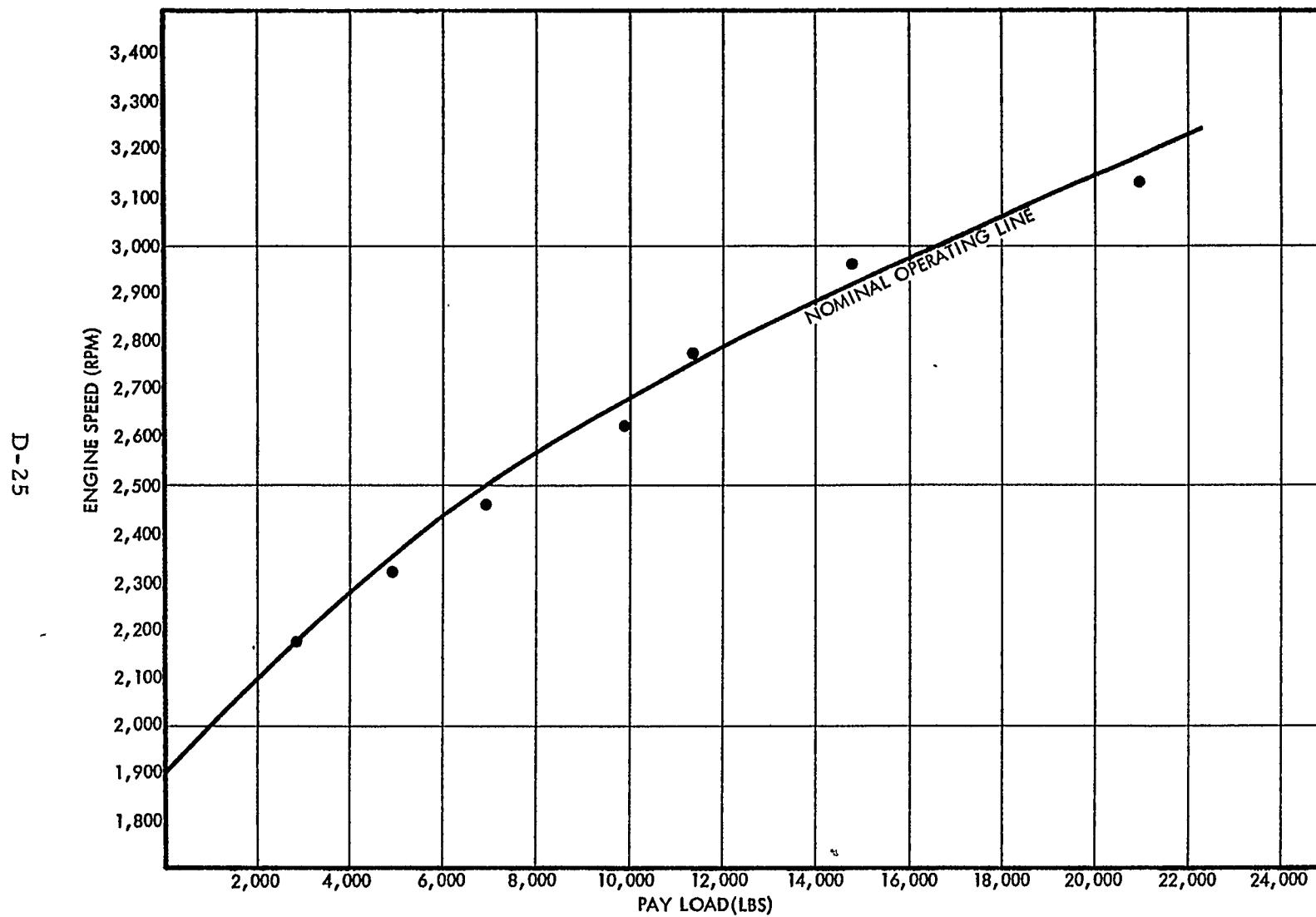


Figure 9 AirBarge Model LP 8 x 20-8-36 Pallet Operating Characteristics

f. Brake Horsepower Required for Various Payloads. Again using the nominal operating line derived in Figure 8 the brake horsepower required for various payloads was plotted and these results are shown in Figure 10.

g. Jacking Height. Jacking height is the vertical distance the AirBarge must be raised before the platform is clear of the operating surface. During the tests these points were measured for each test payload and the results are plotted in Figure 11. Although there was considerable scatter in these data, there was no discernible slope to a curve which might be plotted through them, therefore, the curve shown is actually an arithmetic average jacking height which is independent of payload. The scatter in the jacking height data resulted from two major factors, each of which is described below:

(1) Within certain limits, jacking height can be effectively controlled by the operator by adjusting the green center control lever on the AirBarge. This lever regulates inflation pressure in the seal hangars. The tests indicated that sensitivity of this lever was greater than would be desirable and should be reduced in future Air Barge designs.

(2) Because of the location of the operator's station, the operator experienced difficulty in visually judging the actual floating height of the AirBarge. To assist him, a piece of chain was attached to the front corner of the AirBarge near the control levers midway through the tests. This chain hangs loosely and is of such length that it will just touch the ground

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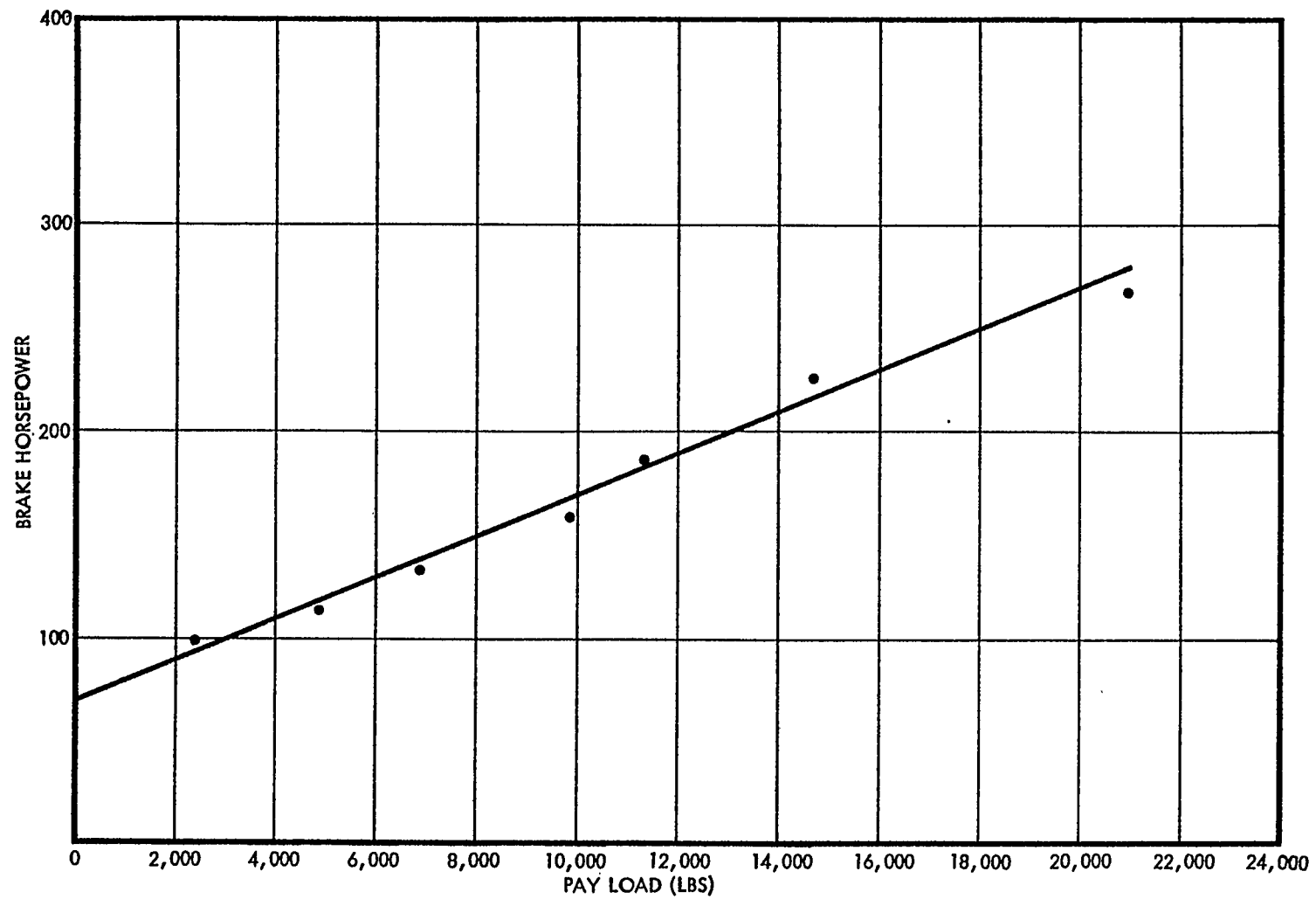


Figure 10 AirBarge Model LP 8 x 20-8-36 Pallet Power Requirements

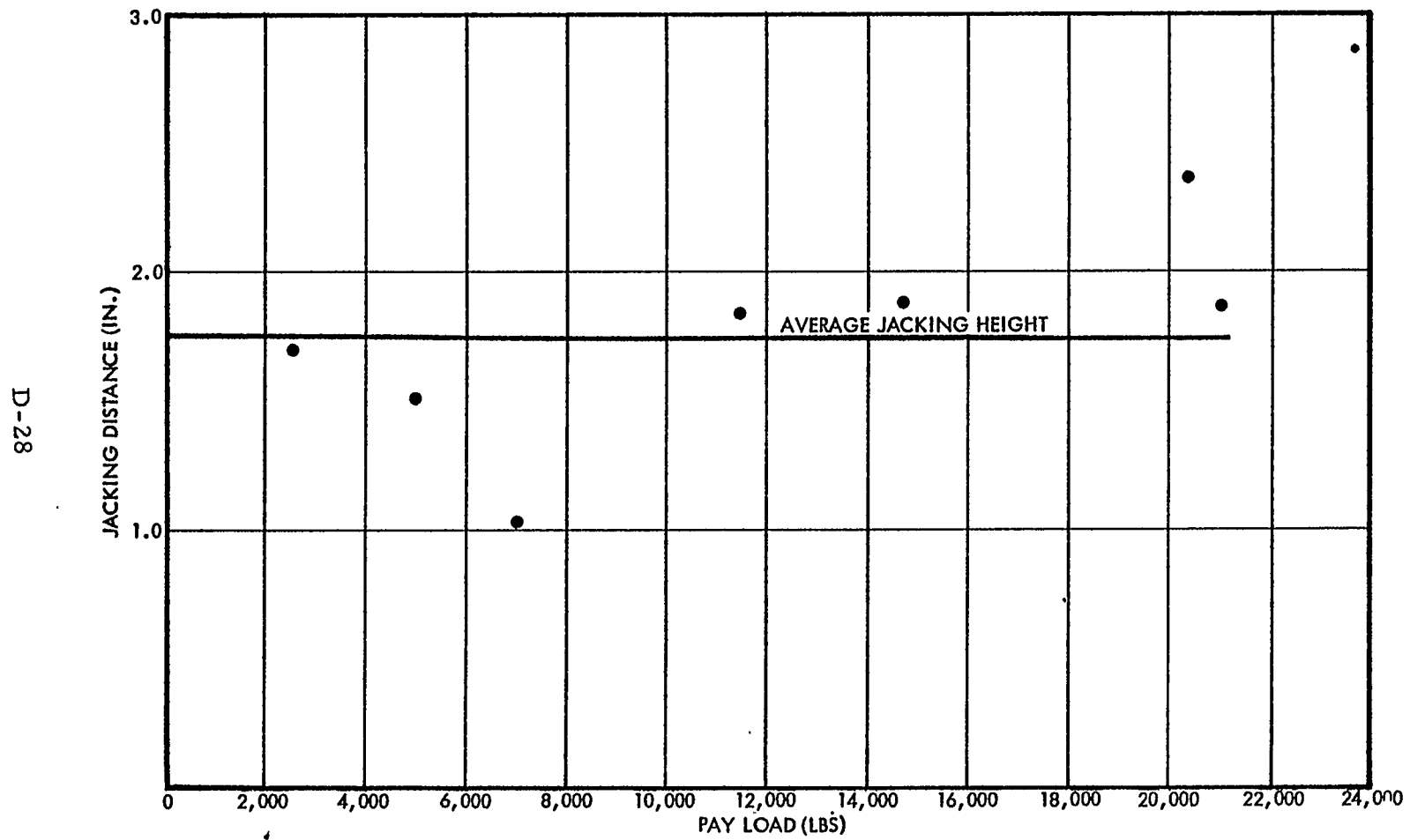


Figure 11 AirBarge Model LP 8 x 20-8-36 Pallet Jacking Height

when the AirBarge is at proper floating height. Later, a second chain was added at the right rear corner to provide a guide to judge rear floating height.

h. Towing Force Required for Various Payloads. Towing force required to overcome seal friction was measured for the model LP8X20- 8-36 AirBarge when operating both on concrete and asphalt. Results of these measurements are presented in Figure 12. The measurements showed that consistently more towing force was required when the AirBarge was operating on asphalt than on the relatively smooth concrete. It should also be noted that there was no discernible increase of towing force required with increased payloads on either surface. The plotted curves are a simple arithmetic average of the data taken on each surface. Therefore, the fact that towing force is practically independent of payload indicates that seal friction depends primarily on total periphery of the seals, which is constant for any given AirBarge. The scatter in the recorded towing force data resulted primarily from the fact that initial towing force to accelerate the loaded AirBarge is much greater than the steady state force required to overcome seal friction. It was difficult, therefore, to separate these two force effects accurately when total drawbar pull was measured. It was found that seal friction could be estimated most accurately by measuring the slope of the operating surface on which the AirBarge would drift sideways with the antidrift wheels removed.

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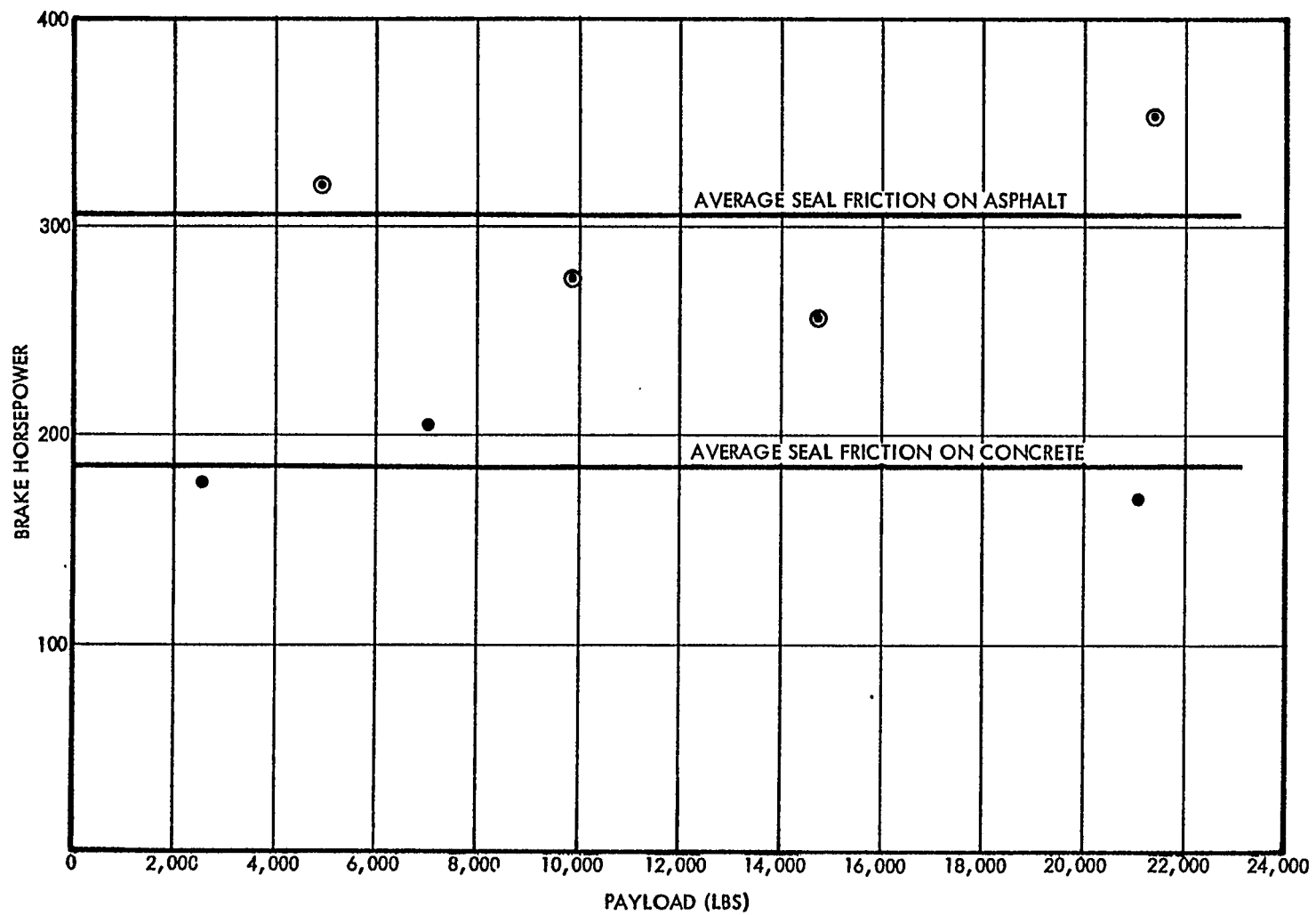


Figure 12 AirBarge Model LP 8 x 20-8-36 Pallet Towing Force

i. Relationship of Towing Force to Seal Friction. Based upon the towing data plotted in the chart of Figure 12, the towing force to overcome seal friction for the fully loaded model LP 8X20-8-36 AirBarge is shown to be approximately 1.1 percent of gross weight on asphalt and approximately 0.7 percent of gross weight on concrete.

