Del Mar Engineering Laboratories

AERONAUTICAL PROJECTS

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D.E.L. REPORT NO. 547

THE DEL MAR RADOP TARGET SYSTEM

MODEL DF-4

26 March, 1955

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I. Introduction

The Del Mar Radop (radar-optical) Target System has been developed to meet the needs of various military installations for training pilots in the use of automatic fire control systems and to generally facilitate the evaluation of rocket and missile weapons systems under realistic combat conditions.

The Radop Target System provides a low cost target having: (a) the radar reflectivity of a contemporary bomber, (b) extremely low drag at high speeds and high altitudes, and (c) a physical size adequate to allow accurate radar-optical assessment of rocket or missile firings.

The Del Mar Radop System includes a wind driven reel, 10,000 feet of tow line, a receptacle installation to permit air launch and recovery of the target, the target itself, and the necessary controls in the cockpit.

When scoring assessment is desired, the D-100 Radar Optical Scoring Device, as described separately in Report D.E.L. 546, may be attached either to the interceptor aircraft or to a chase aircraft flying on the wing of the interceptor.

II. Operation

The Radop Target System permits air launching and recovery of a fin stabilized target from a wing tip or an underwing installation of a high performance aircraft. Minor field-type adjustments will allow the system to be installed on practically all contemporary fighter and bomber class aircraft. The target itself, D.E.L. Model DF-4, has been flown repeatedly on the T-33 aircraft, in addition to many experimental flights on the companys own aircraft, a Cessna 180.

The system functions in the following manner. Prior to flight, the Radop target is attached to the tow line at a swivel provided in the nose of the target. The target is then placed in a receptacle as shown in Figure 15 and the slack in the tow line between the target and reel is removed by hand turning the reel. As the tow line is tightened, the launcher spring on the target centering probe is compressed and the target is pulled against a snubbing ring which restrains the target from moving during the time that it is in the receptacle. The reel brake is energized and the tow craft is ready for take off.

Upon reaching operating altitude the brake is released and the launcher spring ejects the target from its receptacle. The pilot then adjusts the reel control to allow the target to reel out at the proper speed. A footage indicator on the control panel in the cockpit shows cable length out directly in 10 foot increments and indicates cable speed by rate of change of cable out. Upon reaching the desired tow length the pilot reduces the reel-out speed by the control lever and applies the brake.

To reel in, the reel control is moved to the reel-in position and the brake released. As the target approaches the receptacle the reel-in speed is reduced by adjusting the control to a pre-set position and the target allowed to contact the target centering probe which centers the target in the receptacle.

Additional torque is then applied by increasing the pitch of the reel turbine and the target is pulled into the receptacle against the spring load of the centering probe. When the target is again snubbed, the brake is applied and the tow aircraft is ready to return to its base.

III. Components

The Radop Target System is composed of four major components; namely, the target, the target receptacle, the tow reel and the scorer. A description of each of these components together with a brief outline of their operation is given below:

A. The Radop Target - The Del Mar Radop Target, Model DF-4R, is the nucleus of the Radop Target System. This target is a fin stabilized body of revolution as shown in Figure 2. The target is a low drag configuration suitable for stable flight at high subsonic speeds. The equivalent flat plate area (f) of the target is .125 square feet. This figure has been substantiated in actual flight tests. The basic drag of the target is shown in Figure 4 as a function of Mach No. and altitude.

The DF-4R Radop Target is stabilized in pitch and yaw by four identical fins. Fin tabs are used to rotate the target so that minor mass and/or aerodynamic misalignments as might result from a firing hit or ground handling will not cause random variations in the target's flight path. The target has been designed to rotate at a speed of between 2 and 4 RPS, depending on airspeed, in order to improve the radar reflectivity of the target as well as to improve its flight characteristics. In addition, the rotation of the target provides a means of identifying the target by an audio discriminator and thereby distinguishing it from the tow plane or other aircraft in a positive manner.

The DF-4R Radop Target is a light weight, durable target fabricated from plastic coated cellular polystyrene. The weight of the target is approximately 15 pounds; the overall length is 96 inches and the maximum diameter of the body is 18 inches; the fin spread from tip to tip is 26½ inches. Radar reflectivity is provided by an aluminum coated paper backed corner reflector. Each target is equipped with a swivel to allow the target to rotate freely without twisting the cable during flight. The swivel is an integral part of the target and requires no lubrication.

The DF-4R Radop Target is the latest of a series of targets which have been designed and developed by the Del Mar Engineering Laboratories. It is similar to the DF-3 series except for the manner of fabrication and the durability of the target. The DF-3 series target is, likewise, an outgrowth of the DF-2 and the DF-1 targets, and differs primarily in the size and radar reflectivity of the target.

B. The Del Mar Target Receptacle - The Del Mar Target Receptacle is a device which is attached to the aircraft for the purpose of launching and recovering the target in flight. The receptacle includes a target centering probe and a snubbing ring. The receptacle housing is designed to hold the target firmly when it is in the receptacle. The target centering probe consists of a spring loaded mechanism which is compressed by the tension in the tow line as the target is drawn into the launcher and which forcefully launches the target when the tow line tension is removed. The primary function of the centering probe is to center the target in the receptacle during reel-in and reel-out operations. The snubbing ring consists of a rubber faced ring, mounted on the housing, against which the Radop target is drawn when the target is lodged in the housing. The function of the snubbing ring is to prevent the target from rotating while it is in the receptacle and causing damage to the target or vibration feed back into the aircraft.

The target receptacle has been specifically designed for use with contemporary fighter or jet trainer aircraft. The equivalent flat plate area of the receptacle is estimated to be on the order of .1 square feet. Flight tests of a T-33 aircraft with the receptacle (as well as the target) have shown that the mechanism is suitable for high speed flight and does not produce flutter or vibration at the wing tips. These flight tests have also shown the suitability of mounting the Radop system to the wing tips of the T-33 aircraft. A prototype of the target receptacle mounted on the tip tank of a T-33 aircraft is shown in Figure 16.

C. The Tow Reel - The Del Mar Model DF-4 Tow Reel like the DF-4 Tow Target is the product of a development program. The DF-2 Reel shown in Figure 17 is the immediate predecessor to the DF-4 and was itself an application of the Del Mar DX-2 Reel which is a high-performance universal reel for towing rigid wing and banner type targets.

The DF-4 Reel is suitable for installation on Jato racks or underwing bomb shackles and may, therefore, be used on any aircraft which is equipped with these items.

Reel operating power is derived from the air stream through a 10 inch diameter, variable pitch four-bladed propeller which provides a large variation in reel operating speed and precise control within this operating range. The pitch control mechanism includes a control potentiometer installed in the cockpit which is marked in terms of pitch angle. The control voltage from this potentiometer is compared to that from a feed-back potentiometer coupled to the turbine blades in a sensitive polarized relay. When an error exists between the control voltage and the feed-back voltage, the polarized relay senses the direction of unbalance and applies power to a small electric motor which drives the blades in a direction so as to reduce the error voltage and rebalance the system. A small region exists at balance where the error voltage is insufficient to close either contact of the sensitive relay; but this region is so small that its effect on reel performance may be disregarded. This dead spot is, however, large enough so that the pitch-change motor, which is dynamically braked, will come to a stop before

IV. Performance

The performance of an aircraft with the Radop Target System installed is a function of the net available thrust of the towing aircraft, the drag of the basic Radop Target, and the length, diameter and smoothness of the tow cable. The drag coefficient and the drag of the Radop Target are shown in Figure 4 as a function of Mach No. and altitude. This figure shows that the drag of the target alone is less than 60 pounds for all flight speeds and altitudes operationally practical with contemporary aircraft. The tension in the tow cable at the tow plane (i.e. drag) when towing the DF-4R Radop Target with various lengths and diameters of cable is shown in Figures 5 through 8. These figures when compared with the figure showing the drag of the basic target indicate the magnitude of the drag of the tow cable.

