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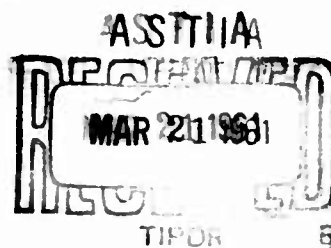
TREC TECHNICAL REPORT 61-7

**STUDY AND EVALUATION OF PORTABLE AIRCRAFT
MAINTENANCE HOISTING EQUIPMENT**

FINAL REPORT

Project 9-38-01-000, HT 12.103

February 1961



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**STUDY AND EVALUATION
OF
PORTABLE AIRCRAFT MAINTENANCE HOISTING EQUIPMENT**

FEBRUARY 1961

Prepared by

Joseph A. Blanco, Project Engineer

U. S. ARMY TRANSPORTATION RESEARCH COMMAND

Fort Eustis, Virginia

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SUMMARY

This report covers the fabrication and testing of a lightweight, portable gantry hoist that was developed to meet a requirement for a hoist that could be used in the field for disassembly of disabled or damaged Army aircraft prior to aerial evacuation of the aircraft and its component parts.

A contract was awarded for the modification of a design of an off-the-shelf tripod gantry hoist that had been previously tested but not accepted. Evaluation of test results on the modified gantry hoist indicated that all technical characteristics except one had been met. The gantry hoist weighed 646 pounds, which was 246 pounds over the 400-pound total weight limitation. The contractor stated, however, that this weight could be reduced to approximately 400 pounds if the legs of the tripods and the mud plates were fabricated of aluminum rather than steel and if the I-beam were constructed of magnesium rather than aluminum.

It was determined from overall test results, however, that the 646-pound tripod gantry hoist, model 2008, would be suitable for type classification if the weight requirement were waived.

Upon completion of the engineering tests, the developed hardware and project files were transferred to U. S. Army Transportation Materiel Command (USATMC) in St. Louis, Missouri.

CONCLUSIONS

It is concluded that:

1. The 646-pound tripod gantry hoist, model 2008, meets the required technical characteristics with the exception of the 400-pound weight limitation, which was exceeded by 246 pounds.

2. The weight limitation of 400 pounds can be met by substituting aluminum for the steel legs and mud plates, and magnesium for the aluminum I-beam.
3. The tripod gantry hoist can also be utilized by other technical services in the support of maintenance activities at all levels.
4. The tripod gantry hoist, model 2008, is suitable for type classification.
5. The tripod gantry hoist, model 2008, is suitable for inclusion in the shop set, Ground Handling and Servicing, Field Maintenance, Army Aircraft, Set A, SM 55-4-1730-SO 1; Set B, SM 55-4-1730-SO 2; and Set C, SM 55-4-1730-SO 3.

BACKGROUND

Special tools and equipment are required for recovering damaged or disabled aircraft by Army cargo helicopter. The immediate need is for a collapsible lightweight hoisting device that can be airlifted by helicopter to the scene of operations for removing various components (such as transmissions, rotor heads, and engines) of the disabled aircraft prior to its aerial evacuation. A contract was awarded for the design and fabrication of a gantry hoist having a lifting capability of 4,000 pounds. Inclusion of the H-37 Mojave helicopter in the Army inventory necessitated this weight requirement. Although this requirement was later eliminated (because of the limited number of H-37's in the Army inventory), the decision was made to continue development of the hoist since its fabrication was so near completion. An off-the-shelf gantry hoist having a 2,000-pound lifting capacity was then procured for the performance of comparison tests. However, neither of these hoists proved to be acceptable.* The first hoist was heavy, cumbersome, and mechanically unacceptable. The second one was structurally inadequate: the I-beam deflected sideways under a 3,500-pound static load, and the legs of the tripods, when extended to maximum height, deflected and obtained a permanent set when a 2,700-pound static load was applied. Although the 2,000-pound capability required by the technical characteristics (Appendix II) was achieved, the required 2:1 safety factor was not.