Section IV

DESIGN OF AIRBARGES FOR LARGER TYPICAL SHIPYARD LOADS

1. INTRODUCTION

Based on the results of the tests described in Sections I through III, design parameters were established by AirBarge for units capable of transporting larger typical shipyard assemblies and modules. Typical loads and anticipated dimensions and weights had been specified by Ingalls as a part of the Purchase Order and each of the design parameters were specifically keyed to these requirements. Tables II through VII tabulate the results of the design planning effort and a brief description of each table is given in the following paragraphs.

2. SIZES OF AIRBARGES

Preliminary calculations established that only three sizes of AirBarges would be required to transport all of the specified load modules. These are:

<u>Size (Ft)</u>	<u>No. Air Cushions</u>
30 x 50	6
50 x 50	4
50 x 50	1

3. POWER UNITS

Engineering calculations showed that three sizes of power units would be required, models ASU- 1, -2, and -3. A prototype model ASU- 1 was constructed and used in the tests described in this report. Design data indicates that the larger units are feasible and will pose no special problems in design and construction.

4. NUMBER OF AIRBARGES REQUIRED

The number and type of AirBarges required to move the Ingalls - specified loads were calculated and are tabulated in Table II.

5. EQUIVALENT GAP

The equivalent gap (clearance between the air seal and the load bearing surface) for each of the anticipated types of shipyard loads is shown in Table III.

6. REQUIRED BLOWER PRESSURES.

Air source primary blower pressures for specified typical shipyard loads are tabulated in Table IV.

7. POWER UNITS REQUIRED TO FLOAT LOADS

Based on the calculated air flow required for each AirBarge and the number and type of power units required to supply that air flow, the number of power units required for each specified load was calculated and is shown in Table V.

Table II Modules Required for Representative Loads

Type of Load	Weight of Load (Lb)		Size of Load	Number of AirBarge Modules Required		
	Minimum	Maximum		No. of Platforms	Dimensions	No. of Air Casters Per Platform
Plate Blanket	6,000	100,000	30 x 50	1	30 x 50	6
Flat Panel	10,000	400,000	50 x 60	2	30 x 50	6
				1	50 x 50	4
Box Section	40,000	400,000	25 x 50	1	30 x 50	6
Stern Section	60,000	600,000	30 x 50	2	30 x 50	6
				1	50 x 50	4
Bow Section	60,000	400,000	30 x 40	1	30 x 50	6
Mast	2,000	100,000	30 x 60	1	30 x 50	6
Deck House	20,000	1,000,000	50 x 50	2	30 x 50	6
				1	50 x 50	4
Ship Module	2,000,000	16,000,000	95 x 200	12	30 x 50	6
				8	50 x 50	1

Table III Equivalent Gap for Representative Loads

Type of Load	Gross Weight AirBarge Module		Air Cushion Pressure (PSIG)		Equivalent Gap (In.)	
	Minimum	Maximum	Minimum	Maximum	Maximum	Minimum
Plate Blanket	106,000	200,000	1.08	2.04	.048	.043
Flat Panel	105,000	300,000	1.07	3.06	.048	.041
	170,000	560,000	1.07	3.52	.048	.040
Box Section	140,000	500,000	1.43	5.10	.046	.040
Stern Section	130,000	400,000	1.33	4.08	.047	.040
	220,000	760,000	1.38	4.77	.046	.040
Bow Section	160,000	500,000	1.63	5.10	.045	.040
Mast	102,000	200,000	1.04	2.04	.050	.043
Deck House	110,000	600,000	1.12	6.12	.047	.040
	180,000	1,160,000	1.13	7.29	.047	.040
Ship Module	267,000	1,433,000	2.72	14.6	.041	.040
	410,000	2,160,000	2.68	13.6	.041	.040

Table IV Primary Blower Pressure for Representative Loads

Type of Load	Air Flow at Cushion Pressure Required Per AirBarge Module		Orifice Pressure Differential		Primary Blower Pressure	
	Minimum	Maximum	Maximum	Minimum	Maximum	Minimum
Plate Blanket	18,500	21,600	.75	.62	2.66	1.83
Flat Panel	18,400	23,600	.75	.42	3.48	1.82
	19,100	25,000	.75	.37	3.89	1.82
Box Section	19,850	26,550	.75	.30	5.40	2.18
Stern Section	19,750	25,000	.75	.36	4.14	2.08
	20,350	27,100	.75	.25	5.02	2.13
Bow Section	20,400	26,550	.70	.30	5.40	2.33
Mast	18,700	21,600	.80	.62	2.66	1.84
Deck House	18,250	27,600	.82	.25	6.37	1.94
	19,150	29,550	.82	.25	7.54	1.95
Ship Module	21,800	29,450	.50	.25	17.85	3.22
	8,300	10,760	.50	.25	16.85	3.18

Table V Power Units Required to Float Representative Loads

Type of Load	Air Flow at Cushion Pressure Required Per AirBarge Module		Power Units Required Per AirBarge Module				Total Number of Power Units To Float Load			
	Minimum	Maximum	Minimum		Maximum		Minimum		Maximum	
			Type	No.	Type	No.	Type	No.	Type	No.
Plate Blanket	17,650	20,800	ASU-1	2	ASU-1	2	ASU-1	2	ASU-1	2
Flat Panel	17,600	23,100	ASU-1	2	ASU-1	3	ASU-1	4	ASU-1	6
	18,250	24,500	ASU-1	2	ASU-1	3	ASU-1	2	ASU-1	3
Box Section	19,000	26,120	ASU-1	2	ASU-1	4	ASU-1	2	ASU-1	4
Stern Section	18,860	24,900	ASU-1	2	ASU-1	3	ASU-1	4	ASU-1	6
	19,400	26,800	ASU-1	2	ASU-1	3	ASU-1	2	ASU-1	3
Bow Section	19,600	26,200	ASU-1	2	ASU-1	4	ASU-1	2	ASU-1	4
Mast	17,800	20,850	ASU-1	2	ASU-1	2	ASU-1	2	ASU-1	2
Deck House	17,350	27,300	ASU-1	2	ASU-2	1	ASU-1	4	ASU-2	2
	18,200	29,200	ASU-1	2	ASU-2	1	ASU-1	2	ASU-2	1
Ship Module	21,200	26,500	ASU-1	2	ASU-3	1	ASU-1	24	ASU-3	12
	8,060	9,650	ASU-1	1	ASU-3	1	ASU-1	8	ASU-3	8

8. TOTAL BRAKE HORSEPOWER TO FLOAT LOADS

The total seal friction, seal friction as a percent of gross weight, and total brake horsepower required to float the stipulated loads were compiled and are set forth in Table VI.

9. RELATIONSHIP OF LOADS TO DEVELOPED BRAKE HORSEPOWER

The calculated relationship of gross and payload weights to developed brake horsepower are tabulated in Table VII.

10. FLOTATION REQUIREMENTS FOR TYPICAL SHIPYARD LOADS

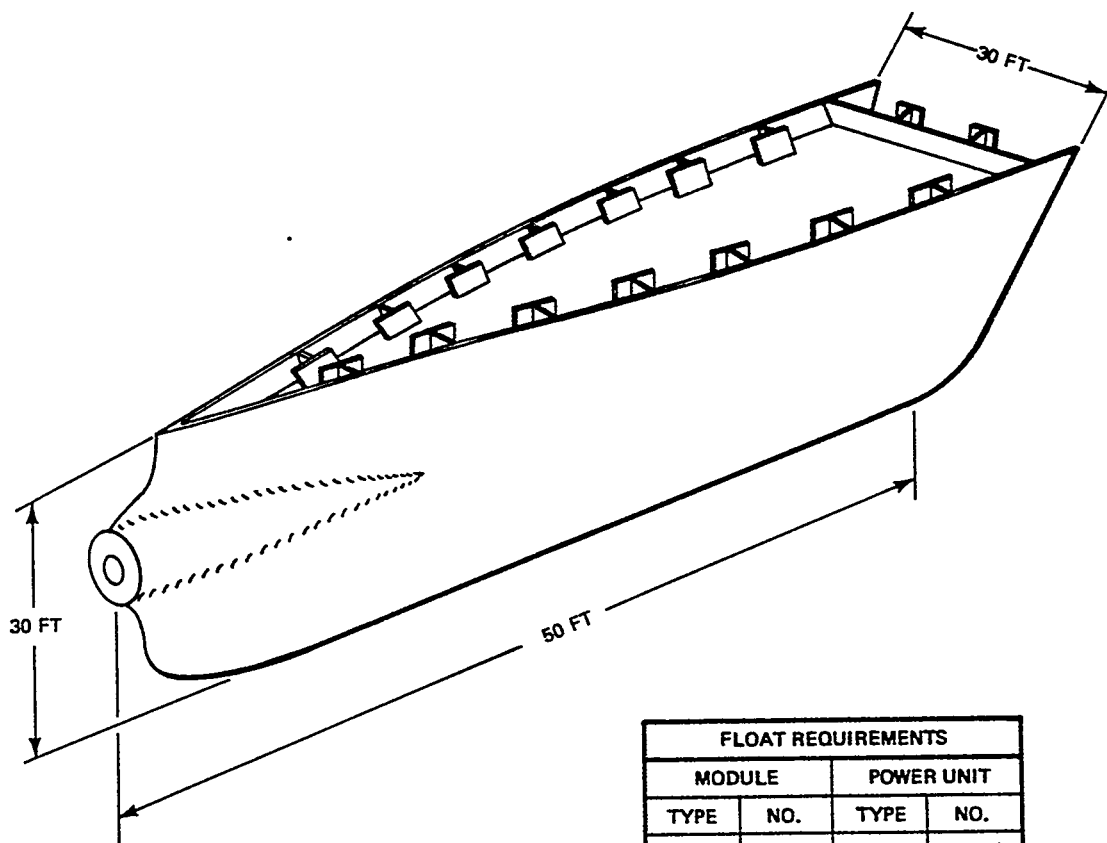
AirBarge flotation requirements for typical shipyard loads, as specified in the Letter of Inquiry Scope of Work, are shown in Figures 13 through 20.

Type of Load	Total Seal Friction On Asphalt*	Seal Friction (per cent of Gross Weight)		Total BHP To Float Load	
		Minimum	Maximum	Minimum	Maximum
Plate Blanket	915 lb	.86%	.46%	.420	712
Flat Panel	1,830 lb	.87%	.61%	860	1,290
	955 lb	.56%	.17%	454	786
Box Section	915 lb	.65%	.183%	524	1,040
Stern Section	1,830 lb	.705%	.229%	924	1,710
	955 lb	.434%	.126%	570	1,095
Bow Section	915 lb	.571%	.183%	570	976
Mast	915 lb	.90%	.457%	408	720
Deck House	1,830 lb	.833%	.153%	820	2,748
	955 lb	.53%	.082%	464	1,760
Ship Module	11,000 lb	.343%	.064%	9,360	45,300
	3,840 lb	.117%	.022%	1,840	10,400

*0.3375 lb/in. of

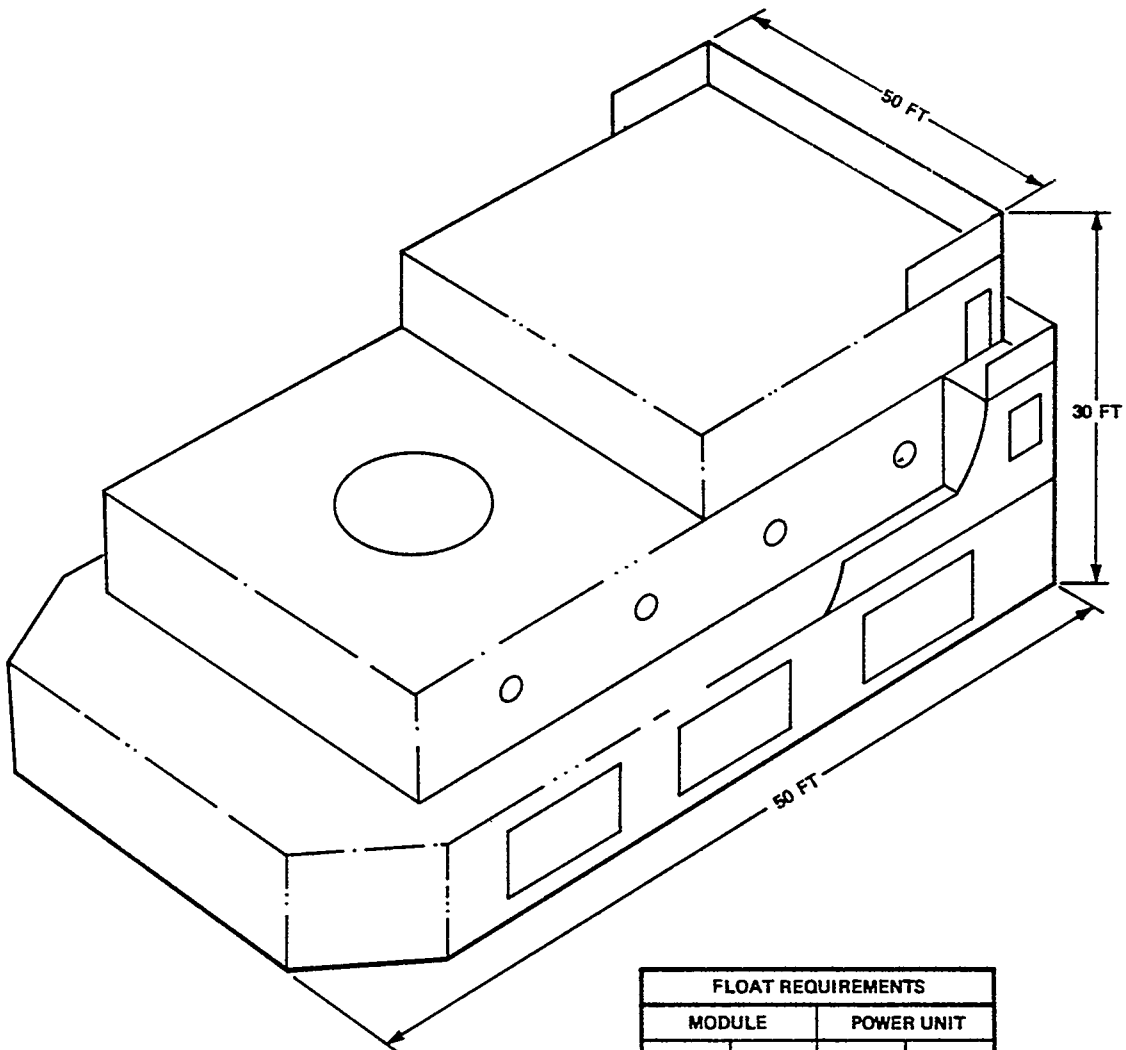
Table VII Weight Carried Per Brake Horsepower

Type of Load	Gross Weight		Payload	
	Minimum	Maximum	Minimum	Maximum
Plate Blanket	252	282	144	140
Flat Panel	244	465	12	310
	374	712	22	510
Box Section	267	480	76	385
Stern Section	282	468	65	350
	386	695	105	550
Bow Section	281	512	105	410
Mast	250	278	5	139
Deck House	268	430	24	360
	388	660	43	570
Ship Module	342	380	214	363
	1,660	1,780	1,088	1,540



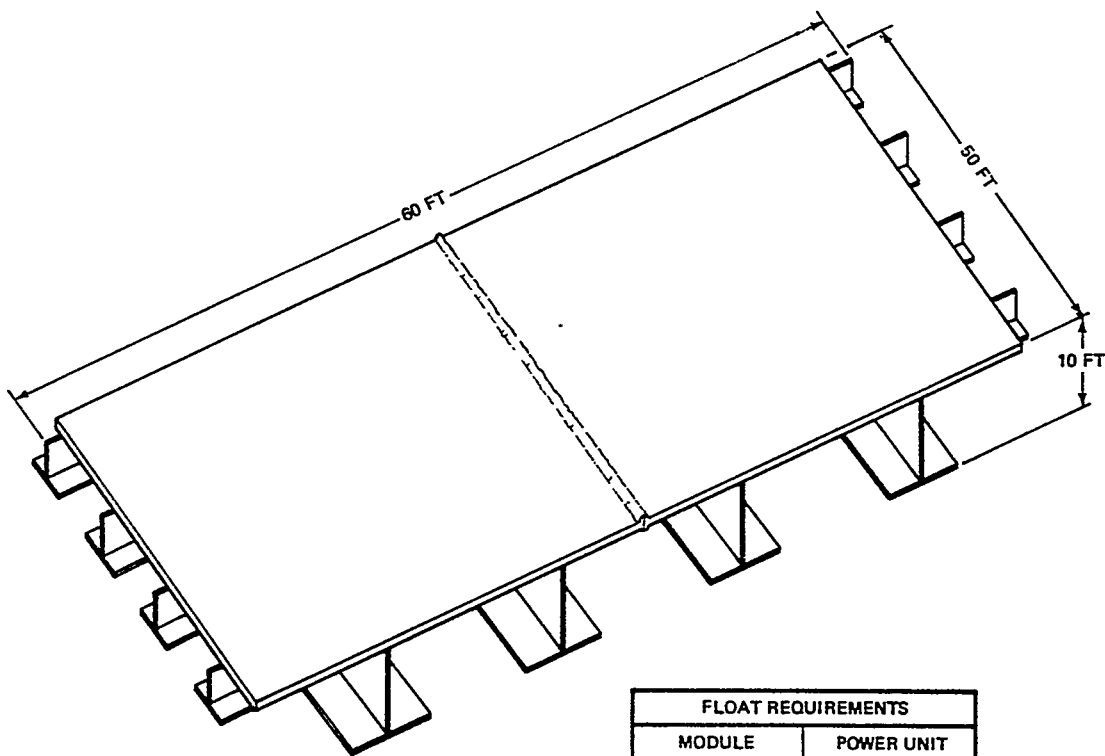
FLOAT REQUIREMENTS			
MODULE		POWER UNIT	
TYPE	NO.	TYPE	NO.
30 x 50-6	2	ASU-1	3 (ea)
50 x 50-4	1	ASU-1	3