The performance of a T-33 aircraft with a Radop system consisting of the target, 6000 feet of 3/64 inch diameter armor clad cable, the tow reel, and the target receptacle is shown in Figure 9. A plot of the performance of the basic aircraft is included in this figure to show the change in performance due to the addition of the Radop Target System. It can be seen from this figure that flight speeds corresponding to .75 Mach No. at an altitude of 30,000 and 35,000 feet are practical even with an aircraft of the trainer class. Furthermore, since the performance of most contemporary aircraft is limited by the sharp drag rise due to compressibility effects, it may be stated that an even smaller penalty on a percentage basis would be imposed if the tow aircraft were an F-89, F-94C or F-86D.

The radar reflectivity of the target has been determined from flight tests conducted at Yuma Air Force Base to be somewhere between the reflectivity of a B-45 and a B-29 bomber aircraft. During these tests radar contact was made at ranges to 20 miles and lock on and separation occured to ranges of 15 miles.

The optical size of the target as shown on a 16 mm. gun camera film taken from an interceptor aircraft at a range equal to that of rocket-target coincidence proves conclusively that scoring assessment from a Del Mar D-100 scoring device will be entirely adequate.

V. Applications

The Radop Target System has immediate application in various phases of the rocket firing training programs. Radop provides a suitable target for initial intercept missions wherein the aircrew is gaining proficiency in basic intercept problems. No firings are made during this period and the relative frangibility of the target as compared to an equivalent aircraft reduces the danger normally associated with mid-air collisions. With this psychological hazard removed, the aircrew will be better able to concentrate on other aspects of the intercept mission. Since the target is in tow only for that portion of the mission during which intercepts are being conducted (at altitudes above 25,000 feet) and is essentially a component of the tow aircraft during climb out and let down, no violation of existing safety air regulations is incurred even in dense air traffic areas. In those areas where firing is permitted at the squadron level, the Radop Target System, including the Scoring Device, finds prime application while still utilizing base aircraft as tow ships.

Normal fighter or trainer tow is not considered suitable for ranges where extensive firings are being conducted. In these cases, where range duration of the towing vehicle assumes greater import, a bomber class aircraft with a multiple target capability appears most suitable. After the target or the tow line has been hit, it is imperative that the tow craft be able to launch successive targets upon demand. The Del Mar Model DF-4S is particularly suited to this application. The DF-4S or Spider Radop Target is a variation of the basic target and is so named because the tow line is stowed internally. When launched, the tow line free spools to its full length. This target incorporates a pair of shackles 14 inches on center for attachment to a standard underwing bomb pylon. Launching is accomplished by energizing the bomb release circuit. Recovery is considered to be irrevelent for this operation since the launch of an additional target only occurs after the previous target has been lost.

Considering a B-57 as the tow plane in this application, six or even eight targets could be attached to the under wing shackles for a firing mission. A maximum of one target would be jettisoned on any mission. In considering the lower cost associated with such a system as compared to that requiring a tow reel for each target the benefit is immediately apparent.

VI. History and Development

The Del Mar Radop Target System and the Del Mar Frangible Target Systems which have preceeded it have been conceived, coordinated, designed and developed with many hours of flight testing through many models and versions to make available to the military an improved training target system at the earliest possible time at the lowest possible cost. Development of the Radop Target System was undertaken by the Del Mar Engineering Laboratories to meet the needs of various military installations for training pilots in the use of automatic fire control systems. This project was of particular interest because of the past experience of the company and its personnel in the field of tow targets and associated training equipment. Among the related products which are presently in production by Del Mar are, (a) a high speed, high performance DELta target suitable for use as a platform for miss distance evaluation, and (b) a high performance air driven tow reel, D.E.L. Model DX-2, with a capacity of 15,000 feet of 1/8 inch armor clad cable. The experience and knowledge accumulated in the development of these systems was used to great advantage in the development of the Radop Target System.

The first frangible target was flown in model form and, subsequently, led to the fabrication and flight testing of the DF-1. This target was a frangible, fin stabilized body of revolution with a maximum body diameter of 12 inches and an overall length of approximately 4 feet. Considerable knowledge concerning the target and target system requirements was obtained from this prototype. Development of the target system was continued with the fabrication of the DF-2 target. This target was a 15 inch diameter body of revolution stabilized by 3 fins which provided roll stability as well as pitch and yaw stability. One particular version of this target, the DF-2S (spider) target, was equipped with an internal spool and launched from a T-33 aircraft. A photograph of this target mounted on the Jato rack of the T-33 prior to flight testing is shown in Figure 10. Since operation of a Spider Target precluded the possibility of airborne recovery and because of the wider applications of recoverable targets, primary effort has since been placed upon the development of a target system incorporating a reel, a recoverable target, and an installation on the aircraft suitable for launching and recovering the target.

An electrically operated reel was assembled from existing standard components to facilitate full scale flight tests of the Radop targets. Installation of this reel was made in a company-operated Cessna 180, Figure 11. The purpose of this flight test program was to investigate various means of launching and recovering the target in flight. A similar installation was then made on a T-33 aircraft as shown in Figure 12 and additional flight tests were conducted.

With the introduction of the DF-3 target a new launching device was rigged on the Cessna and is shown in Figure 13. Figures 14, 15 and 16 show various installation details pertinent to the progress made in the development of the Del Mar Radop Target System on the T-33 aircraft.

Two electric motor driven reels were utilized during this portion of the development program and the operational experience gained from them was instrumental in directing effort toward an air turbine driven reel. The DF-2 reel shown in Figure 17 features a shuttling level wind mechanism and a variable pitch propellor. The DF-4 reel shown in Figure 3 incorporates these same design features and is generally an outgrowth of the experience gained through the entire Radop target development program.

VII. Conclusion

The Del Mar Radop Target System permits squadron level training in the use of automatic fire control systems with base fighter on trainer aircraft serving as tow vehicles.

In operation, the Radop System imposes very little compromise on the performance capabilities of the tow aircraft either in speed or altitude.

The system provides a low drag radar reflective frangible target suitable for air launch and recovery. When used in conjunction with the Del Mar D-100 Radar Optical Scoring Device, accurate assessment of rocket firing missions is possible.