Project 9-38-01-000, House Task 12.103, was then established (Appendix I) for the investigation and evaluation of all portable hoisting equipment currently being used in echelon maintenance. Investigations revealed that the previously tested 2,000-pound-lifting-capacity hoist could be modified to meet the specified technical characteristics. Thus, a contract was awarded in June 1959 for the fabrication and testing of a modified gantry hoist. Upon completion of fabrication, the contractor performed engineering tests. Results of the tests proved conclusively that the modified gantry hoist (model 2008), after minor modifications, met all the technical characteristics with the exception of the weight limitation of 400 pounds, which was exceeded by 246 pounds.

*Aircraft Recovery and Evacuation System, Report of Test 437, U. S. Army Transportation Research and Engineering Command, Fort Eustis, Virginia, 24 April 1959.

Portable Hoisting Equipment, Report of Test 446, U. S. Army Transportation Research and Engineering Command, Fort Eustis, Virginia, 25 August 1959.

Upon completion of engineering tests and contractual actions, the developed hardware and the project files were transferred to USATMC, St. Louis, Missouri, in accordance with Office, Chief of Transportation General Order 43.

DESCRIPTION OF MODEL 2008 TRIPOD GANTRY PORTABLE HOIST

The model 2008 tripod gantry portable hoist consists of an aluminum I-beam monorail that is supported at each end by an adjustable tripod, which is constructed essentially of steel (Figure 1).

Characteristics of the tripod gantry portable hoist are shown in Table 1.

TABLE 1
CHARACTERISTICS OF TRIPOD GANTRY PORTABLE HOIST, MODEL 2008

	Gantry	Tripod
Height		
Maximum	20 ft. *	23 ft.
Minimum	10 ft. *	12 ft.
Width	15 ft. **	
Weight	646 lb.	225 lb.
Rated Load Capacity	2,000 lb.	2,000 lb.
Safety Factor	2:1	2:1
Maximum Lift (Height)	18.5 ft.	21.5 ft.
*Height below I-beam		
**Width of I-beam		

The weight breakdown is as follows: 6 adjustable steel legs, 360 pounds; 2 tripod head assemblies, complete with I-beam erection gear, 28 pounds; 1 aluminum alloy I-beam, complete with end fittings, 141 pounds; one 1-ton hoist, complete with 18 feet of lift chain, 61 pounds; 1 trolley, 19 pounds; six 15-inch square mud base plates, 51 pounds.