Figure 13 Stern Section, Weight Range 30-300 Tons,
Maximum Dimensions As Shown



FLOAT REQUIREMENTS			
MODULE		POWER UNIT	
TYPE	NO.	TYPE	NO.
30 X 50-6	2	ASU-2	1 (ea)
50 X 50-4	1	ASU-2	1

Figure 14 Deckhouse, Weight Range 10-500 Tons,
Maximum Dimensions As Shown



FLOAT REQUIREMENTS			
MODULE		POWER UNIT	
TYPE	NO.	TYPE	NO.
30 X 50-6	2	ASU-1	3 (ea)
50-X 50-4	1	ASU-1	3

Figure 15 Flat Panel, Weight Range 5-200 Tons,
Maximum Dimensions As Shown

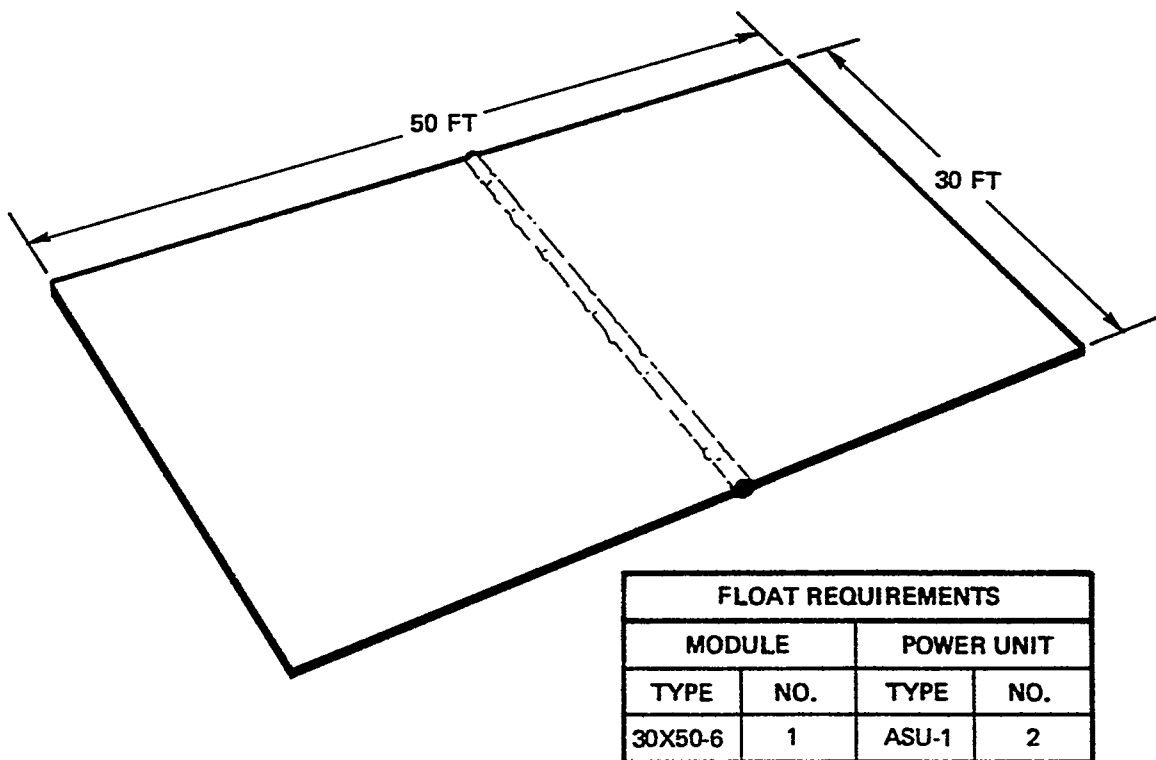
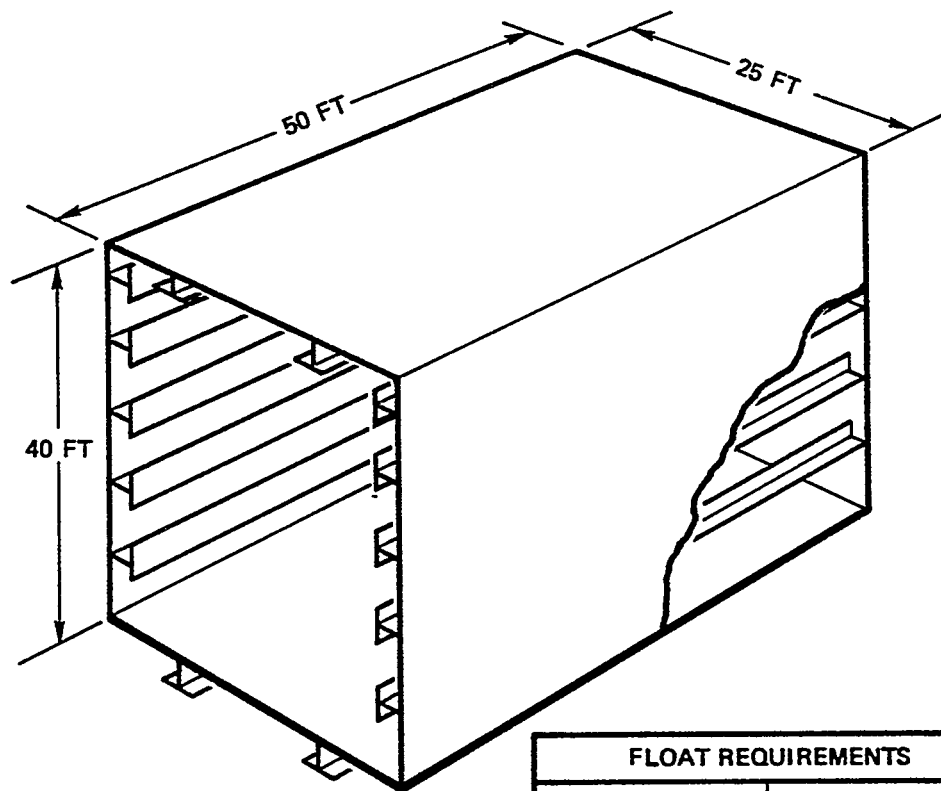


Figure 16 Plate Blanket, 3/8 In. x 1-1/4 In. Thick, Weight Range 3-50 Tons, Maximum Dimensions As Shown



FLOAT REQUIREMENTS			
MODULE		POWER UNIT	
TYPE	NO.	TYPE	NO.
30 X 50-6	1	ASU-1	4

Figure 17 Box Section, Weight Range 20-200 Tons,
Maximum Dimensions As Shown

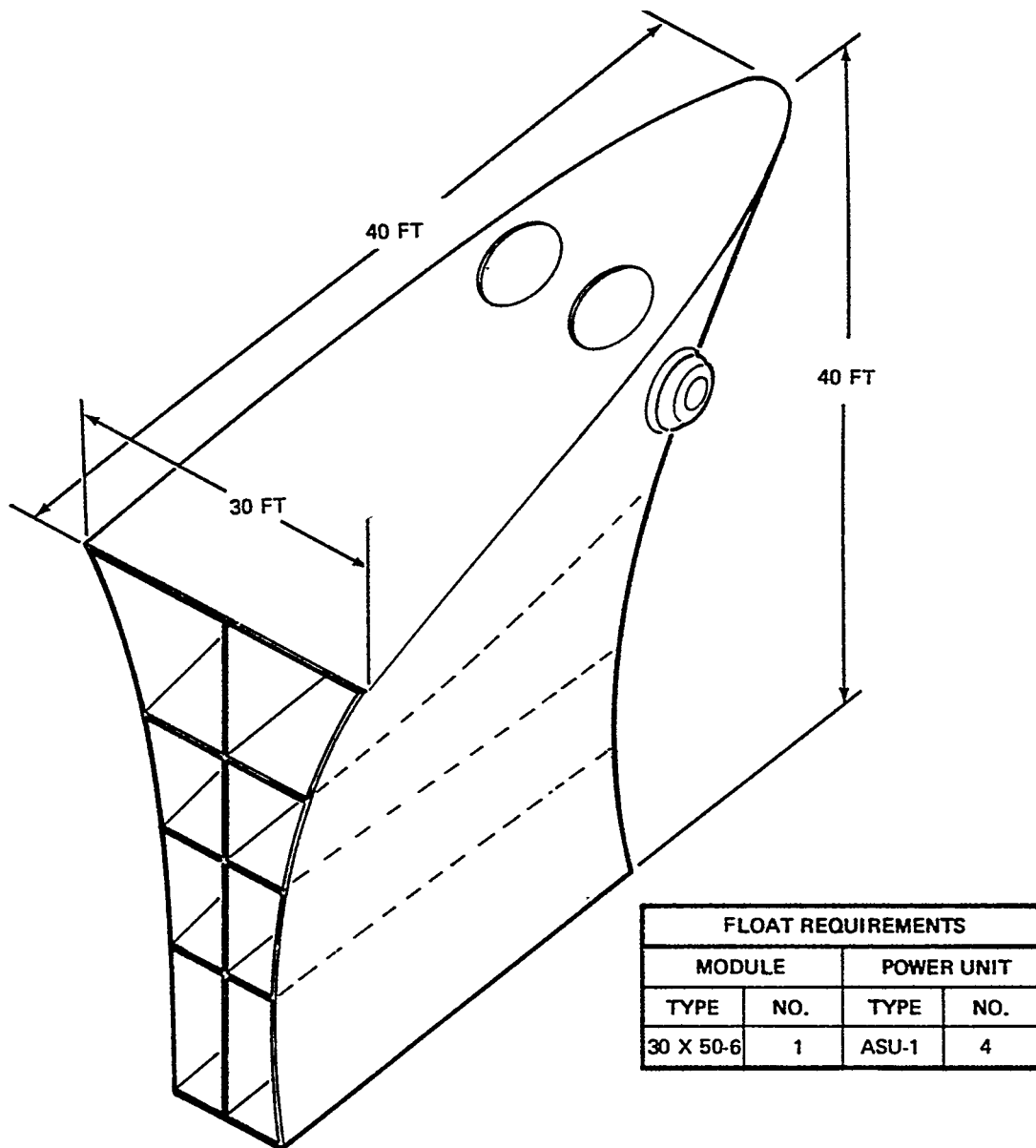


Figure 18 Bow Section, Weight Range 30-200 Tons,
Maximum Dimensions As Shown

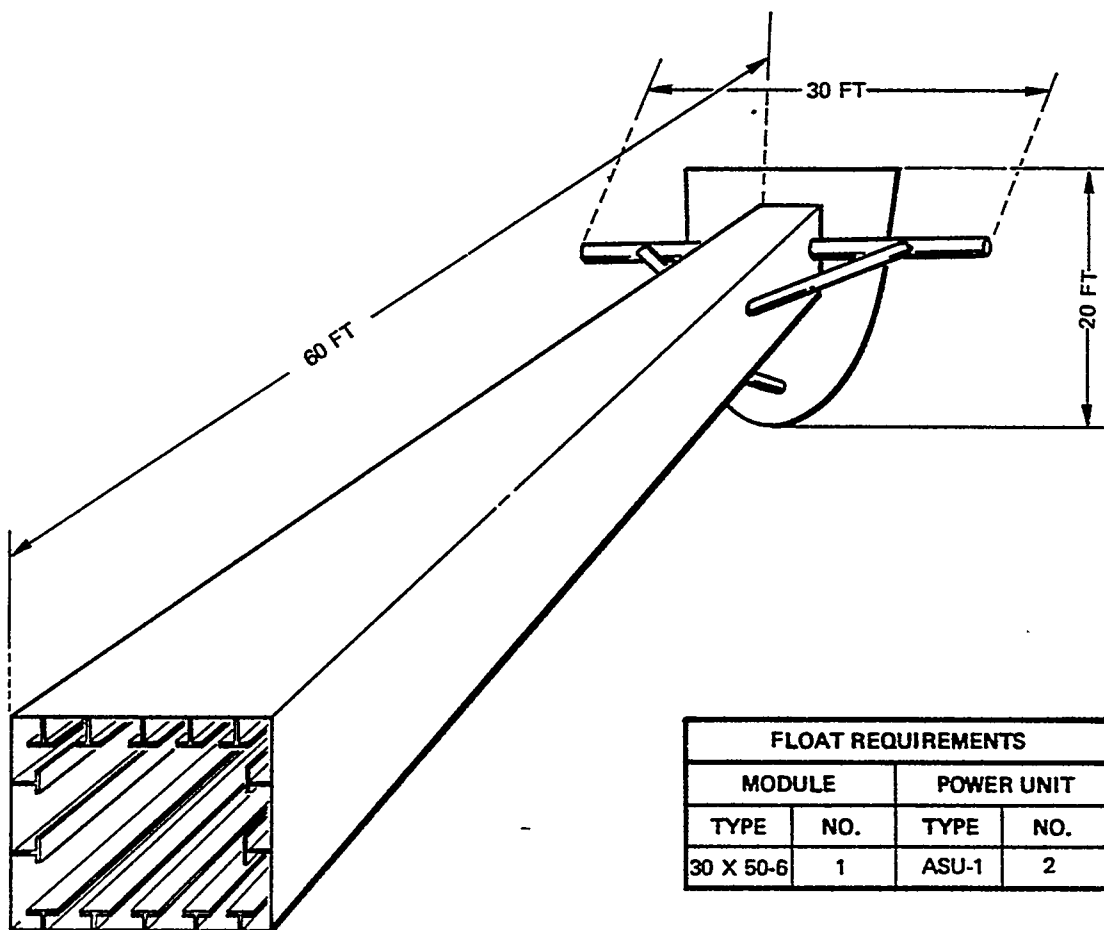


Figure 19 Mast, Weight Range 1-50 Tons, Maximum Dimensions As Shown

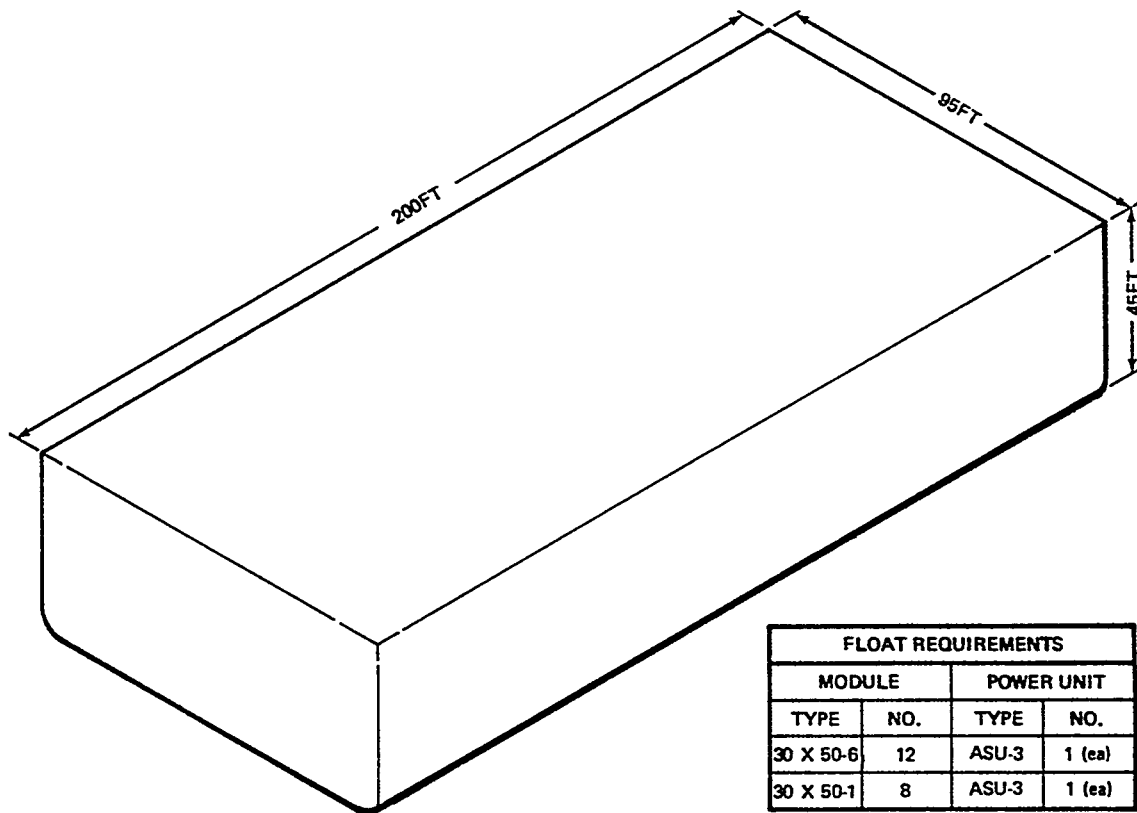


Figure 20 Ship Module, Weight Range 1000-8000 Tons,
Maximum Dimensions As Shown

APPENDIX E
REPORT ON TESTS
CONDUCTED ON
ON A
50 - TON OVER - THE-ROAD AIR LIFT TRANSPORTER
UNDER
CONTRACT 1-36200

APPENDIX E

50 - TON OVER - THE - ROAD AIR LIFT TRANSPORTER

Included in this appendix is technical information concerning the 50-ton over-the-road air lift transporter developed and tested under Contract 1-36200. Included are a description of the vehicle and operational characteristics, conditions of the tests to which the transporter was subjected under terms of the contract and technical data and information developed during the tests.