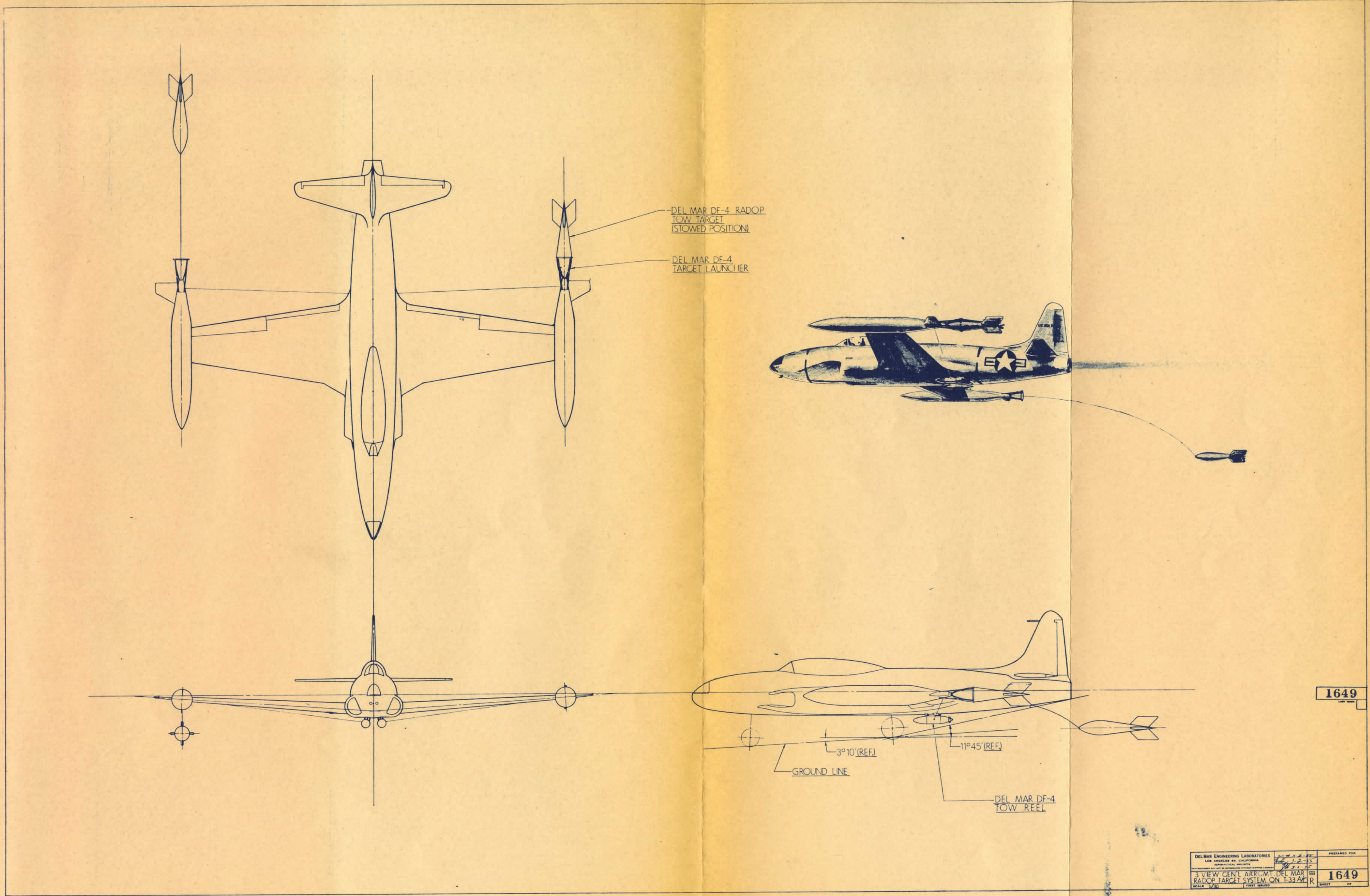


Fig. 1 Three View General Arrangement of Del Mar RADOP Target System on T-33 Aircraft.