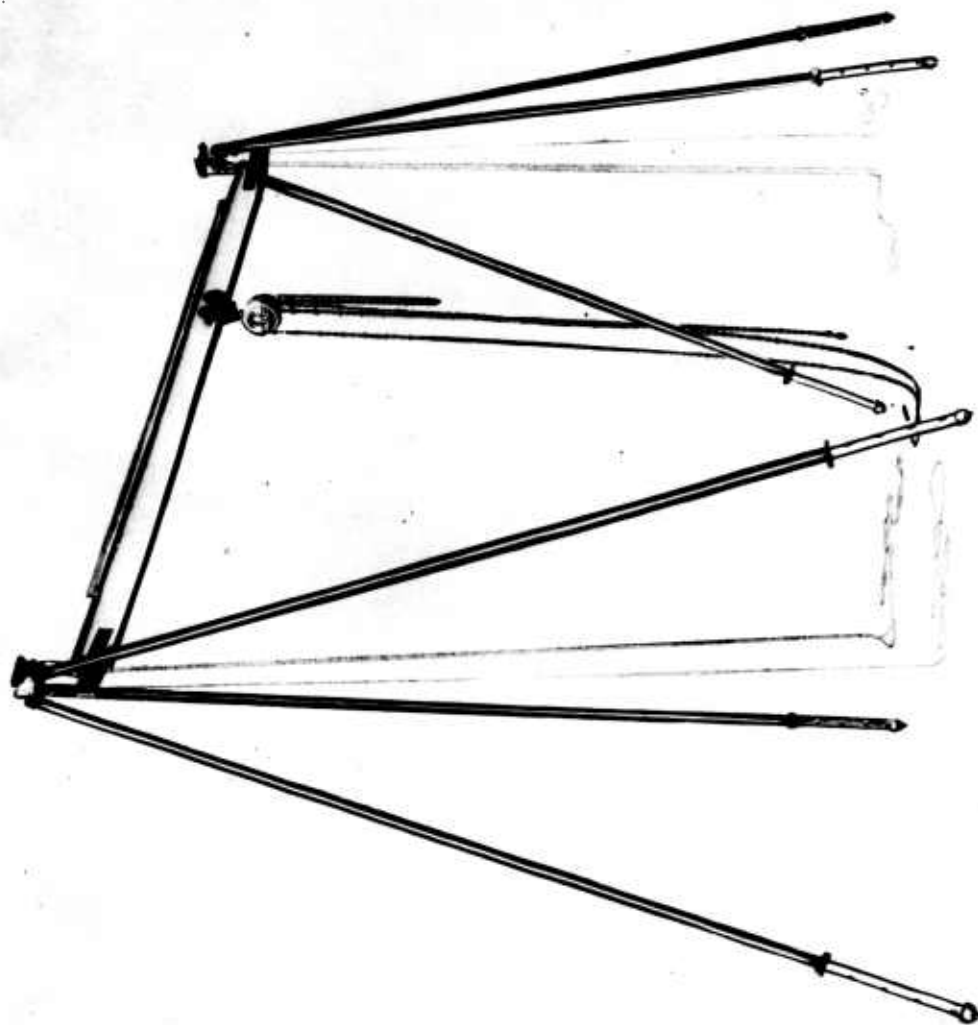


Figure 1. Complete Tripod Gantry Assembly.

The arrangement of adjustable-height tripods supporting an aluminum alloy I-beam results in minimum weight because all major components of the tripod end supports contribute directly to the lifting capability of the I-beam. All components are primary members in compressive load; none are in tension; none are secondary load members whose chief function would be to maintain the proper shape of the configuration.

The height of the tripod end supports can vary from 12 to 23 feet. The individual legs, constructed from steel tubing, can be telescoped and adjusted to meet sloping or other restricting conditions of the terrain. A spring-type pin is used to lock each leg at a selected height. Since three points determine a plane, the tripods are perfectly stable and exhibit no "rocking" characteristics of supports. (Each tripod end support can be used independently, with a lifting capacity of 2,000 pounds.)

A block and tackle arrangement was built into the head of each tripod. Suitable fittings are provided on the I-beam for attaching the block and tackle cable to the I-beam. With the ends of the I-beam directly under the tripod heads, the I-beam is pulled into position at the top of the tripods, at which points the I-beam engages spring-loaded hooks. These steps, as well as those of disengagement, are accomplished from the ground. A trolley with a removable lightweight chain hoist traverses the lower flange of the I-beam.

Securing the I-beam to the top of the tripods is semiautomatic in operation. The tripods can be collapsed so that they, together with the I-beam and other parts, may be fitted into a 15-foot-long container. This is done without disassembly of either the tripods or the built-in block and tackle system. This simplicity, combined with the use of fully tested minor components (such as spring-loaded leg adjusting bolts), assures a minimum of maintenance.

TEST PROCEDURES AND RESULTS

(Extracted from engineering report prepared by the contractor)

The test to determine time to assemble the complete unit was conducted on a cold day in midwinter, using two average-size young men. One man, weighing 145 pounds, had some previous experience with the equipment, while the second man, weighing about 165 pounds, had never seen the equipment before the test. The entire assembly and disassembly sequence was filmed, and the films were turned over to USATRECOM. This test was conducted in the following manner:

The equipment was loaded on the truck, assembled as it would be found in a military container except that the end fittings were left on the I-beam. The truck was then driven to slightly sloping ground, and the components were unloaded and assembled with the following results:

Tripod No. 1, complete with I-beam hoisting gear, was carried to its preselected position, placed in an upright position, and the legs extended until it stood approximately 23 feet high. Time: 6 minutes. Tripod No. 2 was placed in a preselected position about 15 feet from tripod No. 1 and erected in the same amount of time.

Next, the I-beam, with hoist attached, was placed properly with respect to the two tripods, pulled aloft with the block and tackle, and locked in position at the top of the tripods. Time: 9 minutes. Thus, total time, using two men, was 21 minutes. (Time can be reduced if the two men are experienced.)