Section I
DESCRIPTION OF EQUIPMENT

1. GENERAL

The Rolair 50-ton over-the-road air lift transporter (Figure 1) is a self-contained item of material moving equipment requiring no supplementary equipment other than attractive force. The transporter described in this section is an evaluation vehicle specifically designed to establish the practicality of an air lift transporter to be used in existing shipyards and to demonstrate the ability of the transporter to accommodate to prevailing surfaces and loads. The basic components of the transporter are the load bed; the air bearing assemblies, with the associated air sources; the Airide units, and air supply; and the towing and transporting unit. All of these are described more fully in the following paragraphs.

2. DESCRIPTION

a. Load Bed

(1) Construction. The load bed is of all-welded construction and is a boxed platform 11 feet 8 inches wide and 25 feet long. The flat top, made of sheet steel, is the load bearing surface and is supported by vertical members not farther than 34 inches apart parallel to either axis. Thus, concentrated loading is possible with minimal load distribution blocking. Certain transverse structural members extend below the platform to act as a bolster when the flotation devices are not inflated. These also serve to

E.



Figure 1. Rolair 50-ton Air Lift Transporter

prevent the weight of the load bed from resting on the air bearings when the air bearings are not inflated. Each air bearing is equipped with four 4-inch industrial casters to facilitate removal of the air bearing for inspection or replacement without disturbing the load bed. The air bearings are held in place by eight pins. Accessory spaces are built in at each end of the load bed to accommodate air supply equipment (Figure 2).

(2) Towing/Steering. The transporter is equipped with a tow bar (or beam) at the forward end for attachment to motive vehicles. When it is desirable, an additional tow bar can be affixed, with some effort, at the aft end to replace the steering assembly described in this Paragraph. The second tow bar is then utilized as a push bar by a second tractive source. In the event only one motive force is required the transporter is equipped with a two-wheeled steering device at the rear. This arrangement, constructed from the front wheels and axle of a compact automobile, has a steering wheel as an integral part of the assembly. During movement, an operator is thus able to steer the aft end of the transporter, making turns possible within a minimum radius.

(3) Accessory Spaces. Six major accessory spaces are provided in the transporter, three at the forward, or control, end, and three at the aft end. At each corner of the bed is a space for an air blower for the adjacent air bearing. An air compressor and compressed air storage tank for the Airide units is located in the third accessory space in the center of the forward end of the transporter. The uses of each of these air supply systems are covered in Paragraph 3.

b. Air Bearing Assemblies. The air bearing assemblies, one located

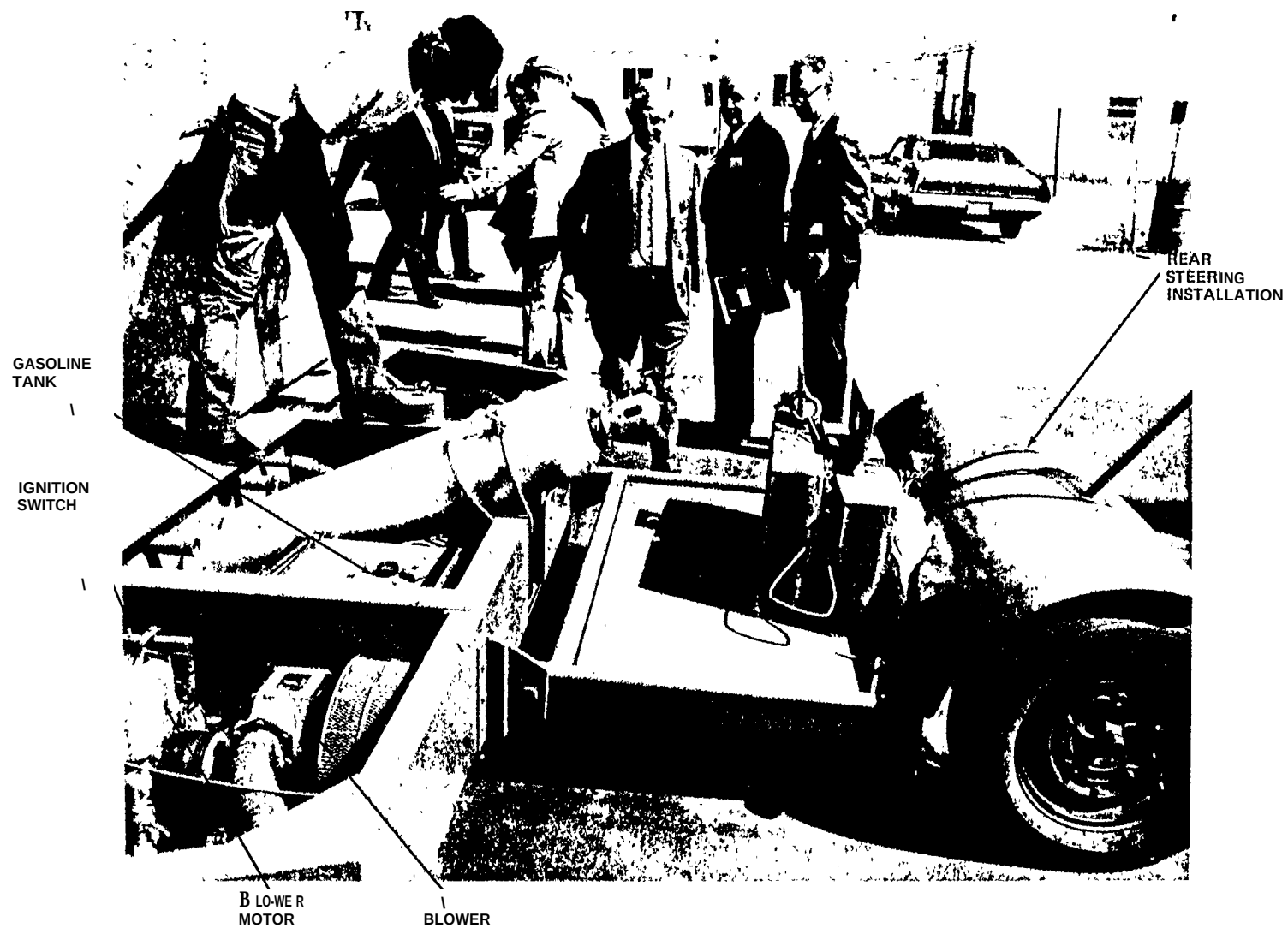


Figure 2. Rolair 50-ton Air Lift Transporter Showing Accessory Spaces

under each quadrant of the load bed, are oval in shape, approximately six feet long and four feet wide. The bearing is constructed of a flexible diaphragm secured to aluminum sheeting at the outer periphery by an aluminum retaining ring, stapled and glued to the bearing body. There are eight 1-inch holes spaced in pairs along the longitudinal axis of the diaphragm, for passage of flotation air. When inflated the diaphragm assumes the shape of a doughnut bisected through the ring. In effect, each bearing is an independent unit providing the lift, or flotation, required for levitation of the transporter. Operation of the air bearing assemblies is covered in Paragraph 3a.

c. Airide Units . The Airide units are flexible rings clustered (six per bearing) near the longitudinal centerline of the bearing structure and are used to provide five inches additional elevation of the load bearing platform. This feature permits negotiation of nonlevel surfaces or isolated obstructions without loss of the bearing under one bearing edge or another. To ensure uniform support under varying degrees of tilt the Airide units are manifolded.

d. Towing Tractive power for the transporter is provided by any vehicle equipped with a standard tow bar hitch. The major requirements for the towing vehicle is that it have sufficient power to overcome the initial inertia of the loaded transporter and that the unit be able to maintain slow rates of speed smoothly over sustained periods of time.

3. OPERATION

a. Air Bearings.

(1) Principle of Operation. The lifting power of the transporter results from the introduction of moderately compressed air into the flexible

diaphragm and by air released into the space under the diaphragm. The air pressure is such that it is slightly more than that required to support the applied load, and escape of surplus air relieves that pressure uniformly below the periphery of the ring. The air which thus escapes to atmosphere becomes a virtually frictionless film of air between the undermost element of the bearing and the operating surface.

(2) Air Supply. The air supply for the bearings is supplied by two - cylinder, two-cycle gasoline engines driving individual blowers mounted in the accessory spaces at each corner of the transporter. Fuel for the engines is carried in separately mounted tanks, one at each end of the transporter manifolded to supply the two adjacent engines. The pressure of the air supplied to the air bearings is infinitely adjustable over a small range by variation of the appropriate engine speed. Engine speed, registered on an integral tachometer, can be translated into a pressure/flow relationship which will provide frictionless support for the various imposed loads. Engine speed is adjustable by a push/pull throttle located on the control panel for the individual engine. The throttles have built-in locking devices for maintenance of set speeds. When the desired speed has been attained, rotation of the handle effectively inhibits maladjustment until the throttle is unlocked. The recommended maximum speed for the blower engines is 6, 500 revolutions-per-minute. Because of a 1. 2:1.0 pulley differential built into the drive mechanism, top engine speed will result in

a top blower speed of approximately 7, 800 revolutions-per-minute. Under normal ride conditions, the speed of the four blower engines should be" equal, but in instances when the load is off- center, one or two engines may be required to provide additional lift and will have to be adjusted accordingly.

b. Airide Units.

(1) Principle of Operation. When it is necessary to traverse uneven roadbed surfaces such as slightly crowned roads or when it is necessary to pass over obstructions of five inches or less, the Airide: units are put into operation. The Airide units consist of flexible, inflatable rings which, when expanded, achieve a distinct separation of the load bed and the air bearing assemblies. When fully distended, the Airide units elevate the load bed an additional five inches thus permitting traverse over difficult road surfaces.

(2) Air Supply. The air supply for the Airide units is provided by a single engine driven compressor located in an accessory space at the forward (tow bar) end of the transporter. Manifolding permits the supply of air to each of the Airide units at desired pressures. When the Airide units are not in use, air pressure is built up in two receivers provided in the load bed structure. The pressure within the receivers is limited by safety valves included in the compressor body; when air released from the receivers into the Airide units, however, the safety valve closes, allowing the receivers to recharge to the original pressure. Control of the air supply is accomplished by a manually operated switch valve which

opens or closes downstream of the relieving pressure regulators that supply a preset pressure to each Airide unit. There is one regulator for each Airide cluster and one cluster for each air bearing. Control air for the switch valve is obtained from another two-position, manual valve which serves as a safety device in that if the loaded transporter loses air bearing pressure in any of the four air bearings, there will be an automatic deactivation of the Airide system.

4. OPERATING PROCEDURES

a. Preliminary Operations. Before initiation of a movement operation utilizing the Rolair 50-ton transporter the following preliminary steps should be performed.

(1) Survey the entire movement route and remove litter, tools, timbers and other such loose material.

(2) Remove accessory storage covers.

(3) Verify that the compressor and blower engine fuel tanks are full.

(4) Ensure that the tractive power source has sufficient power and traction to easily tow the load to be moved.

(5) Ensure that the towing hitch(es) is securely locked.

(6) Verify that the aft steering assembly, if used, is securely attached and that the steering wheel is installed.

b. Airide System. Before activating the air bearing air supply system the Airide system must be activated. The procedure to be followed is as follows.

- (1) Set the lever valve to the LOADED position.
 - (2) Set the switch valve to DOWN.
 - (3) Move the compressor slide valve to green.
 - (4) Check the Airide receiver pressure and verify that the pressure is at least 115 psi.
 - (5) Set Airide regulators to 60-65 psi, with an equality of $\frac{1}{2}$ 1 psi.
- c. Air Bearing System. Activation of the air bearing system is accomplished as follows.

- (1) Open fuel tank vents.
- (2) Open fuel line valves.
- (3) Operate fuel squeeze bulbs in fuel lines.
- (4) Start engines and adjust and run at 2000 rpm for approximately five minutes to ensure engines are thoroughly "warmed-up".

d. Movement. The following is the procedure to be followed during movement of the load.

(1) Ensure that precautions have been taken to verify that the movement route is clear and free of traffic, particularly if the load transporter will require a large portion of the route. If necessary, provide road guides to prevent snarling of oncoming traffic.

(2) Adjust engine speed of air bearing blowers to provide sufficient pressure to float the load.

(3) Activate Airide units by setting switch valve to up.

(4) Move load to destination.

e. Stop and Shutdown. After the load has arrived at the destination the following procedure is followed to shut down the transporter.

(1) Deactivate Airide assemblies by setting switch valve to DOWN.

(2) Idle blower engines to approximately 2000 rpm. Idle engine in pairs at forward and aft ends of transporter to allow transporter to settle evenly to ground.

(3) Stop air compressor engine by shutting off ignition switch.

(4) Set compressor slide valve to red.

(5) Stop blower engine by shutting off ignition switch.

(6) Shut off blower engine fuel valves.

(7) Close blower engine fuel tank vents.

Section II

TEST CONDITIONS

1. GENERAL

The conditions under which the tests of the Rolair 50-ton air lift over-the-road transporter were conducted were set up so as to simulate, as closely as possible, conditions encountered in daily shipyard material movement operations. The tests were conducted at the manufacturer's facility and were witnessed by Ingalls representative s..

2. TEST SURFACES

Flotation runs were conducted over three asphalt surfaces of varying porosity in an attempt to duplicate typical shipyard material movement routes. The types of surfaces are described in the succeeding paragraphs.

a. Unsealed Asphalt Roadway. This was an unsealed asphalt roadway with typical irregularities including cracks, gouges, and minor elevations and depressions. The porosity of this surface was that normally found in such surfaces.

b. Sealed Asphalt Roadway. This surface had been treated with Chevron Jet Seal sealant to reduce the porosity of the surface to a figure considerably below that of the surface described in Paragraph a.

c. Sealed Asphalt Parking Lot. The surface of this test area had been treated with a commercial slurry resurfacing compound. The resultant surface porosity was reduced to that approximating a surface sealed during the laying process or that of finished concrete.

3. LOAD

The loads used during the tests described herein consisted of 6.5-ton concrete blocks. Portions of the tests and demonstrations were conducted with a total load of 26 tons; a portion with 32.5 tons; and the remainder with 39 tons.

4. TRACTIVE POWER

The tractive power for the tests of the 50-ton Rolair transporter was provided by an 8,000-pound capacity fork lift. The forklift was attached to the transporter as described in Section I, Paragraph 2a(2), and provided braking power as well as motive power.

5. DURATION OF TESTS

The tests and demonstrations described herein extended over a period of time during which a total of 13,700 feet of travel was accumulated. Given below is a breakdown of the various phases of the travel under load tests.

<u>Load Total</u>	<u>Distance Traversed</u>
26.0 tons	4,200 feet
32.5 tons	4,400 feet
39.0 tons	5,100 feet

Section III

TEST RESULTS

1. GENERAL

This section describes the results of the tests conducted on the Rolair 50-ton transporter.

2. BEARING WEAR

The bearings were inspected at intervals during the test and were found to exhibit very little wear. A puncture, or gash, located outside of, and above, the peripheral contact area was discovered in one seal during one of the inspections. The puncture, about 0.5 inches long, was easily repaired with a commercial inner tube patch.

3. CASTER IMPRINTS IN ASPHALT

A minor problem discovered during the tests was the imprints made in the asphalt on hot days by the mechanical casters because of the relatively high loading of the casters. The purpose of the mechanical casters is to allow easy insertion and removal of the air bearings. This is a minor design problem that may be solved by a number of methods, one of which would be incorporated in a final design.

4. TOW BAR PULL

Ordinarily, any report on tests of a towed vehicle would include data on tow bar pull requirements. Measurements of the tow bar pull required

for air lift platforms in the past have revealed that the coefficient of friction is so small as to be negligible. The direct effect of this characteristic is that the tow bar pull capacity of any tow vehicle used with an air lift transporter is dependent only upon the dynamics of a load in motion or at rest and upon the gravity induced forces caused by roadway slope.

5. COEFFICIENT OF FRICTION

For the same reasons stated in Paragraph 4, no attempts were made to arrive at statistical data pertaining to the magnitude of the coefficient of friction for the 50-ton air lift transporter.

6. BLOWER SPEED VS LOAD

Air supply blower speeds required to maintain the optimum equivalent (flotation) gaps between the bearings and the road surfaces for the various loads and different operating surfaces were carefully noted and the results are plotted in Figure 3 . In this regard, it should be noted that the equivalent gap is not constant under the same load but under different circumstances. For example, it was noted that the equivalent gap was influenced by roadway slope, initial position of the fork lift hitch, inertia of the load, and the type of transmission used in different tractive sources. Generally, when the unit is floating the point of flotation is noted by the following characteristics.