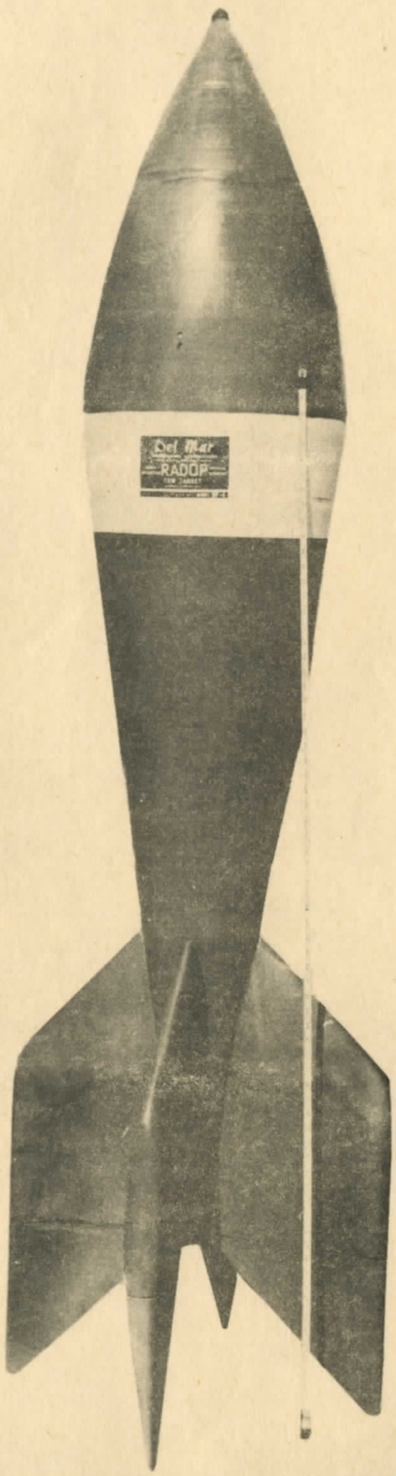


Fig. 2 Del Mar RADOP Tow Target.
Model DF-4

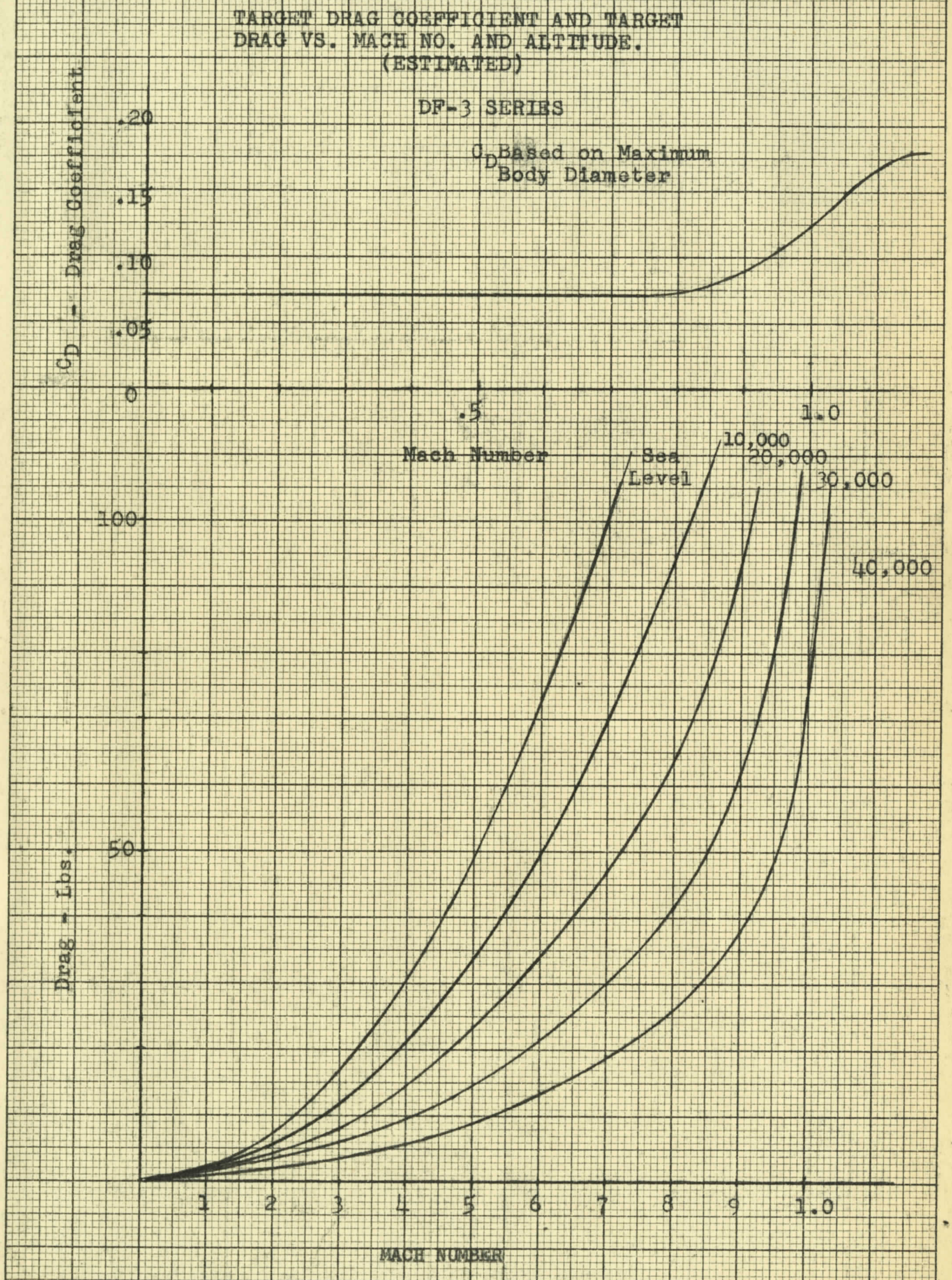

TARGET DRAG COEFFICIENT AND TARGET DRAG VS. MACH NO. AND ALTITUDE.
(ESTIMATED)
DF-3 SERIES
C_D Based on Maximum Body Diameter
C_D - Drag Coefficient
.20
.15
.10
.05
0
.5
1.0
Mach Number
Sea Level
10,000
20,000
30,000
40,000
100
50
Drag - Lbs.
1
2
3
4
5
6
7
8
9
1.0
MACH NUMBER

Figure 4

TENSION IN CABLE AT TOW PLANE WHEN TOWING DF-4R TARGET WITH 3/64 INCH DIAMETER ARMORED CLAD CABLE VS. AIR SPEED

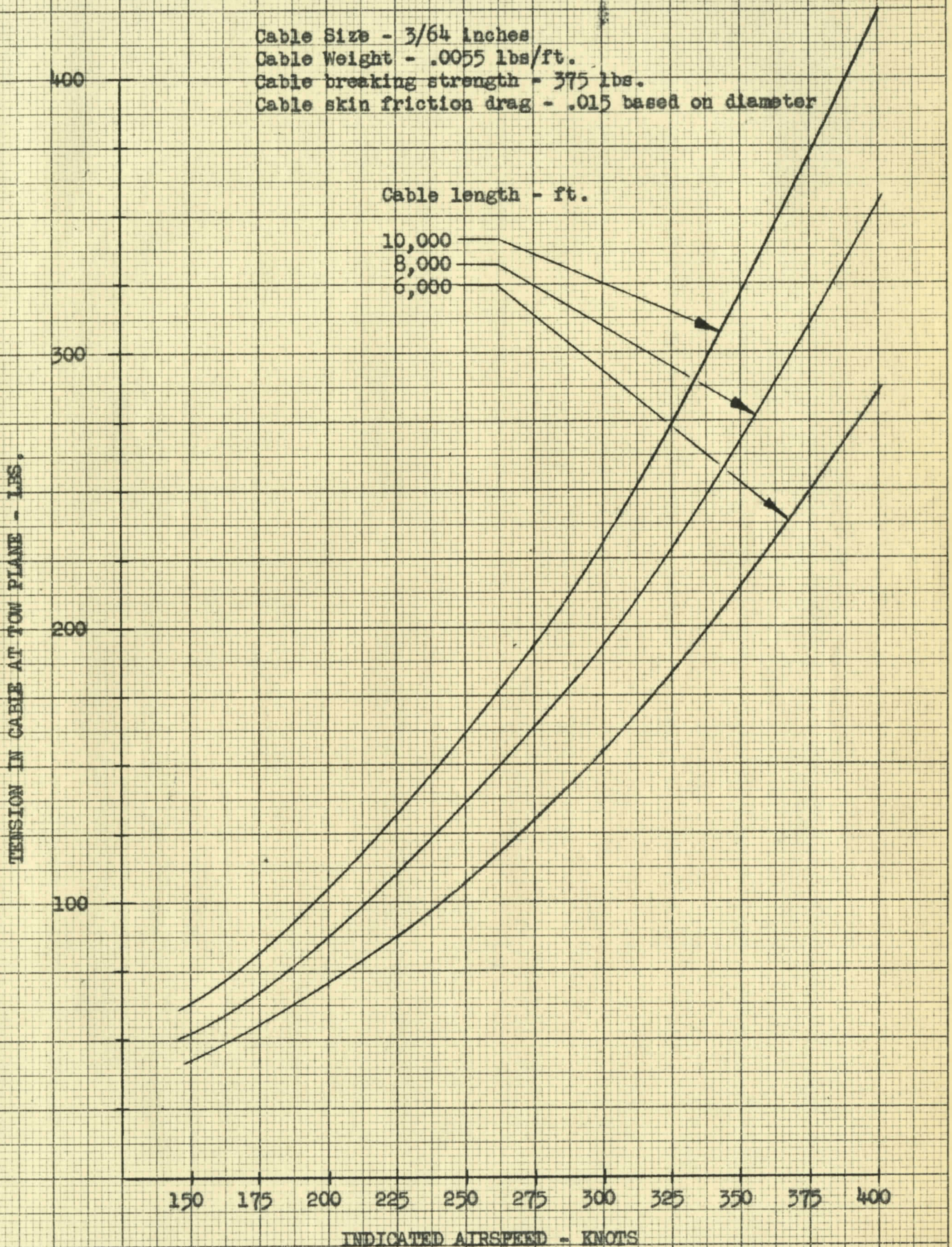


Figure 5

TENSION IN CABLE AT TOW PLANE WHEN TOWING DF-4R TARGET WITH .030 INCH DIAMETER PIANO WIRE VS. AIR SPEED

Cable size - .030 inch
Cable weight - .00243 lbs/ft.
Cable breaking strength - 220 lbs.
Cable skin friction drag - .014 based on diameter