Disassembly time in each instance was about 25 percent less than assembly time, or a total of about 15 minutes.

All test loads were measured with a calibrated gage, and the 100-percent overload requirements were met without exceeding the yield point in any instance. Thus, the unit completed the tests without damage of any kind.

Load-bearing qualities of normal soil, clay, sand, and mud, with full load and with 100-percent overload gave the following results: These results assumed the worst condition; i. e., the entire overload was concentrated at one end of the gantry. Photos were made of tests in sand, because this is a most critical condition and is most easily duplicated in different areas of the world. Normal soil, clay, and mud are subject to variations resulting from water content, extent of compacting, etc., which are not readily duplicated. However, the following table will give a very good idea of results to be expected under all conditions. The loads refer to total tripod loads, of which each leg is bearing only one-third the total weight. The 49-square-inch steel plates are 1/8 inch thick.

TABLE 2
SOIL DEFLECTION OF MUD PLATES

Type Ground	Load per Tripod (Lb.)	Sinkage in Ground (In.)	
		49-Sq. In. Mud Plate	225 Sq. In. Mud Plate
Clay	1,000	None	None
	2,000	1/4	None
	4,000	1/2	None

TABLE 2 (Cont'd)
SOIL DEFLECTION OF MUD PLATES

Type Ground	Load per Tripod (Lb.)	Sinkage in Ground (In.)	
		49-Sq. In. Mud Plate	225-Sq. In. Mud Plate
Soil	1,000	1/4	None
	2,000	1/2	None
	4,000	1	1/4
Sand	1,000	1	1/4
	2,000	3	1/2
	4,000	Excessive	1
Mud	1,000	1-1/2	3/8
	2,000	4	3/4
	4,000	Excessive	1-1/2

Two facts in Table 2 stand out. First, the 49-square-inch plate offers too limited an application. On firm ground, it is probably practical to use the tripods with no base at all. Second, it is absolutely necessary to lash the legs at the base to prevent slip and the resultant digging-in of the base plates into sand or mud.

Because the tests showed conclusively the importance of lashing the legs on soft ground and because a block and tackle arrangement had been built into the tripod heads, eyebolts were included to secure the block and tackle rope to the bottom of the legs for lashing.

Tests were made of the I-beam capacity at the center-span location, the critical point. Without a "cap", the standard 8-inch-deep 6061T6 aluminum alloy I-beam rotated on its longitudinal axis with less than a 2,800-pound load. With a 10-foot length of standard 4-inch-deep aluminum alloy (6061T6) channel bolted to the top of the I-beam, there was no evidence of rotation and resultant I-beam unloading. The basic theory behind this is, of course, based on the fact that on a relatively long I-beam, loaded at the center, the upper portion of the I-beam is in compression and relatively unstable, compared to the lower portion which is relatively stable, being loaded in tension. At a critical load condition, the upper portion of the I-beam yields in compression, sidewise displacement takes place, and the I-beam rotates to be further relieved of the load. All this can take place before the individual fibers of the I-beam exceed their yield points. The "cap", by greatly stiffening the upper compressive portion of the I-beam,

restores a balance of strength between the lower fibers in tension and the upper fibers in compression. The result is maximum use of the I-beam. Thus, with the "cap", the I-beam, which had previously failed at under 2,800 pounds, was able to support a load of 4,100 pounds, at which load, sag of the I-beam at the center point was 1-1/2 inches, though the yield point had not yet been reached. Displacement of the I-beam was proportional to the load; thus, sag at the rated capacity of 2,000 pounds was 3/4 inch, an acceptable figure.