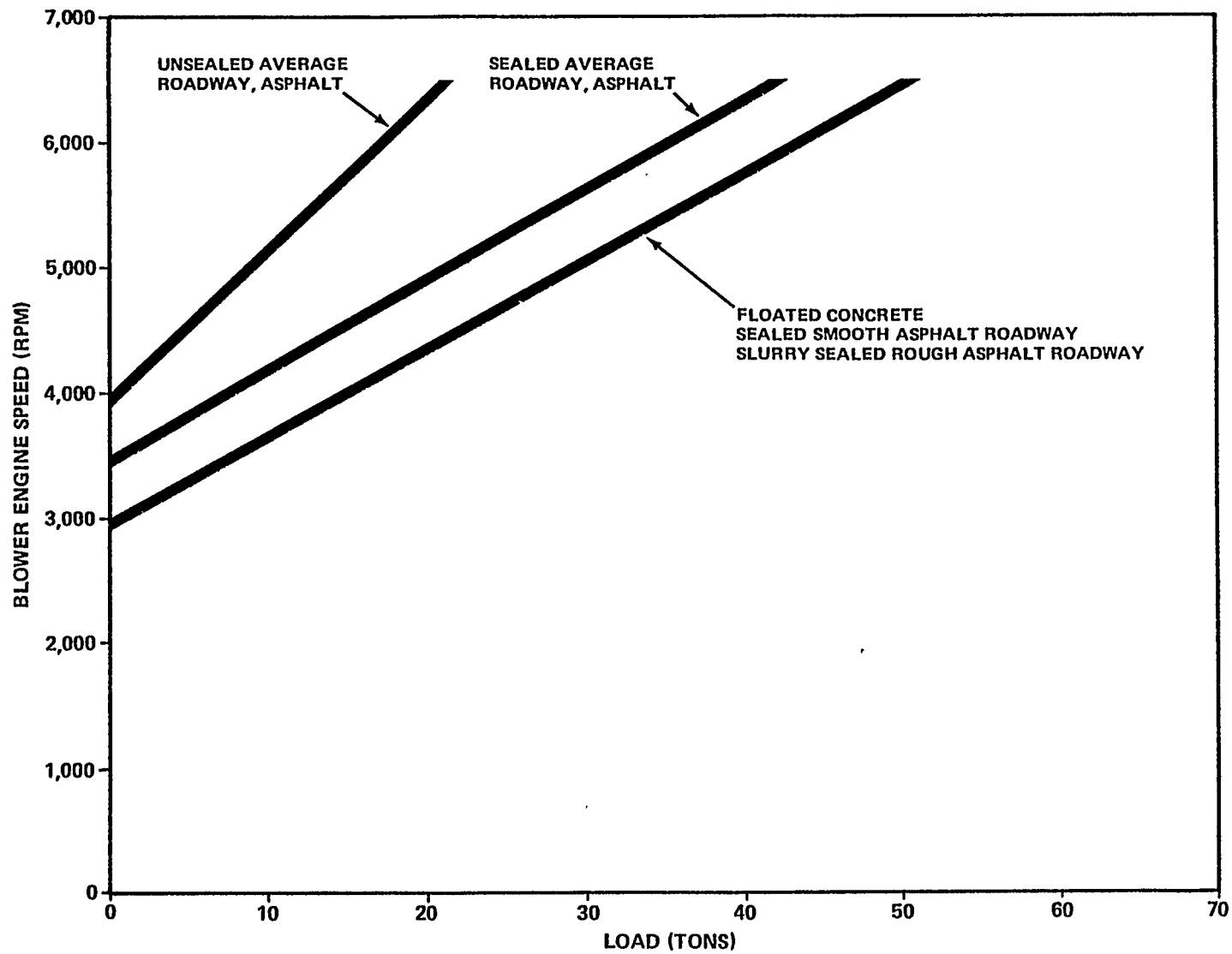


Figure 3 Blower Speeds Required to Maintain Equivalent Gap for Various Loads

a. If the blower speed is increased, there will not be as great an increase in bearing pressure as would be evident at a lower blower speed, nonfloating condition. In other words, blower speeds and bearing pressures are not directly proportional.

b. If the blower speed is increased, there will not be as great an increase in the equivalent gap as would be evidenced under a lower blower speed, nonfloating condition. Again, increases in equivalent gap are not directly proportional to increases in blower speed.

c. The transporter in floating, nonmoving condition will tend to move about within the constraints of the tow hitch if there is a slope in the operating surface, or if there is some freedom of motion in the tow hitch.

d. If the towing force is relaxed when the transporter is in the levitation state, the transporter will act as a dead weight, but if the transporter is not floating it will act as a spring weight and exhibit some recoil when coming to a stop.

7. AIRIDE SYSTEM

The Airide (additional lift) air supply system failed to operate satisfactorily. For example, the entire system was inoperable during the Material Movement Equipment Demonstration and bottled carbon dioxide gas was used as an air source (See Figure 2). The failure was induced by a poor design concept and resulted from air pressure that was too low complicated by insufficient storage capacity.

APPENDIX F

REPORT ON TESTS

CONDUCTED

ON A

500-TON AIR LIFT TRANSPORTER

UNDER

CONTRACT 1-36200

APPENDIX F
500-TON AIR LIFT TRANSPORTER

The information presented in this appendix includes technical details pertaining to the subject transporter. Included in the appendix are physical characteristics of the vehicle, conditions under which the transporter was tested in compliance with the subcontract, and results of the tests including technical data developed as a result of the tests.

Section I
DESCRIPTION OF EQUIPMENT

1. GENERAL

The Rolair 500-ton air lift transporter covered in this report consists only of the transporter. Air (water) film supply was provided from an outside source (see Section II, Paragraph 4) as was the tractive power.

2. TRANSPORTER

a. Structural Fabrication. The transporter (Figure 1) is fabricated of steel, consisting of basic standard sized U-channels, I-beams, and plate with standard pipe and fittings for plumbing as required. The transporter is 12 feet wide by 20 feet long and is 14 inches thick. Total weight of the transporter less the water used in the system is 14, 000 pounds.

b. Load Capacity. The transporter was designed to levitate a load of 500 tons. Because a suitable test load was not available the tests were scaled down to an approximate 220 tons. This was done by utilizing only four air bearings of the nine installed in the vehicle. This approach resulted in bearing operating pressures identical to that which would exist if all nine bearings were used and the full 500-ton load was being transported.

c. Air Bearings. The air bearings (Figure 1) are fabricated from a preformed coated fabric and are clamped to a load-bearing plate which directly supports an equal area on the lower surface of the transporter. There are nine bearings, each weighing 30 pounds, arranged in three rows

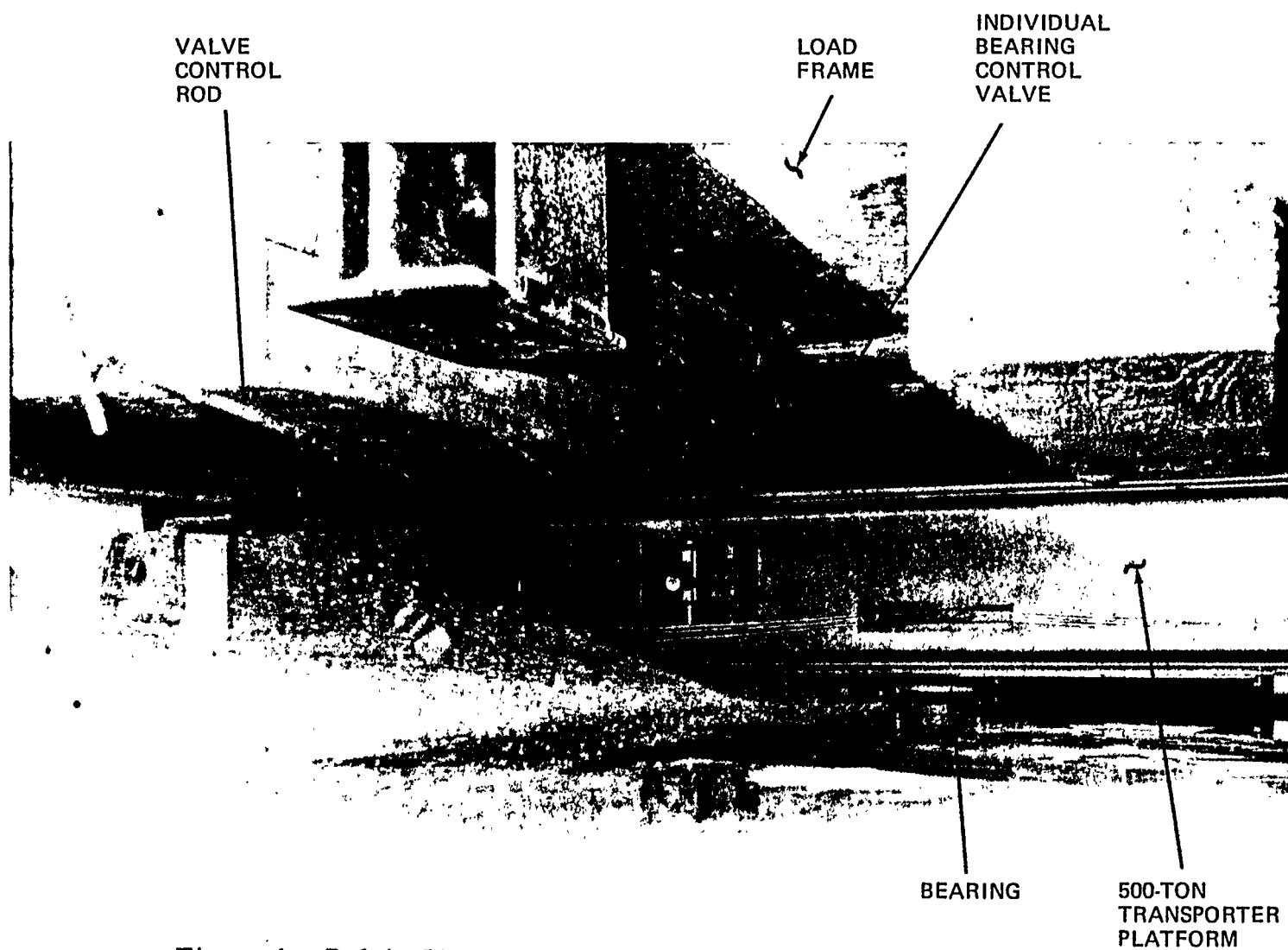


Figure 1. Rolair 500-Ton Ship Module Transfer Air Lift Transporter

of three bearings each. The bearings, with the exception of the center bearings, are easily installed or removed by one person and all are accessible from the sides or ends of the vehicle even during flotation. To replace the center bearing it is necessary to raise or tilt the transporter.

d. F1otation Medium Supply. The flotation medium (in this instance, water) supply system for the Rolair transporter is derived from a separate source. The transporter flotation medium system (Figure 2) is composed of standard plumbing and is manifolded to distribute the medium flow equally to each bearing. The flow of medium to each bearing is controlled individually by valve controls (Figure 1) easily accessible from the side or end nearest the bearing. As a protection against damage, each of the valve controls is located in recessed enclosures. A means is provided for indication of pressure at the individual bearings and each must be adjusted to attain the correct flotation pressure and gap.

3. LOAD FRAME AND LOAD

a. Load Frame. The load frame (Figure 1) was a concrete filled steel pallet constructed primarily of 30-inch wide flange steel beams resting on 12-inch x 12-inch timbers. The total weight of the load frame and water tank (see next Paragraph) with the tank empty was 76 tons.

b. Load. The load consisted of a circular steel riveted tank (Figure 3) 21 feet in diameter and 16 feet, 8 inches in height. During progressive stages of the test the tank was filled with additional water until the total load reached 220 tons.

INDIVIDUAL
BEARING
CONTROL
VALVE

LOAD
TANK
FILL
VALVE

LOAD
TANK
DUMP
VALVE

WATER
SUPPLY
PRESSURE
INDICATOR

MAIN
SUPPLY
CONTROL
VALVE

MAIN WATER
SUPPLY LINE

Figure 2. Flotation Medium Supply

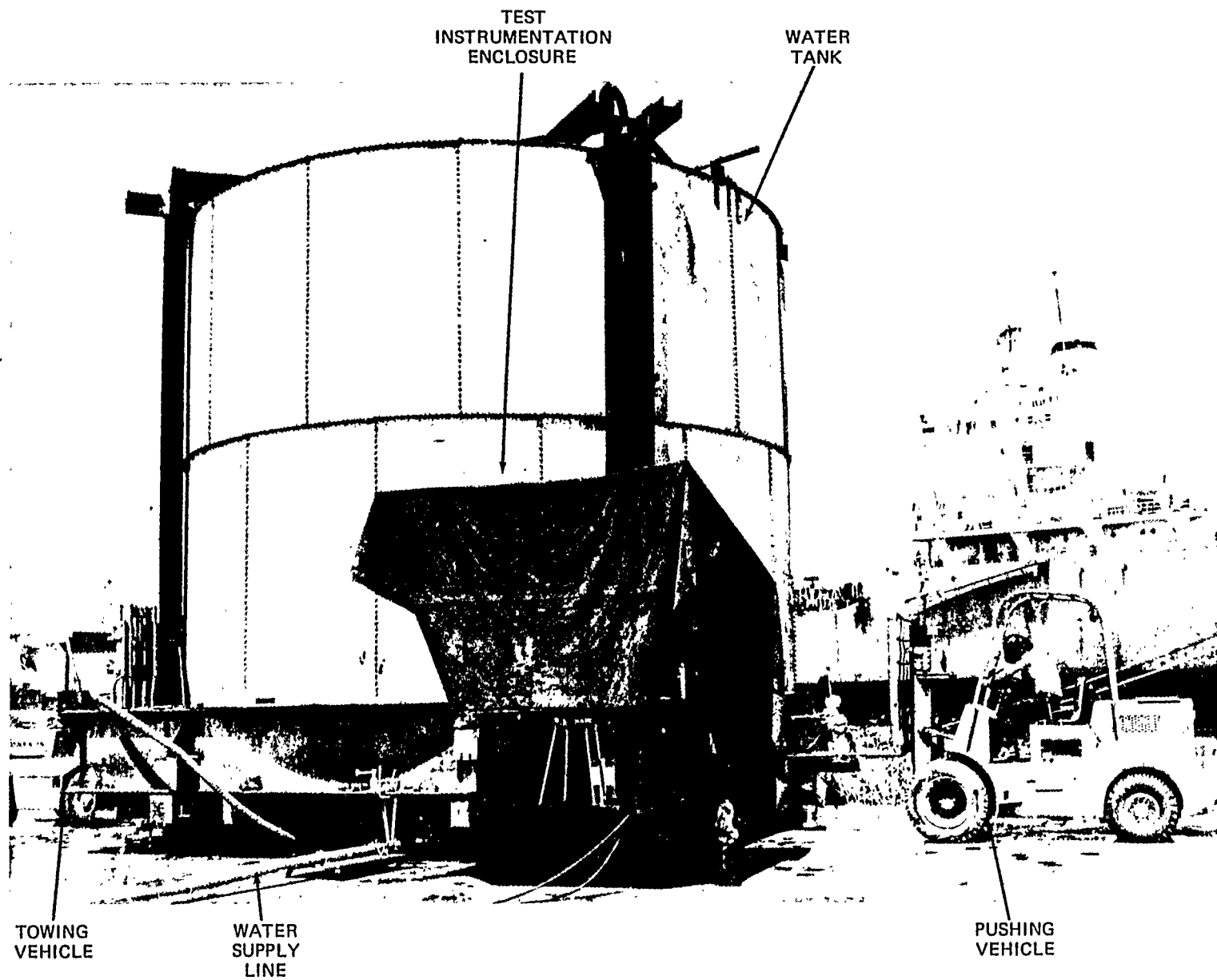


Figure 3. Rolair 500-Ton Air Lift Transporter and Load

4. MOTIVE POWER.

Motive power required to move the Rolair vehicle during the tests was provided by two standard fork lift trucks rated at 3,000 pounds capacity (Figure 3). One fork lift was affixed to the forward end of the load frame to a jury-rigged tow bar, while the other pushed with the forks from the rear. Braking power was available from both fork lifts.

5. OPERATION

a. General. Because of obvious reasons, no mention is made in this paragraph concerning procedures followed in loading and unloading the test tank.

b. Preparation of Motive Power. Before initiating movement operations the motive power should be attached to the movement vehicle(s) (Figure 3) and the engine(s) "warmed-up" to ensure positive action after the movement starts.

c. Preparation of Medium System (Figure 2). The following steps should be taken in preparation of the medium system for the movement operation.

(1) Connect main water supply line.

(2) Verify that control valves to the bearings (Figure 1) are in the fully off position.

(3) Check all connections and plumbing to verify serviceable condition of these items.

d. Activation of the Air Bearings. As stated earlier, unless the available water supply is in excess of 110 psi, two-way communications must be established between the Central or Area Pumping Station and the movement site. The procedure given in this paragraph is based on that premise.

(1) Transmit orders to the appropriate pumping to increase the main pressure to approximately 115 psi.

(2) Open individual bearing supply valves.

(3) Open main supply control valve to allow water supply to flow into bearings.

(4) Adjust individual bearing control valves to achieve desired pressure and flotation height in each bearing.

e. Movement. When free flotation of the air lift platform has been achieved, initiate movement of the load. Move the load at a slow rate of speed commensurate with the material movement route and braking power of the towing vehicle. When the destination has been reached, maneuver the load to the desired unloading area, set brakes on towing vehicle, and initiate shutdown procedures.

f. Shutdown Procedure. To shut down the air lift platform follow the procedure given below.

(1) Shut off main supply control valve in gradually decreasing steps to allow platform to settle to the operating surface slowly.

(2) Shut off individual bearing control valves.

(3) Call pumping station to reduce main pressure to normal value.

Section II

TEST CONDITIONS

1. GENERAL

The purpose of the tests described in this report was to evaluate the performance of a 500-ton ship module airlift platform manufactured for Ingalls under the circumstances set forth in Volume III. Although the transporter is designed to work on a prescribed surface and travel path, the tests described herein were made under conditions which simulated those encountered in daily shipyard material movement.

2. FLOAT FILM MEDIUM

Use of the term air lift platform to describe the equipment covered in this report is perhaps a misnomer. An air lift platform depends upon confined cushions of air at a slightly higher than ambient pressure to support the platform. Early in investigations of application of the technique to industrial uses, however, it was found that water could be substituted for air and the results would be essentially the same. The equipment covered in this portion of this report used water as a lubricating, or flotation, medium and thus provided realistic comparison of the two media for use with shipyard material movement equipment.

3. TEST SURFACE

a. Finish. The test surface (Figure 4) was a finished concrete slab, approximately 50 feet by 90 feet in size. However, because the slab had been used as a floor for a welding school for two years, the original finish had been badly scarred and pitted. This damage had been incurred by steel being burned directly on the slab and from steel segments being dropped from various heights, as well as general weathering. In an effort to provide a satisfactory test surface, all cracks and gouges greater than 3/8 inch were chipped out to hard, white concrete. The chipped areas were then filled with epoxy and after the epoxy had fully cured, the repaired spots were sanded flush to the concrete surface.

b. Level. Air lift vehicles, from their nature, require a high degree of level in the operating surface as well as a finished surface. During a survey of the test surface it was noted that the slab contained many cracks from 3 to 6 feet long running parallel to the 50 foot dimension. In addition, various humps were superimposed on a gentle slope toward the south end along the long dimension of the slab. The slope later was found to be a total of 0.35 foot from the north to south end.