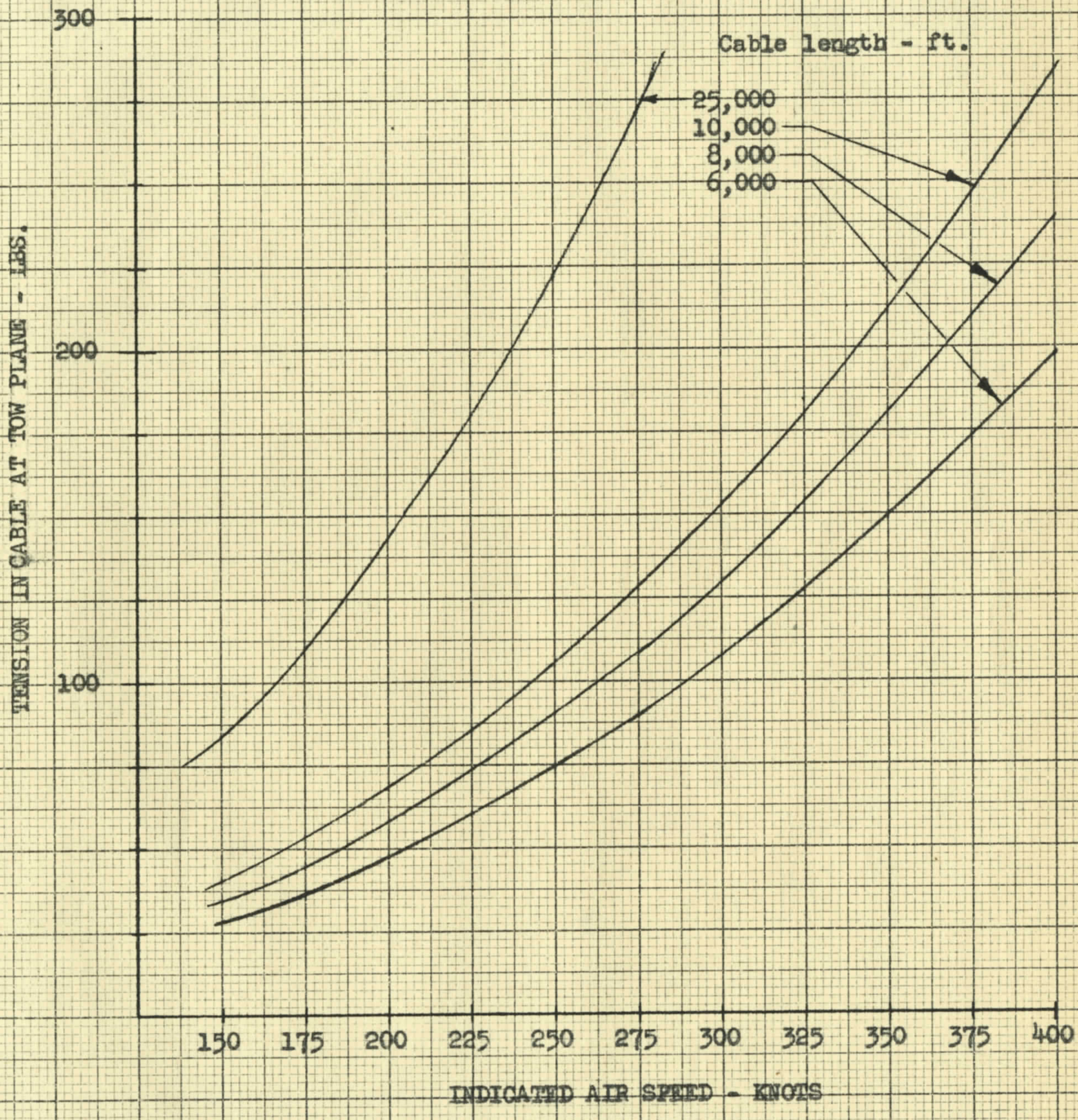


Figure 6

TENSION IN CABLE AT TOW PLANE WHEN TOWING DF-4R TARGET WITH .060 INCH DIAMETER NYLON MONOFILAMENT CABLE VS. AIR SPEED

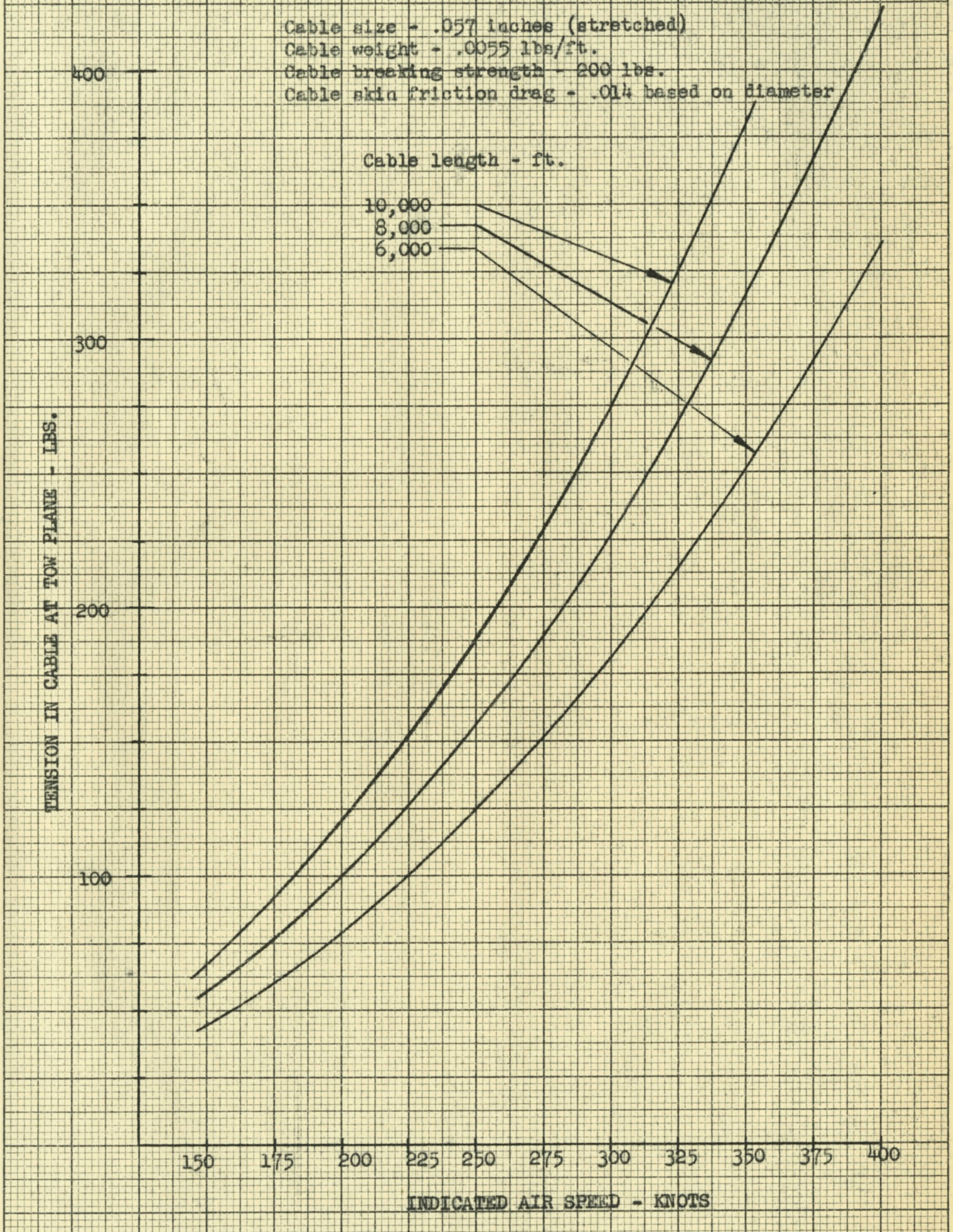


Figure 7

TENSION IN CABLE AT TOW PLANE WHEN TOWING DF-4R TARGET WITH 25,000 FT. OF .030 INCH DIAMETER PIANO WIRE VS. MACH NO.

Cable size - .030 inches
Cable length - 25,000 ft.
Cable weight - .00243 lbs/ft.
Cable breaking strength - 220 lbs.
Cable skin friction drag - .014 based on diameter