In turn, the tripods were also loaded to 4,000 pounds, representing the situation that would exist if the load were concentrated at one end. From previous experience with the detail components, notably the load bolt and leg end fittings together with the tripod head, it was known that these would not fail with the modest loads required. Tests were therefore confined to determining load-absorbing ability of the legs. It was found that with essentially uniform loading on all legs, displacement was 1 inch from the longitudinal axis at 2,000-pound loading and 3 inches from the longitudinal axis at 4,000-pound loading. The tripods were not loaded beyond this point, and none of the tubing fibers were loaded beyond their yield points, since in all cases the material returned to normal. It should be noted here that, in the interest of easier erection by two men, the upper portion of the leg is approximately 14 feet long and the lower portion is approximately 12 feet long. These lengths were used to bring the load bolts an important 1 foot closer to the ground so that erection could be made by men less than six feet tall. Stress calculations on these legs are difficult to determine. Though the legs are pinned at the top and pivoted at the bottom, the presence of holes throughout the length of the lower portion of the leg assembly makes it impractical to calculate. This is shown by the fact that, though the upper portion uses 2-3/4-inch tubing with a .049 wall, the lower portion failed to meet requirements with a 2-1/2-inch tube using an .083 wall. It was necessary to use a .120 wall to carry the load.

Here it should be noted that these tubes fail as a function of shear rather than a function of compression. Thus, they are governed by the modulus of rigidity rather than the modulus of elasticity. This modulus would normally favor aluminum alloys to a slight degree.

The following illustrations show the results of a 100-percent overload on a single tripod end support, a 100-percent overload applied at the middle of the 15-foot aluminum alloy I-beam, a 100-percent overload applied to a single tripod in which the steel lower leg has been replaced by an aluminum alloy lower leg, and finally a series of illustrations showing soil test loads.



Figure 2. Photo shows the tripod fully extended, with the steel lower portion replaced with an aluminum alloy tube of .120 wall and made of 6061T6 alloy. The load is approximately 3,700 pounds, 4,000 pounds being a full 100-percent overload.

There is considerable bowing in the legs at this loading, indicating that it could not satisfactorily take the required 100-percent overload.



Figure 3. Photo shows the tripod fully extended, using steel on both upper and lower legs. The tubes have almost undetectable bowing at the full 100-percent overload of 4,000 pounds.

With steel lower tubes, replacing the aluminum alloy of Figure 2, the weight has been increased by 40 pounds per tripod.



Figure 4. Photo shows a close-up of the gage while the tripod shown in Figure 3 was under test.

The reading is just under 4,000 pounds.



Figure 5. Photo shows the complete tripod gantry in place under a full 100-percent overload of 4,000 pounds.

The load is at the center of the I-beam, with the result that the two tripod end supports are being subjected to only 2,000 pounds each.

This view shows the I-beam cap, which, with the addition of 16 pounds, has increased the I-beam capacity from 2,700 pounds to over 4,000 pounds.

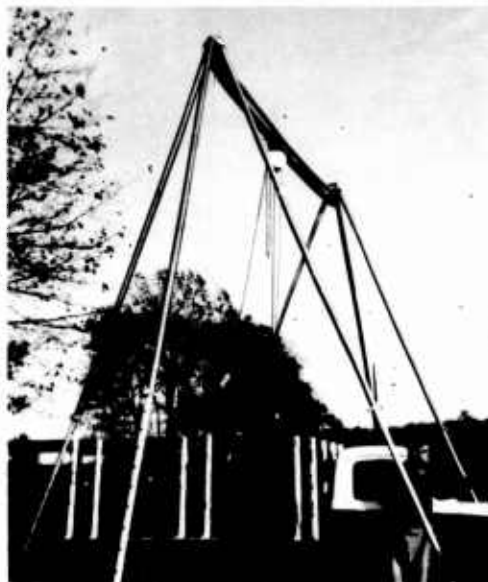


Figure 6. Photo shows the tripod gantry without the cap on the I-beam.

Though being subjected to a load of only 2,700 pounds, the I-beam is sagging badly and is also being distorted laterally along its longitudinal axis and will, with the addition of about 100 pounds, "roll over" in such a way as to unload the compressive load from the upper portion of the I-beam. The cap prevents the I-beam from unloading by lateral distortion.



Figure 7. Photo shows the 7-inch square steel plate resting in dry sand and being subjected to 1/3 of the total tripod load of 500 pounds.



Figure 8. Photo shows the 7-inch square steel plate resting in dry sand and being subjected to $\frac{1}{3}$ of a total tripod load of 1,000 pounds.