4. WATER SUPPLY

a. Source. Water used to provide the water film was supplied to the transporter from the shipyard integral water system. An existing firemain was tapped, the water conveyed to the transporter through a standard fire hose to an external connection on the transporter, and

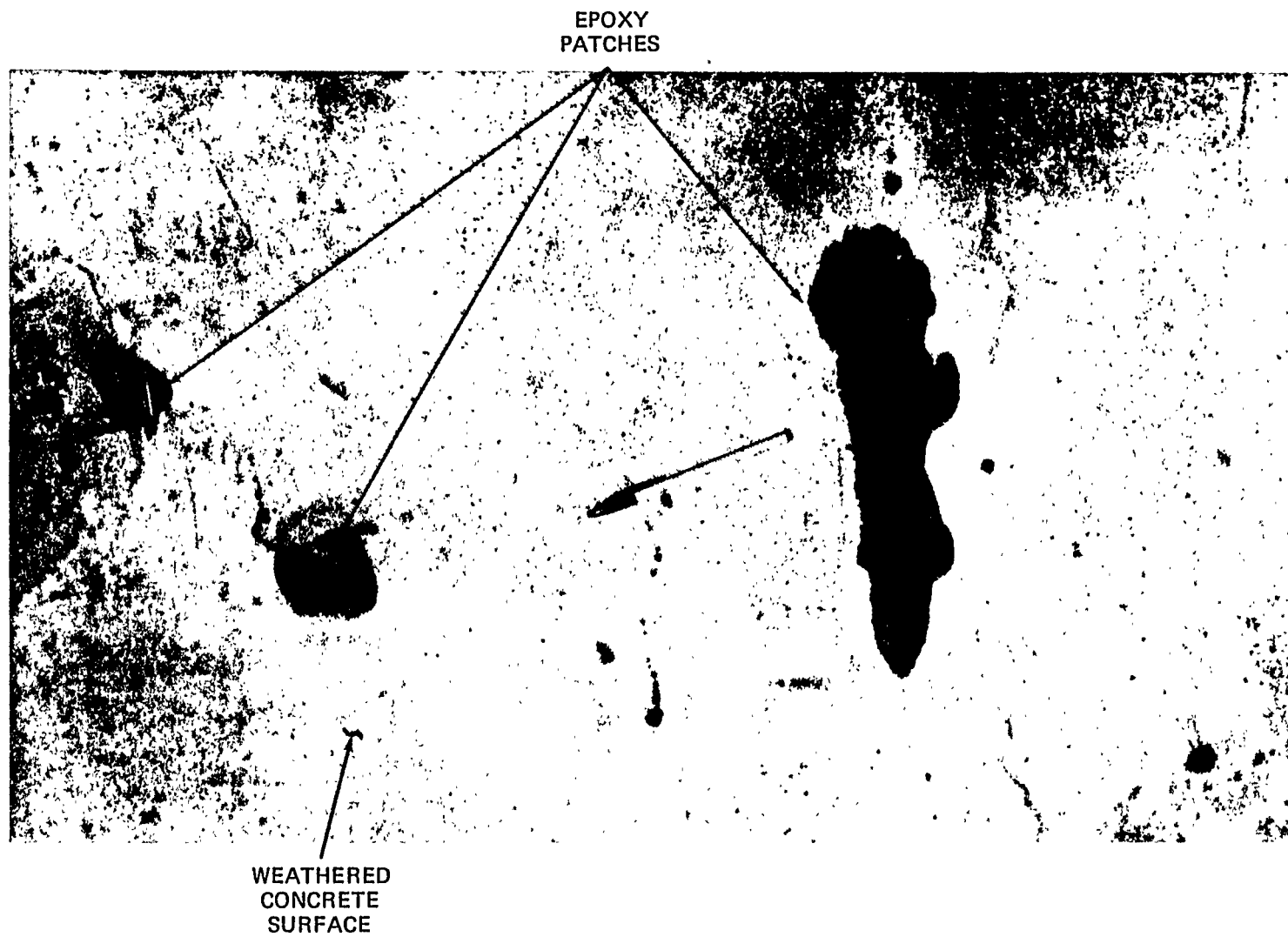


Figure 4 Test Surface Showing Refinished Areas

manifolded through the transporter structure to the water bearings.

b. Pressure. The water pressure used for the test was slightly above that normally carried in the shipyard system. To assure that sufficient pressure was available, two employees, each with "walkie-talkie" radios were utilized, one at the test site, the other at the Central Pumping Station, During actual testing the water pressure was increased and reduced again when tests were halted.

5. TRACTIVE POWER

Tractive power for the tests was provided by two standard 3,000 pound capacity fork lift vehicles, one pushing, the other pulling, at opposite ends of the transporter.

6. TEST LOAD

The test load consisting of a water tank filled to various levels was varied as the test progressed. The weight during initial stages of the test was 76 tons. As the test progressed the weight was increased by filling the tank until the weight had reached 220 tons.

7. DURATION OF TEST

The transporter, loaded with varying amounts of water was traversed back and forth across the test surface a total of 1 mile during tests and the Material Handling Demons tration held at Ingalls on 17-18 October 1973.

Section III

TEST RESULTS

1. GENERAL

This section of this report includes the results of the tests performed on the Rolair 500 -ton air lift platform over-the-road transporter. Some results included in the section are purely narrative in nature while others are accompanied by illustrative graphs and tables, appropriately referenced,

2. BEARING WEAR

a. After 1, 200 feet of travel, the No. 4 bearing was removed and inspected for wear. Wear marks on the membrane were visible to the eye only after the bearing membrane was thoroughly dried.

b. All of the bearings were inspected after 2, 535 feet of travel. Micrometer measurements of the bearing evidencing the worst signs of wear indicated a material loss in thickness of 0.0024 inch. This measurement, together with visual observation of the exact nature of the wear, indicates a nominal wear life in excess of 25 miles.

c. See Section V, Paragraph 2c, for other information pertaining to bearing wear and failures.

3. FLOTATION MEDIUM FLOW RATE

The major factors governing flow rate are the manifold pressure, total bearing circumference, and surface texture, assuming a frictionless condition. The plot of the flotation medium flow rate volume versus manifold pressure is shown in Figure 5 and represents the nonoptimized bearing flow settings during the test. After the tests it was estimated that water

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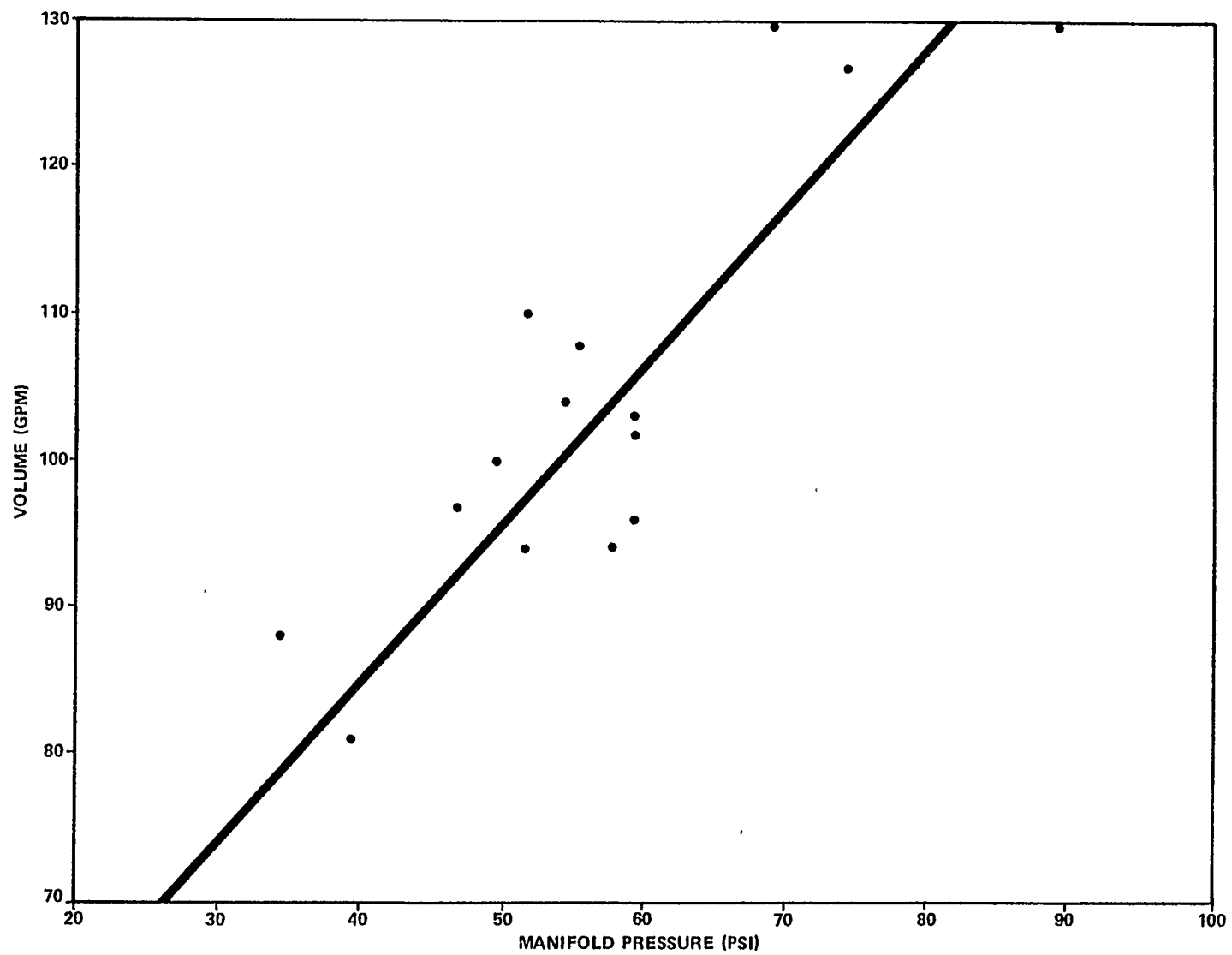


Figure 5. Flotation Medium Flow Rate

consumption could have been reduced by 25 percent and still have maintained a frictionless condition.

4. EQUIVALENT (FLOTATION) GAP

The equivalent (or flotation) gap, the height from the ground, or load bearing surface, at which the transporter achieved the "frictionless" state is shown in Figure 6. Data points used in plotting were obtained by averaging the equivalent gap at all four corners of the transporter under various load conditions. Some of the data spread in recorded data is attributable to fluctuations in water main-pressure, resulting in flow variations with the consequent effects upon the equivalent gap.

5. COEFFICIENT OF FRICTION

a. Due to a low level of confidence in the measured towing force versus load, as discussed in Paragraph 6, a means was sought to determine the coefficient of friction by some other manner.

b. In a detailed review of the test procedure, and especially those procedures involving towing force measurement, it was noted that upon activation of the transporter from a grounded (resting on test slab) condition, a definite pattern of events occurred. It was also noted that this pattern culminated in a static, steady state condition in which the transporter was "frictionless" (drifting about within its constraints), and the time at which the transporter became "frictionless" was marked by a change in the restraining force of the uphill towing line. This restraining force change was usually from a nontension value to a some tension value, but occasionally was a change from some value to some other value.

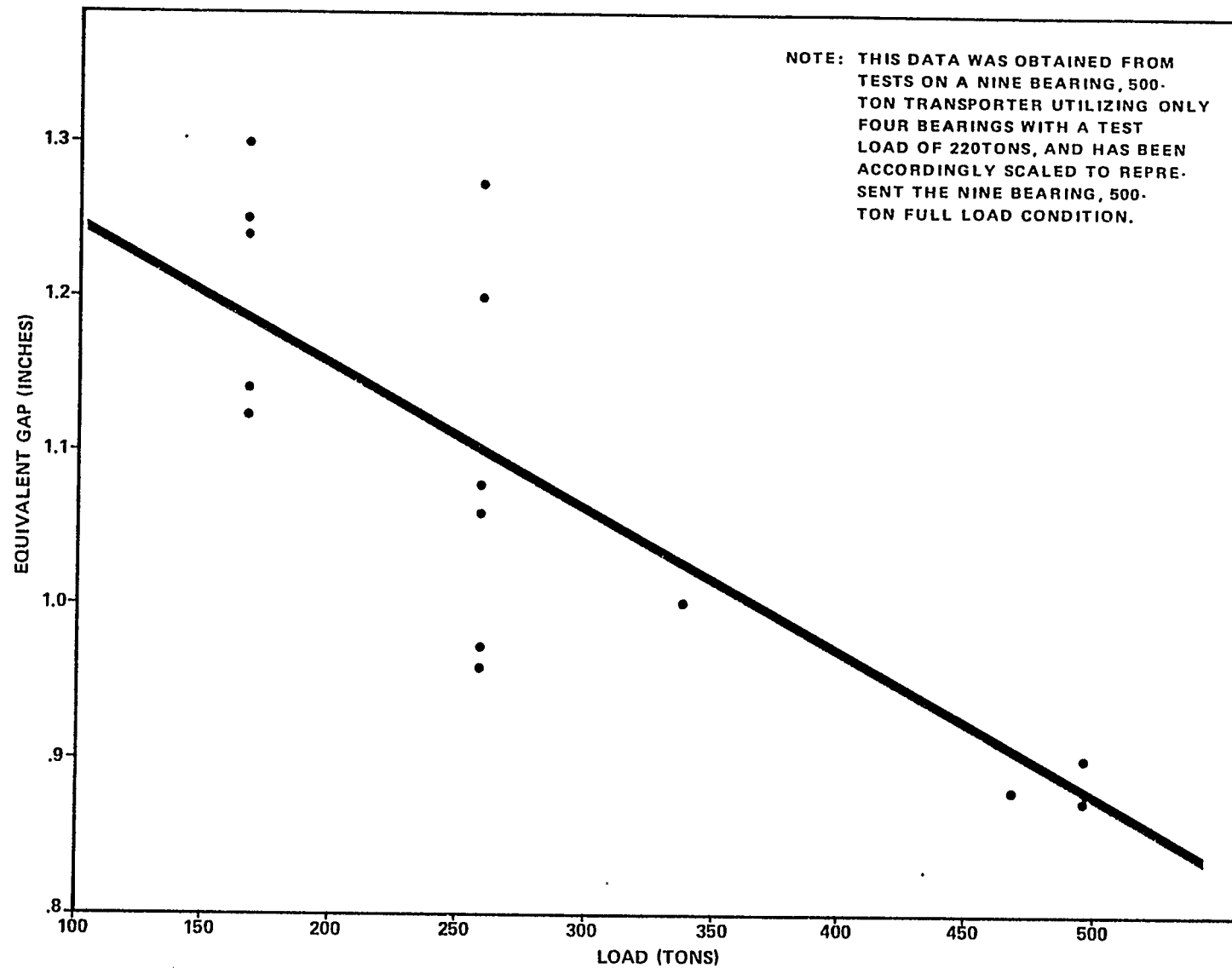


Figure 6. Equivalent (Flotation) Gap Under Various Load Conditions

c. It is believed that the initial towing force prior to frictionless drift was attributed to the happenstance conditions at the previous deactivation of the transporter, and that the final tensile force upon reactivation was a result of the down slope component of the load in the frictionless state. By taking the 0.35 percent average slope component and subtracting the tensile force in the restraining cable, the resultant force due to actual friction between the transporter and the test slab was determined. This resultant force was then used to calculate the coefficient of friction. Such calculations were made for six different loads at various places on the test slab and then averaged for a resultant coefficient of friction of 0.00113. The processes by which this figure was derived are shown in Table I. The average value was then used to calculate the towing force necessary to overcome friction, as explained in Paragraph 6.

6. TOWING FORCE

a. Early in the tests it was quite noticeable that the optimum towing data occurred at the start and immediately following the start of a 30-foot pull, either north or south, uphill or downhill; however, it was not until the data was carefully analyzed that it became clear that the south, or downhill, pull was not really downhill, but instead more closely a level pull due to the slab profile. For this reason, the data represented became very dependent upon where the data was taken, a situation that became even more critical when the length of the run (30 feet) and the mass were considered.

b. Taking all of the above factors into consideration, it was concluded that the optimum data adequately represented the apparent conditions, and

Table I. Calculation of Coefficient of Friction

Load (tons)	Force Vector (lbs.) @ O. 3570 Slope	=	Force Hold	+	Force Friction	Coefficient of Friction
80	560		450		110	. 000688
80	560		250		310	. 00194
192	1, 344		900		444	. 00116
220	1, 540		1, 100		440	.00100
220	1, 540		1, 250		290	. 000659
220	1, 540		950		590	. 00134
Average						. 00113

$$\text{Coefficient of Friction} = \frac{F_x - F_{\text{hold}}}{F_y} = \frac{\text{Load (sin } x) - F_{\text{hold}}}{\text{Load (cos } x)}$$

$$\text{Coefficient of Friction} = \frac{(\text{Load})_{(70 \text{ Slope})} - (\text{Force Hold})}{(\text{Load})}$$

consequently was plotted and is presented in Figure 7.

Figure 7 contains five towing force plots:

(1) Measured uphill

(2) Calculated uphill -- no wind

(3) Calculated uphill -- includes
wind

All data taken near
south end on a north-
ward pull.

(4) Measured level

(5) Calculated level

All data taken near
north end on a south-
ward pull.

c. The accuracy of these curves deserves to be questioned; however, there is definitely a degree of correlation between measured and calculated values. The purpose of attempting to derive meaningful towing data is primarily an attempt to establish a coefficient of friction, which then could be used to determine towing forces required to move any load under any conditions of runway slope and wind conditions. The calculated values of towing force vs. load just preciously discussed were derived from the use of a coefficient of friction of . 00113, a value determined as described in Paragraph 5.