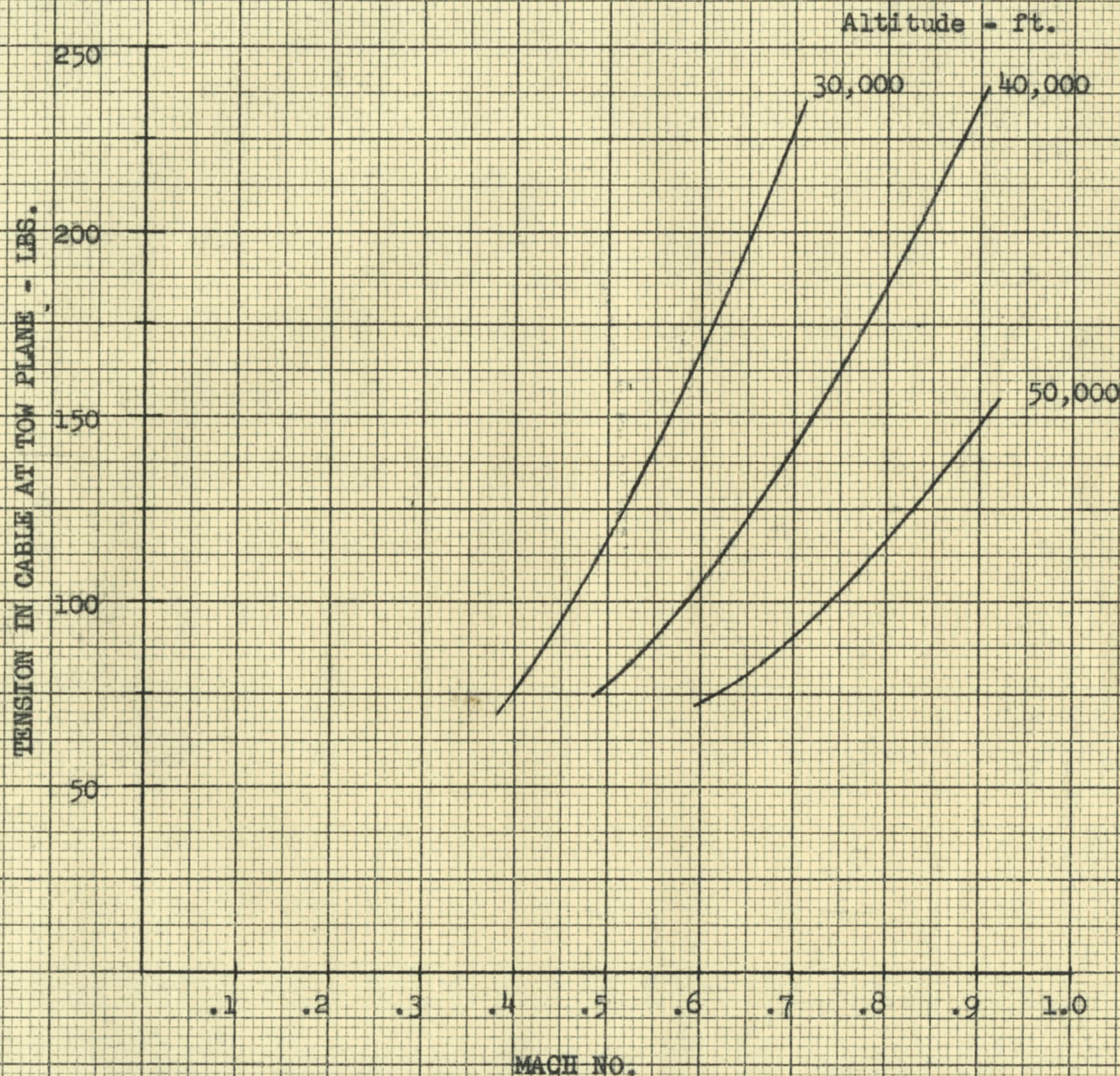


Figure 8

PERFORMANCE OF T-33 AIRCRAFT WITH DF-4 RADOP SYSTEM
AS A FUNCTION OF MACH NO.