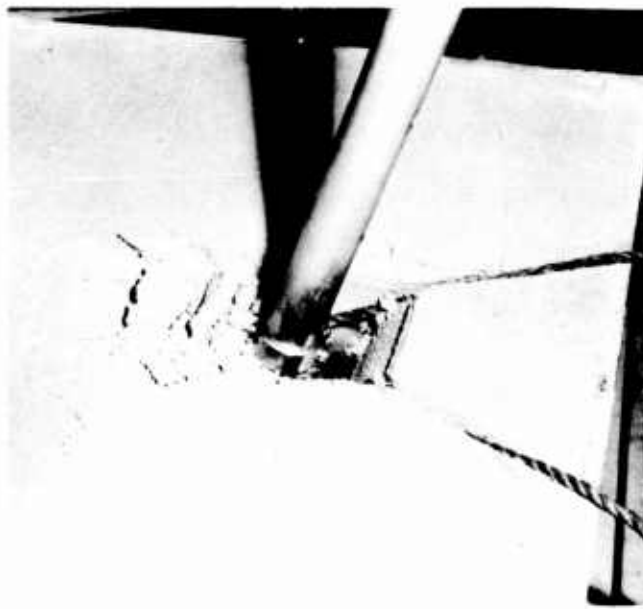


Figure 9. Photo shows 7-inch square steel plate resting in dry sand and being subjected to $\frac{1}{3}$ of a total tripod load of 2,000 pounds.



Figure 10. Photo shows 15-inch square steel plate resting in dry sand and being subjected to $1/3$ of a total tripod load of 1,000 pounds.



Figure 11. Photo shows 15-inch square steel plate resting in dry sand and being subjected to $1/3$ of a total tripod load of 2,000 pounds.



Figure 12. Photo shows 15-inch square steel plate resting in dry sand and being subjected to 1/3 of a total tripod load of 4,000 pounds.

EVALUATION

Only one significant problem was encountered during the design and development of the model 2008 tripod gantry. During the preliminary erection and load tests, the I-beam monorail rotated along its longitudinal axis when a load of 2,700 pounds was applied to the chain hoist. The difficulty resulted from a requirement for a 15-foot monorail span. The contractor successfully solved the problem by bolting a 10-foot length of standard 4-inch-deep aluminum alloy channel to the top of the monorail. This "cap" stiffened the upper compressive portion of the I-beam, restoring a balance of strength between the lower fibers in tension and the upper fibers in compression, which resulted in maximum use of the I-beam.

To prevent the trolley from rolling on the I-beam, the contractor recommends that the trolley for the hoist be equipped with a suitable brake. The resulting weight increase would be approximately two pounds. The contractor also recommends that the I-beam be furnished with fitting assemblies with quick-release pins, rather than the nuts and bolts now in use. This would permit the end assemblies to be removed (in order to meet the overall length requirement of 15 feet for the I-beam proper) as complete units in less than one minute. However, it was determined that

the added weight and expense that would result from incorporating these two ideas could not be justified during the development of the model 2008 tripod gantry.

An analysis of the results of the contractor's engineering tests showed that the tripod gantry fulfilled the technical characteristics with the exception of the overall desired weight limitation of 400 pounds for the complete unit. (The 400-pound total weight limitation specified in the technical characteristics was based on the weight of the off-the-shelf gantry hoist that was used in comparison tests with an earlier model.) Although the completed gantry weighed 646 pounds, the contractor has stated that a weight reduction of approximately 200 pounds could be realized by replacing the steel legs and mud plates with aluminum, and the aluminum I-beam with magnesium. Table 3 shows the weight reductions (per gantry) that the contractor believes could be effected.

TABLE 3
WEIGHT REDUCTION POSSIBLE BY USING ALUMINUM AND MAGNESIUM

Item	Weight Reduction	
	Aluminum	Magnesium
Replace steel upper leg with .083 wall	50 lb.	70 lb.
Replace steel lower leg with .200 wall	97 lb.	136 lb.
Replace aluminum alloy I-beam and channels	-	40 lb.
Replace 15-inch square mud plates	30 lb.	36 lb.