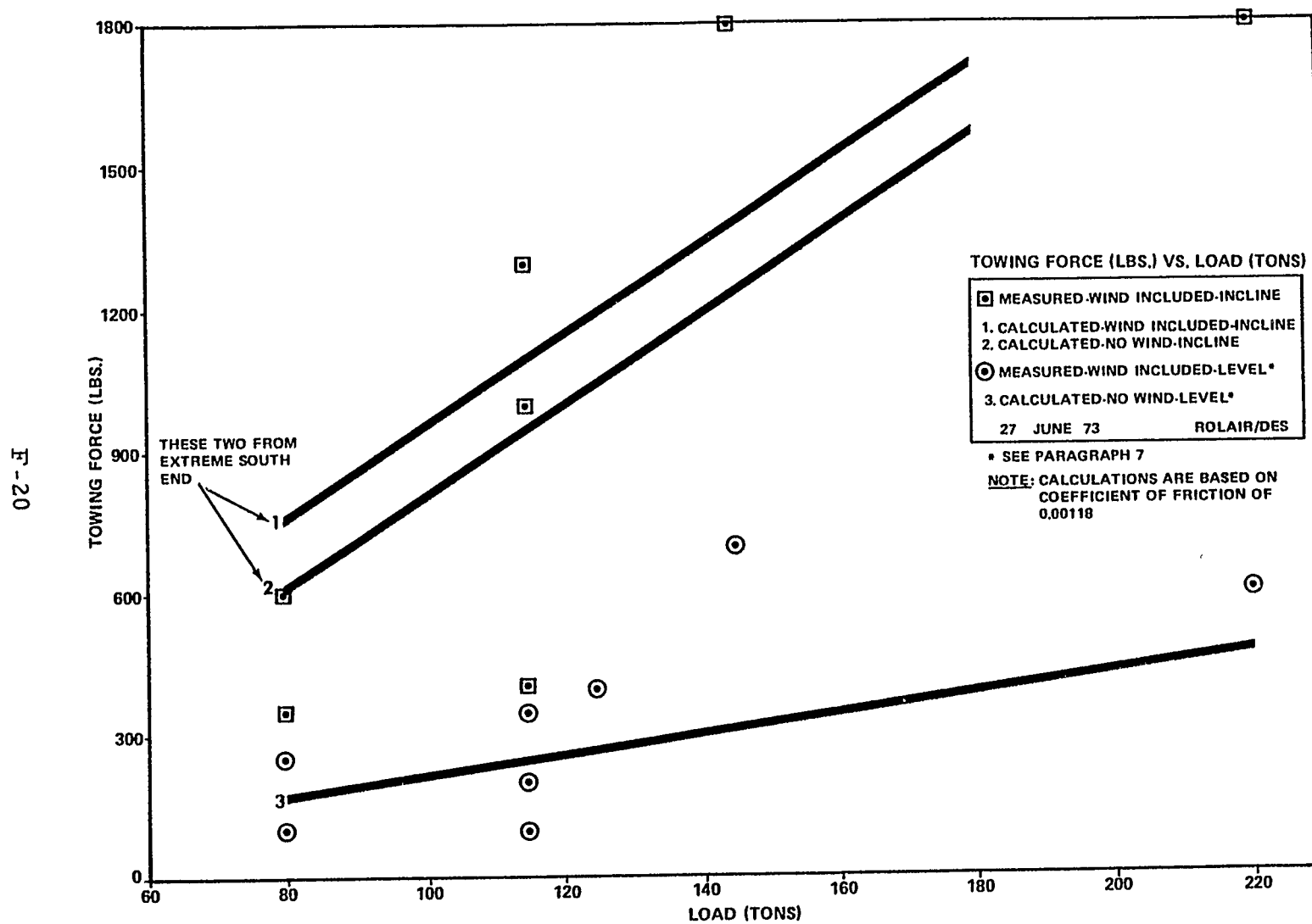


Figure 7. Towing Force Required for Different Loads

APPENDIX G
REPORT ON TESTS
ON
A MU ULTIPALLET TRANSPORTER

CONDUCTED
UNDER
CONTRACT 1-36200

APPENDIX G
MULTIPALLET FORKLIFT

Presented in this appendix are technical details pertaining to the multipallet transporter tested under the terms of the subcontract with the vendor. Included in the text are physical characteristics of the vehicle, conditions under which the tests were conducted, test results, and favorable and unfavorable comments concerning the design and construction of the transporter. Attached as enclosure 1 is a detailed record of maintenance performed on the vehicle tested at Ingalls Shipbuilding including downtime and maintenance costs.

Section I
DESCRIPTION OF EQUIPMENT

1. GENERAL

The multipallet vehicle tested under the provisions of the Ingalls contract represents a radical departure from the standard forklift now so widely used in industry and commerce. As such, it combines the forklift capability with certain truck characteristics that make it appear to be a workable solution to the problem of transporting palletized loads (up to 12,000 pounds) to distant points (one-half mile or more) over existing road surfaces with a minimum of delay.

2. CHARACTERISTICS.

The characteristics of the multipallet forklift are tabulated below.

a. Physical Characteristics.

Overall Length:

With fork: 171 inches

With mast reversed: 128 inches

Width: 82 inches

Height: 95 inches

Weight:

General Construction: All welded steel frame

b. Automotive Characteristics.

Engine:	Slant- six, 225 cu. in., 119 hp @ 4,000 rpm
Transmission:	Automatic industrial type
Steering:	Full hydraulic with manual override
Brakes:	Industrial power
Fuel capacity:	19 gallons
Turning radius (inside):	7 ft., 10 in.
Number of speeds:	3 forward, 1 reverse
Electrical system:	12 volts, heavy duty
Road clearance:	9 inches
Tire size:	
Front:	14X 17.5
Rear:	12x 16.5
Road speed:	Zero to 30 mph

c. Forklift and Cargo Characteristics.

Mast speed:	45 fpm at 2800 rpm (max)
Lift height:	108 in. or 144 in.
Mast tilt:	10 deg. fwd, 12 deg. back
Mast horizontal arc:	185 deg.
Bed speed:	45 fpm at 2800 rpm (max)
Bed travel:	4 ft. fwd and back
Bed capacity:	8000 lbs.

3. AUTOMOTIVE CAPABILITY

The multipallet forklift has the design and demonstrated capability to successfully negotiate shipyard movement routes at speeds from zero to 30 miles-per-hour, dependent upon road conditions. The minimum road clearance, nine inches, is sufficiently great to permit travel over virtually any obstacle that might be encountered in shipyard use. The vehicle is also equipped with a 12-volt road lighting system which will permit use on an around-the-clock basis, even in unlighted areas.

4. VEHICLE CAPABILITY

a. General. The multipallet forklift can pick up a pallet, or stacked pallets, if the pallets have flat level tops, rotate the mast and deposit the pallets in the cargo area. After the movement has been completed, the operator, without assistance, a necessity if a truck or rail car were utilized, can unload and stack the pallets in the desired location.

b. Operation of the Vehicle as a Cargo Platform. The operation of the moveable cargo platform presents the newest innovation in the area of palletized material moving equipment. The entire concept is so simple and ingenious that operation of the vehicle does not require extensive operator education, yet, sufficiently innovative that it requires some explanation.

(1) Forklift. Operation of the forklift itself is so similar to that of standard forklifts that it will not be described here. The only departure from standard forklift characteristics inherent to the multipallet vehicle is the ability of the forklift mast to rotate in the horizontal plane at all heights.

In performing this operation care must be exercised that the lift is not rotated until it reaches the pre-indexed mark on the lifting mast indicating the height of the cargo bed. The rotation of the forklift mast is controlled hydraulically by means of controls located in the driver's compartment. The characteristics and capabilities of the forklift are tabulated in Paragraph 2.

(2) Cargo Platform. The U-shaped cargo platform of the multi-pallet forklift is unique in that it can move hydraulically along the longitudinal axis of the vehicle from a rearmost point 48 inches beyond the body of the vehicle to a point where the tines of the U extend forward a short distance beyond the driver's compartment. Longitudinal movement of the platform totals 8 feet. It is this feature which permits multipallet loading utilizing a standard forklift capability; The steps followed in loading the cargo platform are set forth below.

(a) At the initiation of the loading operation the cargo bed is in the normal traveling position, i.e., with the platform entirely over the vehicle body.

(b) The operator next engages a pallet, and raises and rotates the fork mast until the pallet is over the vehicle body and aligned along the longitudinal axis.

(c) The cargo platform is moved to the most forward position until the aft section is beneath the pallet. The pallet is then lowered to rest on the cargo platform.

(d) The cargo platform is then moved to the normal traveling position to provide clearance for removal of the forks and the forklift mast is returned to the loading position (Figure 1.)

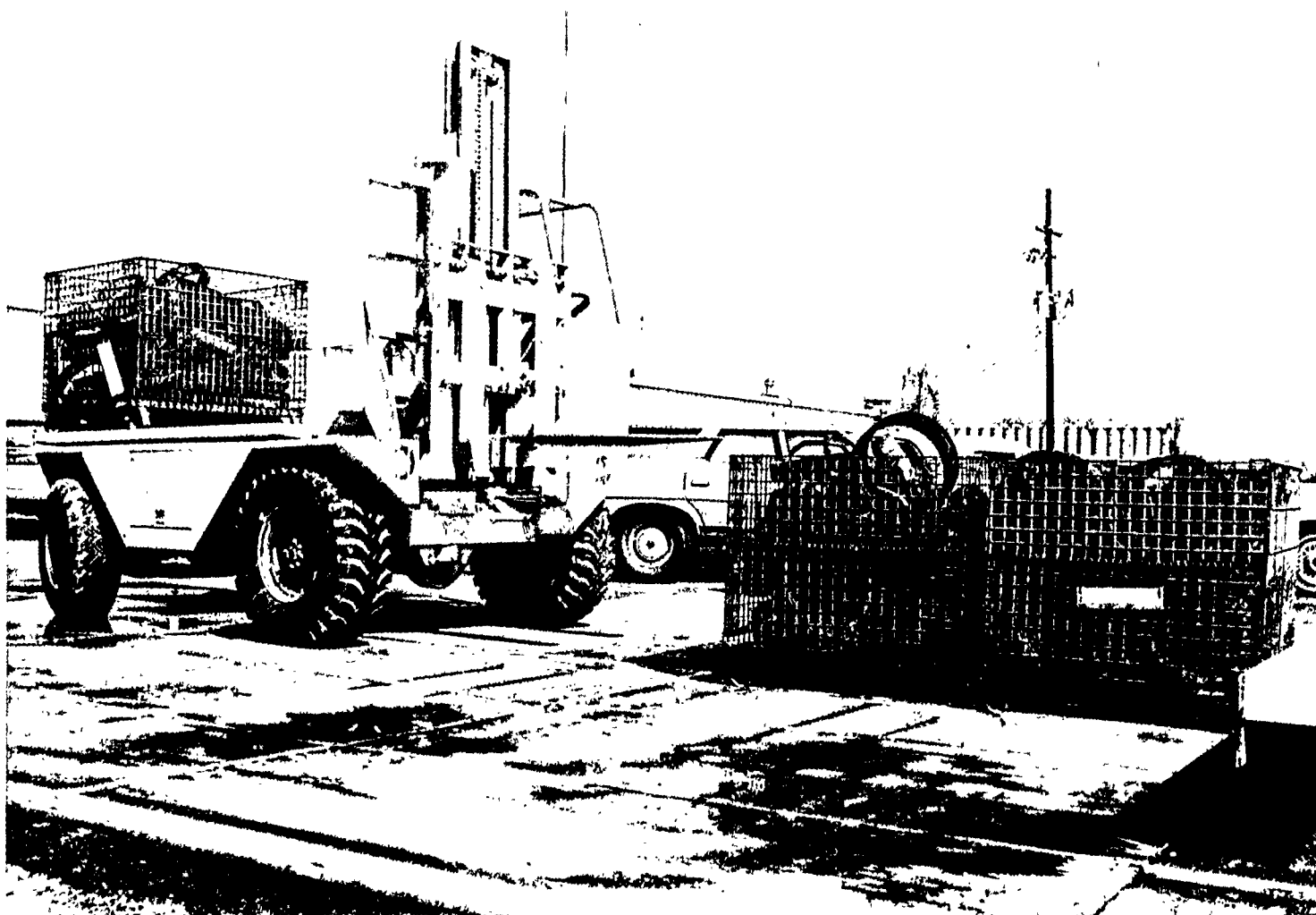


Figure 1. Multipallet Forklift Preparing to Engage Second Pallet

(e) Another pallet engaged, the operator rotates the forklift, aligning the pallet with the cargo platform (Figure 2.) The pallet is lowered to rest on the two tine sections of the U-shaped platform.

(f) The cargo platform is next moved to the rear-most position to provide clearance for the forks and the forklift mast is returned to the loading position.

(g) The cargo platform is returned to the normal traveling position, i.e., with the platform positioned over the vehicle.

(h) The forklift then engages a third pallet for movement on the forks (Figure 3.)

NOTE

If the pallet loads have flat, even loads, stacked pallets may be loaded using the above procedure providing the load limit of the vehicle is not exceeded.

c. operation as a Side-Hauler. An additional feature which emphasizes the versatility of the multipallet vehicle is the fact that the vehicle can be used as a side-hauler, if the occasion demands (Figure 4.) When such demands arise, the long material is picked up as with a standard forklift. The mast is then rotated 90 degrees to carry the material parallel with the longitudinal axis of the body, permitting travel through relatively narrow doorways and storage aisles, It should be noted, however, that when this is done the material must be lashed if it is over 6 feet in length.