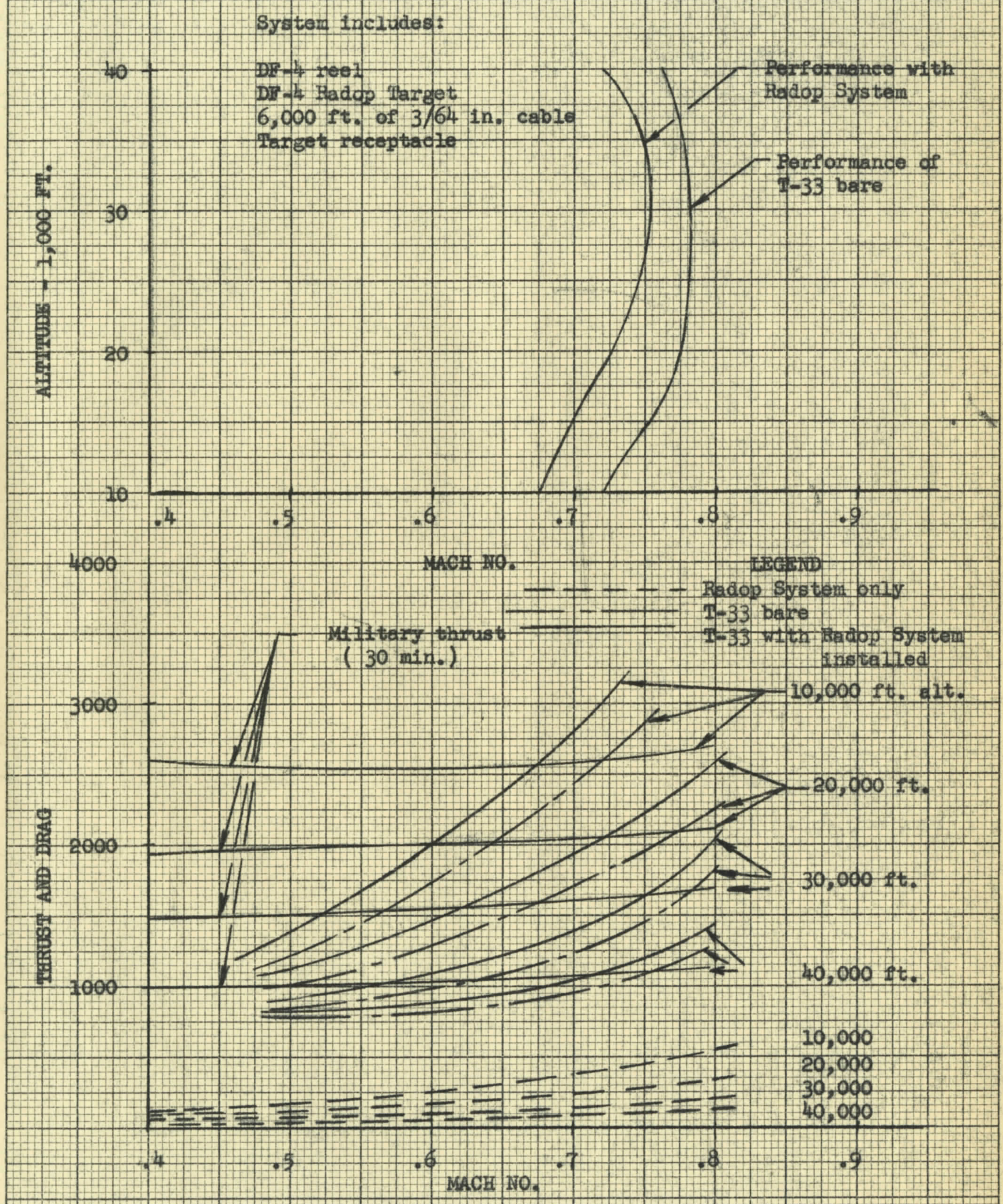


Figure 9

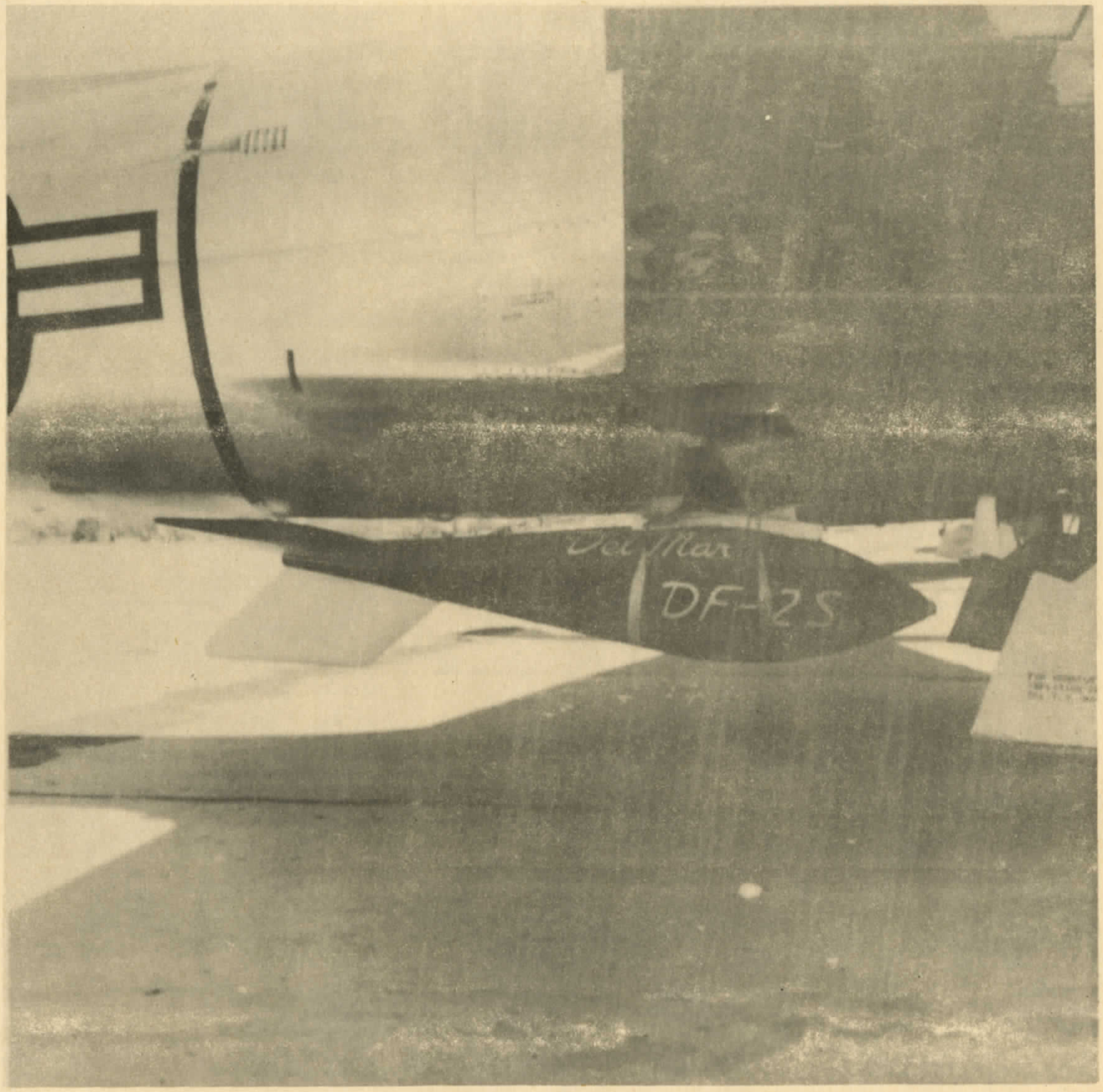


Fig. 10 Del Mar DF-2S (Spider) Target Mounted on Jato Rack of T-33 Aircraft.

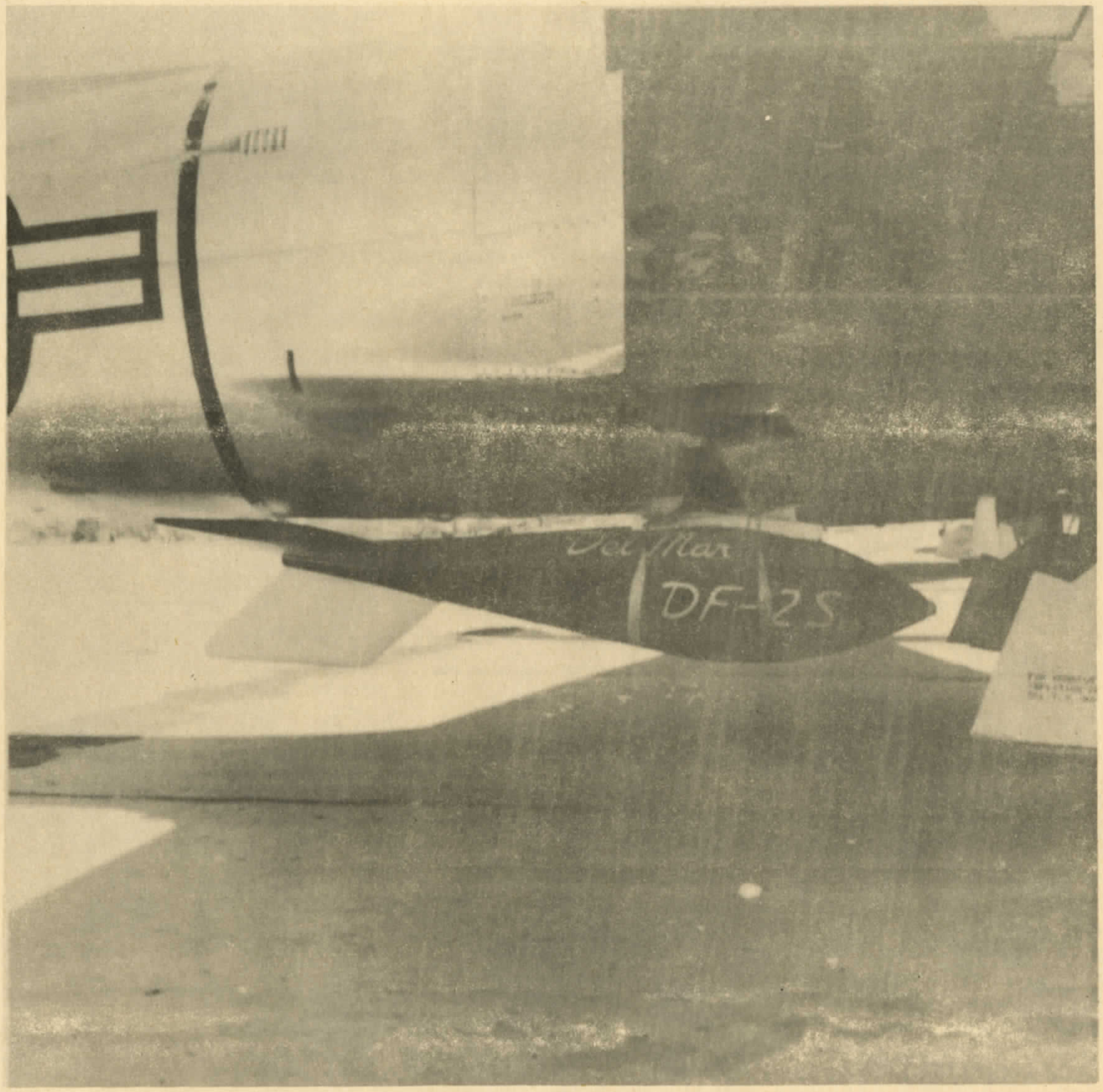


Fig. 10 Del Mar DF-2S (Spider) Target Mounted on Jato Rack of T-33 Aircraft.