The tripod legs that were standard with the first off-the-shelf gantry were strengthened by increasing the wall thickness of the tubing members of the legs. It was determined that substituting 6061ST aluminum alloy for steel in the fabrication of the tripod legs would be preferable to redesigning the steel tripod legs to counteract the increased weight. However, since aluminum was not specified prior to the award of the fixed-price contract, the steel legs were used. Holding design changes to a minimum permitted construction of an economical gantry--approximately \$1,000 per gantry, including hoists. According to the contractor, the substitution of aluminum for steel would increase the cost 75 cents for every pound saved. Also, if magnesium were used in the I-beam instead of aluminum, approximately \$1.25 to \$1.50 would be added for each pound saved.

The contractor believes that if 7- and 15-inch square mud plates of 24ST4 aluminum alloy, weighing less than one-half of the steel plates, had been used in testing the support capability of the plates during soil and sand

tests, the same results would have been obtained. An added advantage of using aluminum for the plates would be that aluminum is less subject to corrosion than steel.

An evaluation of the developed gantry, however, indicated that the excess weight does not greatly affect the overall efficiency and usage of this item. The gantry can be erected easily by two men having little or no experience with the unit; therefore, the overall weight becomes secondary to its weight-lifting capability of 2,000 pounds plus 100-percent overload.

There is a need in the field for a portable hoist that can be used for maintenance operations, not only by the Transportation Corps as an aircraft recovery unit, but by other technical services. It is evident that the tripod gantry (the tripods can also be used independently as hoists) is a universal-type piece of support equipment that is suitable not only as a piece of aircraft recovery support equipment but as a TOE support item for Army-wide use.

DISPOSITION FORM

SECURITY CLASSIFICATION (If any)

C
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YFILE NO. 9-38-01-000
TCREC-CO-OTD 12.103SUBJECT House Task 12.103, Project 9-38-01-000, Study and
Evaluation of Portable Aircraft Maintenance Hoisting
Equipment

TO Ch/Army Avn Div

FROM CO, USA TRECOM

DATE 8 Aug 58

COMMENT NO. 1

Mr Pierce/6275/ss

1. The following house task is assigned to your division for prosecution:

a. Title: Study and Evaluation of Portable Aircraft Maintenance Hoisting
Equipment.

b. Task Nr.: 12.103

c. Project Nr.: 9-38-01-000

d. Date of assignment: 8 August 1958

e. Target date for completion: 1 November 1958

f. Scope:

(1) To study, investigate and evaluate all portable hoisting equipment
currently being used in echelon maintenance.(2) To prepare a staff study report for submittal to the Chief of
Transportation and TSMC, with copy to OTD.g. Remarks: Requirements for this house task have arisen from verbal re-
quests by Fort Rucker maintenance personnel and from representatives of TSMC.
Consideration will be given to future establishment of project card to prosecute the
development of any items for which a requirement is determined.

h. Reference: None

2. This task does not constitute authority to procure or to initiate contracts.

3. Fiscal Cost Code for this task will be 5030X1203.

/s/ Vancel R. Beck
VANCEL R. BECK, Colonel, TC
Commanding

APPENDIX II
TECHNICAL CHARACTERISTICS

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1. General

- a. Shall consist of a tripod gantry assembly, including the hardware necessary to erect and operate the unit.
- b. Shall include a hoist trolley.
- c. Shall include two (2) sets of ground-bearing pads: one set standard and one set capable of supporting the unit on ground-bearing loads not to exceed 4 p.s.i. under the maximum design load.
- d. Shall be capable of lifting 2,000 pounds throughout its entire range of operation with a safety factor of 2:1.
- e. When erected, shall have a maximum vertical clearance of 20 feet to the underside of the monorail.
- f. When erected, shall have a minimum vertical clearance of 13 feet to the underside of the monorail.
- g. Shall have a total monorail span of 15 feet.
- h. The unit shall be capable of being erected and operated by two men.
- i. All locking devices shall be easy to operate and provide a positive lock.
- j. No component shall exceed 15 ft. 4 in. in length when disassembled.
- k. Weight of the assembled unit, complete with the associated hardware, shall not exceed 400 pounds.

2. Logistics

- a. The units shall be constructed of readily available, nonstrategic and noncritical material.
- b. The units shall be designed for ease of maintenance and shall not require any special tools for maintenance and/or operation.

DISTRIBUTION

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