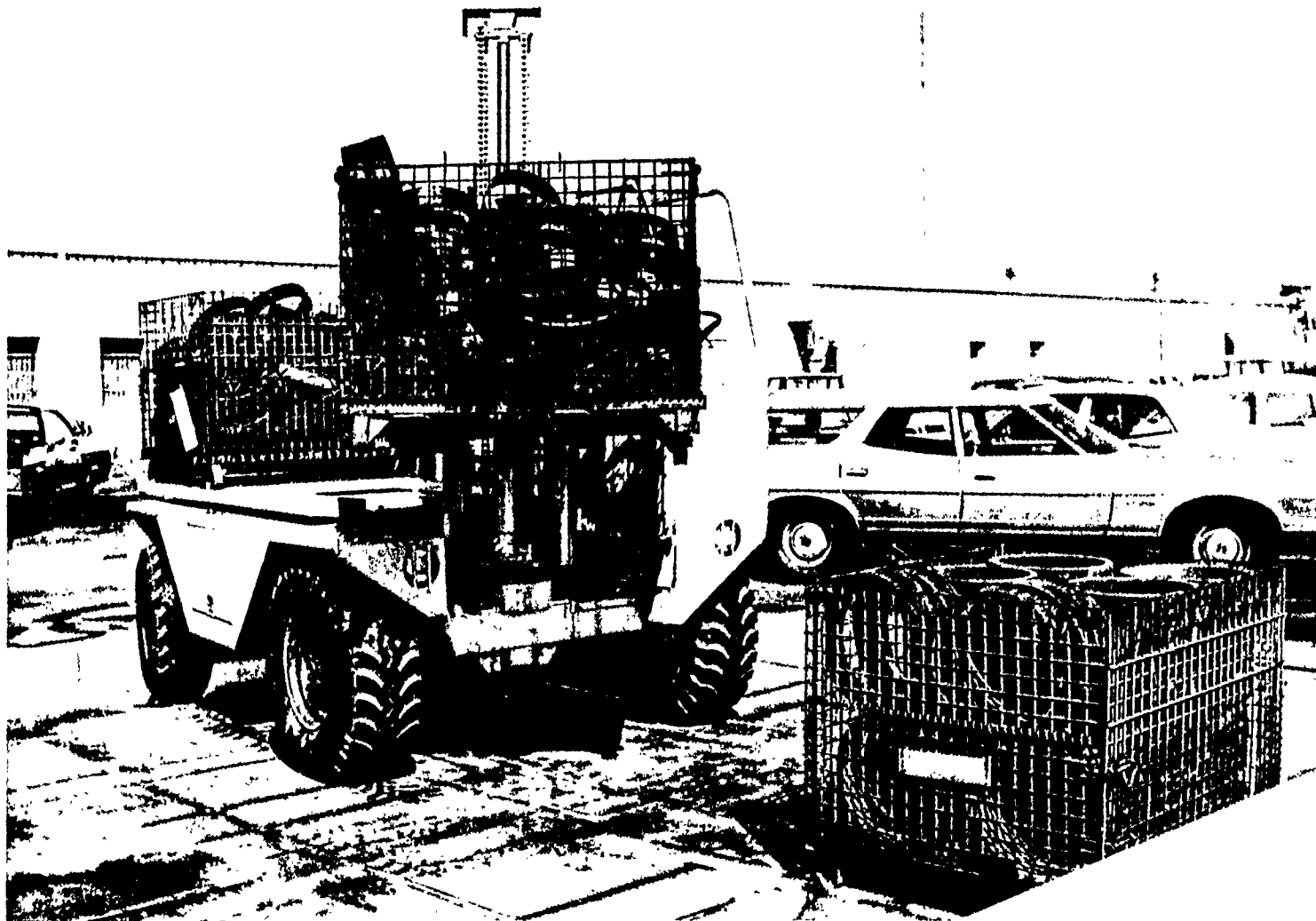


Figure 2, Rotating Second Pallet for Loading



Figure 3. Multipallet Forklift Ready for Travel

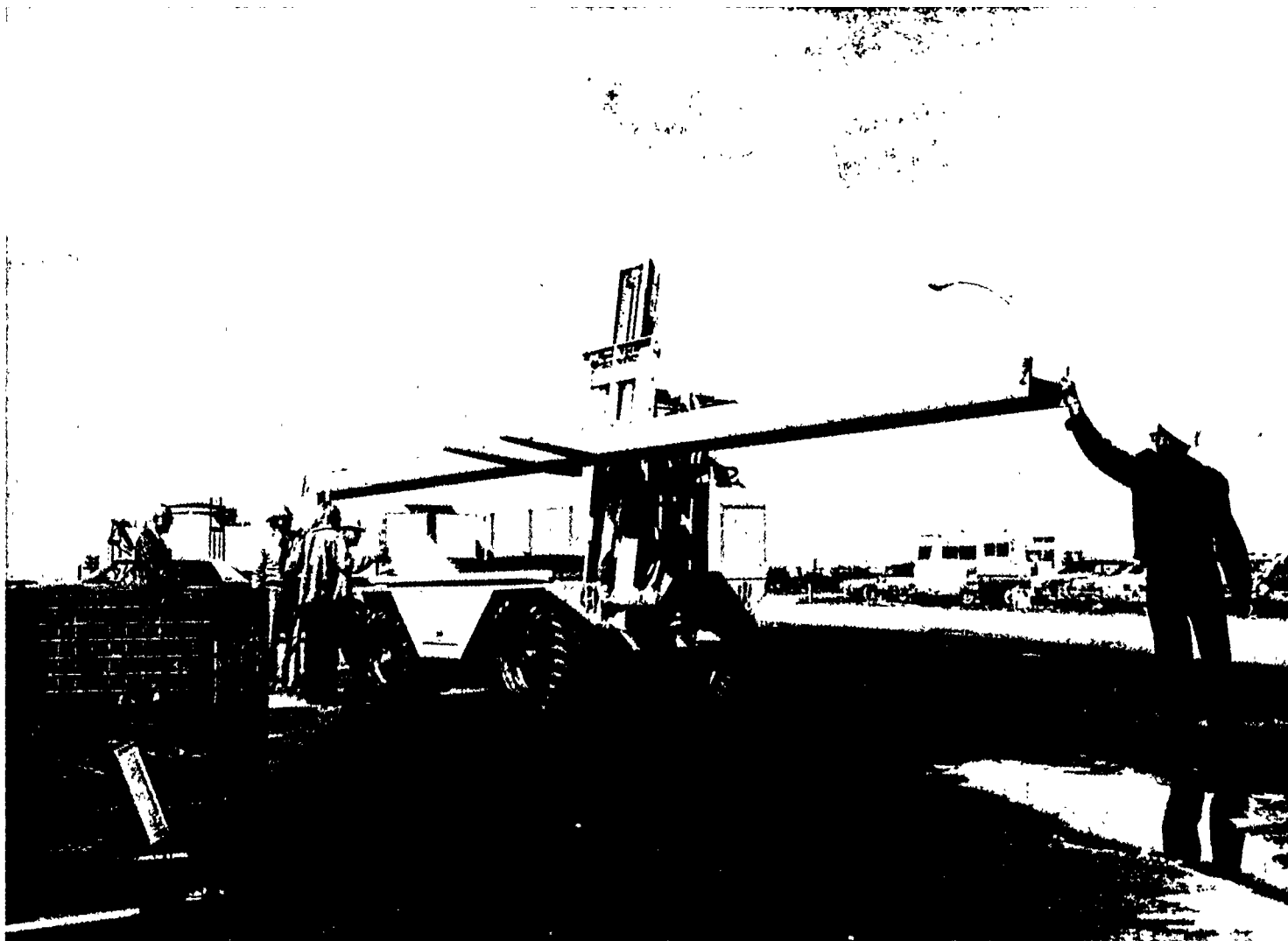


Figure 4. Use of the Multipallet Forklift as a Side-Hauler

Section II

TEST CONDITIONS

1. GENERAL

The user organizations were placed under no constraints regarding the use of the multipallet vehicle other than those imposed by the design capabilities of the equipment. Instead, they were requested to utilize the vehicle in as wide a variety of uses as possible to fully test the inherent capabilities and to reveal deficiencies that might militate against use of the equipment in day-to-day shipyard use.

2. TEST DATA

The only data recorded during user tests concerned frequency of usage, lengths of delivery distances, and weight of loads. Because this data revealed nothing of significant interest beyond the points already stated, the data will not be included in this report. In addition to the tabulated data, users were requested to submit written comments, both favorable and unfavorable, concerning the performance of the vehicle while under their jurisdiction. These comments have been summarized and are included in Section III, Test Results. Also included in the same section are comments submitted by the users bearing upon suggested alterations of the design of the vehicle that it was felt would increase the utilitarian value of the vehicle.

Section III

TEST RESULTS

1. GENERAL.

As stated earlier, Todd Shipyards and Newport News Shipbuilding and Dry Dock Company were placed under no specific constraints in test use of the multipallet vehicle other than loads be kept within design limitations. Rather, each shipyard was urged to utilize the vehicle to the maximum to ensure that deficiencies as well as favorable points would be emphasized. Inasmuch as it was felt that tabulated usage data was of less importance, in this instance, than operators' and managers' perceptions concerning the utility of the vehicle, only minimal data was requested from each user. The contents of these comments, which are on file and are available upon request, are condensed and summarized in this section.

2. FAVORABLE COMMENTS.

a. The consensus of comments by the users was that the vehicle performed well when assigned tasks for which it was designed. Todd Shipyards, for example, stated that the vehicle is "at least 50% more efficient than a regular forklift truck.

b. The vehicle also is capable of carrying odd- shaped, long narrow loads (such as piping and bars) over rough, narrow roads. This feature increases the versatility of the unit.

c. The over-the-road characteristics of the vehicle such as speed, power, and tire size enables it to negotiate terrain where vehicles with a lesser clearance would not have been able to traverse. Users reported that despite use under adverse conditions the vehicle was never mired.

d. The quietness of the engine permits movement orders and directions to be transmitted to the operator without engine shut-down.

e. The gas consumption was low, considering the size of the vehicle, thus reducing down-time required for refueling.

3. ADVERSE COMMENTS

a. One user considered the vehicle too large for use in confined storage areas. Note that the vehicle was not designed for such usage.

b. The hydraulic system was "a constant source of irritation" according to one user, citing excessive leakage in the power steering cylinder, and an unsatisfactory fitting on the mast. In an allied vein, another reported leakage of hydraulic fluid from the mast cylinder.

c. One user felt that skilled operators could perform more efficiently using a standard forklift, citing peak operator performance with both pieces of equipment in terms of number of pallets handled during an 8-hour shift. This comment did not include further information such as distance loads were moved, area restrictions, and such other considerations and must be judged accordingly. It is significant that the comment infers that the cited figures were only for warehouse work and short hauls, ignoring the over-the-road capability of the multipallet vehicle. A later comment further strengthens this belief.

4. COMMENTS ON MECHANICAL AND DESIGN FEATURES

a. The operator's cab is cramped and unprotected from precipitation. It is believed that a windshield and roof could solve a portion of the weather problem but it is doubtful the cab could be made satisfactory for severe winter use,

b. Unsecured loose material can be lost through the tailgate during movement. It was suggested addition of screening over the open spaces would solve this problem.

c. A fork positioner and lock would enable the operator to adjust the space between the forks without dismounting from the truck. This feature is available on these vehicles although it was not installed on those leased for the tests.

d. The emergency brake failed at one facility when a crimped fitting came loose at the handle. The fitting was locally fabricated and replaced, after which the brake-performed satisfactorily. It should be noted that this braking system is intended for use only as a parking brake or for emergency use if the primary hydraulic brake system fails.

e. The braking system was considered "touchy" although usable. It was suggested alteration of the design to incorporate rear wheel brakes would provide a more satisfactory method of braking the vehicle.

f. It was also suggested that incorporation of an "inching valve" would allow a more smooth approach to loads.

g. Some users felt the springs on the vehicle are too bouncy for shipyard use. It is believed that this comment arises from improper driver orientation regarding speeds over difficult terrain. Incorporation

of air or hydraulic shock absorbers to supplement the springs on the vehicle would serve to lessen the bounciness but would not be a substitute for operator judgement in speed selection.

h. A safety stop to act if the cargo bed chain breaks or jumps the sprockets is required as a safety feature.

i. It is recommended that the hose at the upper end of the hydraulic cylinder be connected to the hydraulic reservoir to eliminate hydraulic fluid draining from the cylinder during use.

j. The brake pedal angle is such that it is difficult to advantageously use the ball of the foot on the pedal. This could be solved by addition of a tilt-angle adjustment such as is commercially available on many vehicles.

k. A study of the location of operator controls should be made to facilitate operator usage.

l. The shift mechanism should be relocated from the dashboard to the right side of the driver's compartment.

m. One comment suggested addition of guard features on the bed and on the operator's compartment to eliminate the possibility of the operator's arm being injured while the bed is in motion.

n. On two occasions, foreign objects or protrusions caused punctures in the lower portion of the vehicle radiator. This suggests a design deficiency which could be remedied by installation of a protective guard to shield the lower part of the radiator.

5. SUMMARIZATION

a. In adjudging the comments included in this section it should be noted that the vehicle being tested was either the prototype or early production models and that the overall design had not been thoroughly tested,.

as yet, through use. Some of the deficiencies found in the prototype had already been corrected on production models. Among such design changes Were: relocation of the power cylinder; substitution of a larger, more efficient hydraulic pump; and an increase in the lift height. In this light, it should also be noted that many of the other adverse comments and suggested design changes arose from design or mechanical deficiencies as easily corrected as those already accomplished, or from what may be presumed to be usage that did not utilize the maximum capability of the multi-pallet forklift.

b. To provide documentation of maintenance experience with one of the multipallet forklifts, a chronological summary of the maintenance record for the vehicle tested at Ingalls has been compiled and is presented in enclosure 1.

ENCLOSURE 1

TO

APPENDIx G

DETAILED MAINTENANCE EXPERIENCE

DURING

USER'S TESTS OF THE MULTIPALLET FORKLIFT

AT

IN GALLS SHIPBUILDING

Enclosure 1

DETAILED MAINTENANCE EXPERIENCE DURING USER'S TESTS
OF THE MU MULTIPALLET FORKLIFT AT INGALLS SHIPBUILDING

1. GENERAL.

During the user's tests of the multipallet forklift, Ingalls operated one vehicle for 158 days during which 1171 hours operational time was accumulated. Two other shipyards, as stated in the Introduction, also took part in these tests. In the belief that a detailed account of the maintenance pertaining to one of these vehicles would be of assistance in evaluating the vehicle, a summarization of the maintenance experience at Ingalls is presented in this Appendix. Detailed information regarding the cause, corrective action, downtime, labor costs, parts costs, and recommendations are included for each item.

2. SPECIFIC MAINTENANCE EXPERIENCE.

a. Voltage Regulator Failure.

(1) Cause. This failure was discovered during the receiving inspection and was classed a non-predictable fair wear and tear failure.

(2) Corrective Action. The voltage regulator was replaced.

(3) Downtime. One hour.

(4) Labor Costs. \$4. 30

(5) Parts Cost. \$20.00

(6) Recommendations. None

b. Broken Hydraulic Lift Cylinder Vent Coupling.

(1) Cause. This occurred three times and was the result of a maladjusted lift drive chain on the tine hoisting mast. When lifts were made to fully extended height, vibration of the lift chain would shear the vent coupling flush with the lift cylinder.

(2) Corrective Action. The lift chain was adjusted to the correct tension.

(3) Downtime. Three hours

(4) Labor Costs. \$12.90

(5) Parts Costs. \$9.00

(6) Recommendations. Adjustment of the lift chain tension be performed during periodic maintenance and inspections. A more certain solution is relocation of the vent coupling to another quadrant of the lift cylinder as was done at Ingalls after the third occurrence.

c. Scoring and Bending of Power Steering Hydraulic Cylinder

(1) Cause. Maladjustment of the adjustable wheel stops by the manufacturer allowed the steering wheels to impact the steering cylinder shaft causing the cylinder to be bent and abraded and also resulted in failure of the hydraulic seal.

(2) Corrective Action. The hydraulic cylinder shaft and seal were replaced. The mechanical stops were also adjusted to eliminate contact of the wheels and the steering cylinder shaft during turning maneuvers.

(3) Downtime. Ten days.

(4) Labor Costs. \$19.35

(5) Parts Costs. \$135.00

(6) Recommendations. None. The manufacturer has already altered the vehicle design to relocate the power steering cylinder on all production vehicles, which will obviate any such failures in the future.

d. Failure of Mast To Slew.

(1) Cause. This failure was caused by four teeth having been sheared off the planetary slewing gear. The teeth were sheared off because an operator attempted to slew the mast before the tines were sufficiently elevated to clear the load bed.

(2) Corrective Action. Even though the planetary slewing gear has teeth around the entire periphery only half of the teeth are used during slewing. Repair of the mast was effected by removing the gear retaining bolts and rotating the gear until the sheared teeth were in that segment of the gear not engaged during slewing.

(3) Downtime. Four hours.

(4) Labor Costs. \$17.20

(5) Parts Costs. \$3.00

(6) Recommendations. All operators must be thoroughly briefed and tested on operation of the vehicle before being given a work assignment. They must be particularly cautioned about slewing the mast before it has reached the slewing index mark on the mast.

e. Primary Hydraulic Cylinder Seal Failure.

(1) Cause. This problem, which resulted in excessive hydraulic fluid leakage on two occasions, was classified as fair wear and tear failures.

(2) **Corrective Action.** The hydraulic cylinder seals were replaced; one set was purchased while the other was provided by the manufacturer.

(3) **Downtime.** Nine hours.

(4) **Labor Costs.** \$34.40

(5) **Parts Costs.** \$3.00

(6) **Recommendations.** None.

f. **Sheared Steering Axle Shackle Bolts.**

(1) **Cause.** These shackles are acted upon in both directions by the power steering cylinder as the pistons drive in and out during turns. The shackles were made from mild steel and ultimately failed from fatigue.

(2) **Corrective Action.** The broken shackles were replaced with shackles made from hardened steel provided by the manufacturer.

(3) **Downtime.** Two hours.

(4) **Labor Costs.** \$6.45

(5) **Parts Costs.** No costs.

(6) **Recommendations.** None

g. **Radiator Punctured, Tie Rod Severed, and Drive Shaft Coupling Bolts Sheared.**

(1) **Cause.** This damage, while not classified as caused by failures is included in this record because it is representative of incidents that might occur in normal shipyard use. The damage was incurred during a weekend and neither the operator nor the circumstances could be ascertained.

(2) **Corrective Action.** The radiator was removed, repaired, and replaced; the severed tie rod was welded; and the sheared drive shaft coupling belts were replaced.

(3) **Downtime.** Twenty-four hours.

(4) **Labor Costs.** \$43.00

(5) **Parts Costs.** \$48.00

(6) **Recommendations.** Two major factors were responsible for this damage; improper supervision, and faulty driver assignment. Supervisors must be alert concerning areas to which this vehicle is assigned and operation should be entrusted only to trained, competent operators.

3. TOTAL MAINTENANCE COSTS.

The total maintenance costs for the specific maintenance problems detailed in Paragraph 2 are summarized below. Note that these costs do not include scheduled periodic maintenance, excluded because it is a foreseeable, normal expense.

	Labor Costs	Parts Costs	Downtime (hrs)
	\$ 4.30	\$ 20.00	1
	\$12.90	\$ 9.00	3
	\$19.35	\$135.00	240
	\$ 17.20	\$ 3.00	4
	\$34.40	\$ 3.00	9
	\$6.45	-----	2
	<u>\$43.00</u>	<u>\$48.00</u>	<u>24</u>
TOTALS:	\$137.60	\$218.00	383

4. COMMENTS ON GENERAL DESIGN

During the period in which the multipallet transporter was in use at Ingalls particular attention was paid to noting deficiencies and weaknesses in the design concept. The comments included in this paragraph are the results of that effort as opposed to those incorporated in Section III which were primarily derived from the comments of the other two users. Suggested features which, if added, would further *serve* to enhance the value of the vehicle were also noted and are listed in Paragraph 5.

a. Hydraulic System. The system is marginal when multiple hydraulic demands are made simultaneously and is generally unsatisfactory for maneuvering at low engine speeds. A hydraulic accumulator added to the system would overcome this deficiency.

b. Load Bed Locks.

(1) The load bed drive system should have a rearwards limit stop incorporated in the system as a safety feature. This would prevent the load moving to the rear from inertia if the vehicle starts and the drive chain breaks.

(2) A mechanical safety lock, operable from the driver's compartment, should be designed into the system to lock the load in place after loading to prevent dumping if the load bed drive chain breaks.

c. Mast Rotation Drive Stop. An automatic stop should be incorporated in the mast rotation drive to prevent the drive being activated until the forks have been elevated sufficiently to allow the forks to clear the load

bed in slewing.

d. Cab and Load Bed Safety Screen. Heavy mesh screening must be added to the forward side of the drivers' compartment and to the cargo frame and tailgate. These additions are required as protection to the operator and cargo.

5. OPTIONAL DESIGN FEATURES

Because of the versatility of this vehicle and the strong possibility that it would be used on a 24-hour day, 7-day week basis, Ingalls has compiled a list of certain other optional features that should be considered for inclusion in the overall design. For the same reasons given above, some of the optional features suggested herein would virtually be mandatory.

a. Mast Lights. For use at night, lights should be added to the mast for illumination of the loading and unloading areas. These lights must be rugged and protected from breakage by the pallets.

b. Turn Signals. Turn signals should be incorporated, fore and aft, for use in over- the- road operations.

c. Caution Light. A flashing caution light, designed to automatically operate when the vehicle is moving, should be affixed above the operators' cab.

d. Sideview Mirror. A sideview mirror with a parabolic lower segment should be added to improve the drivers' rear vision.