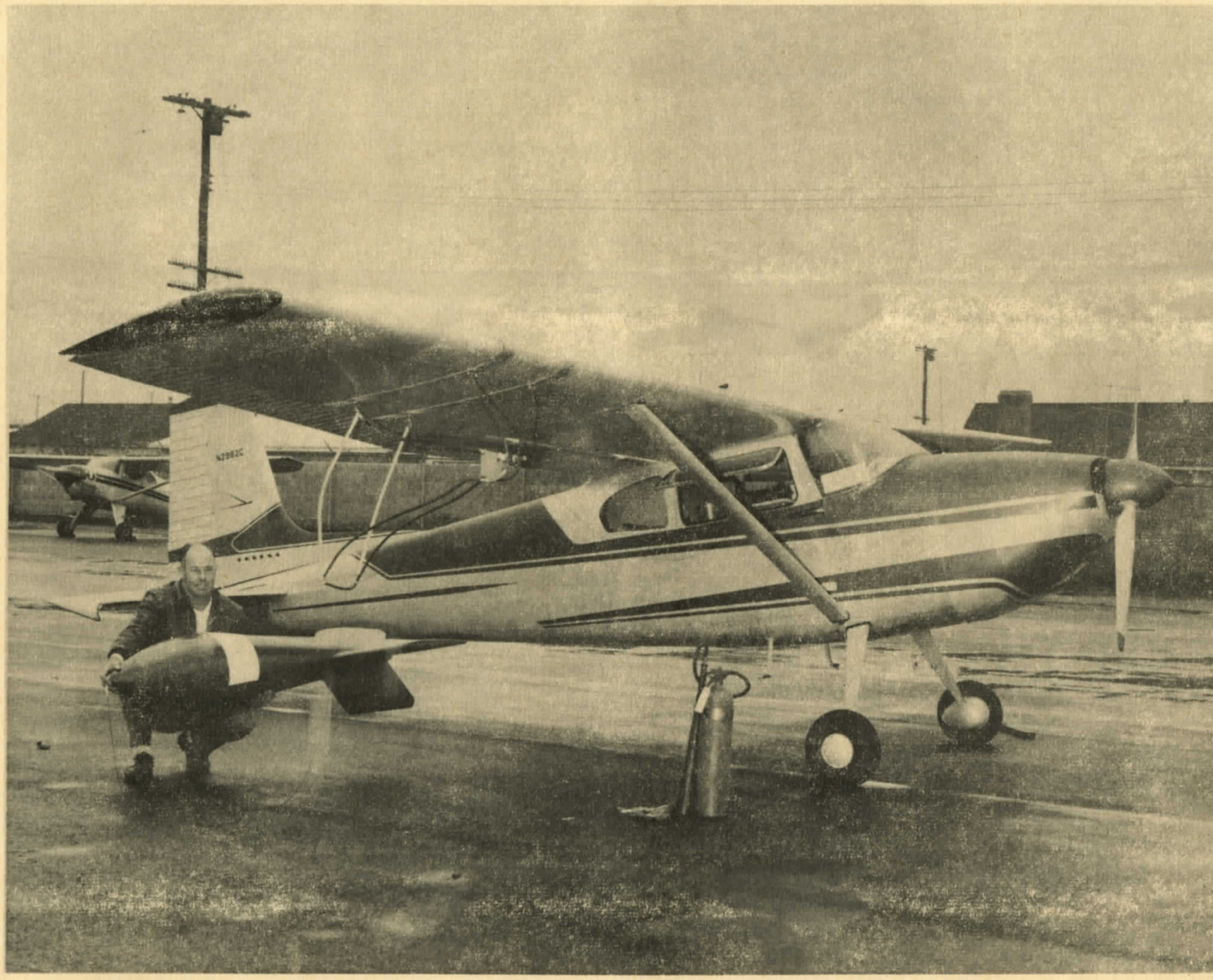


Fig. 11 Del Mar DF-2 Target and Launcher Mounted on Cessna.

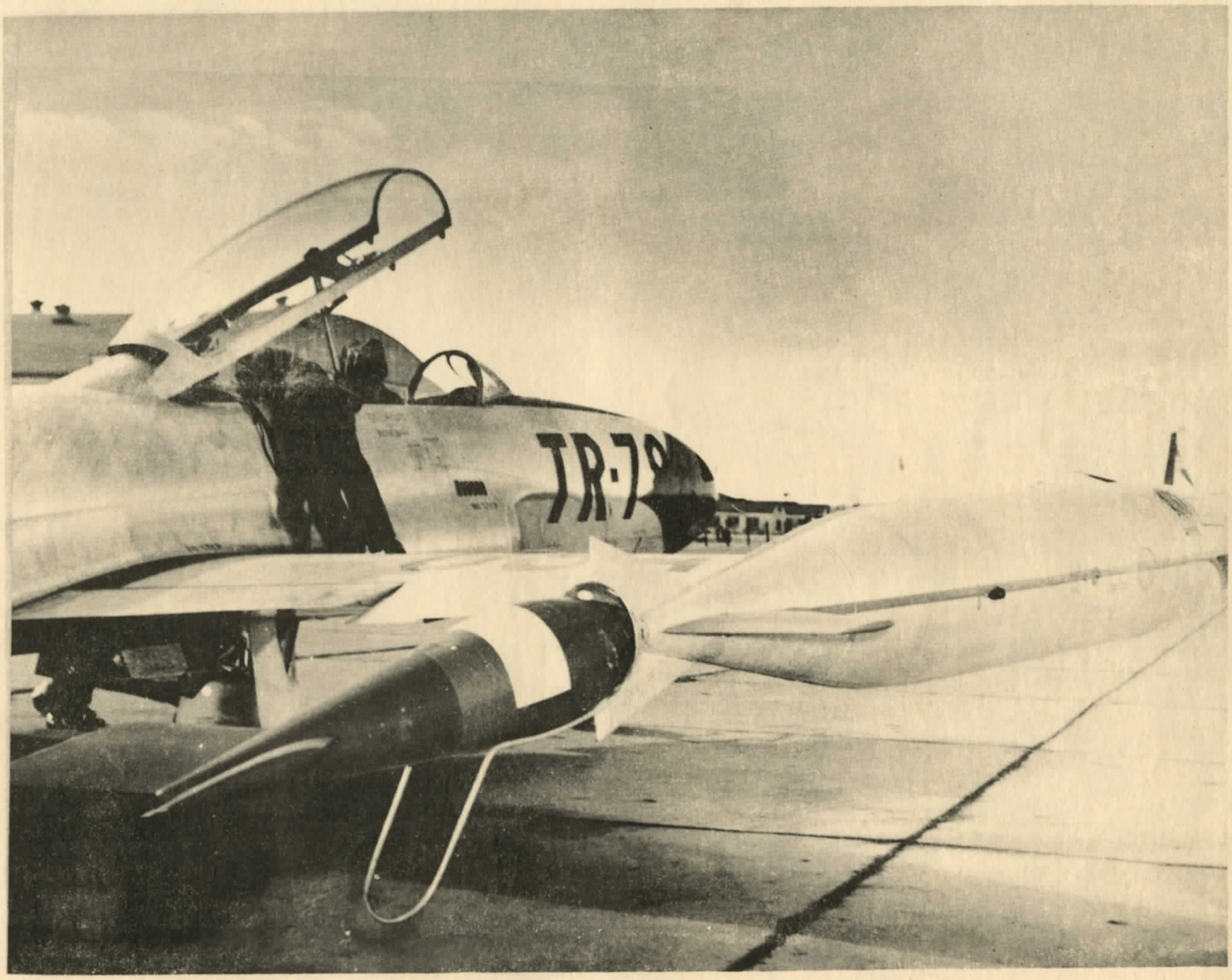


Fig. 12 Del Mar DF-2 Target and Launcher Mounted on Tip Tank of T-33 Aircraft.

Fig. 13 Del Mar DF-3R Target and Receptacle Mounted on Cessna Aircraft.

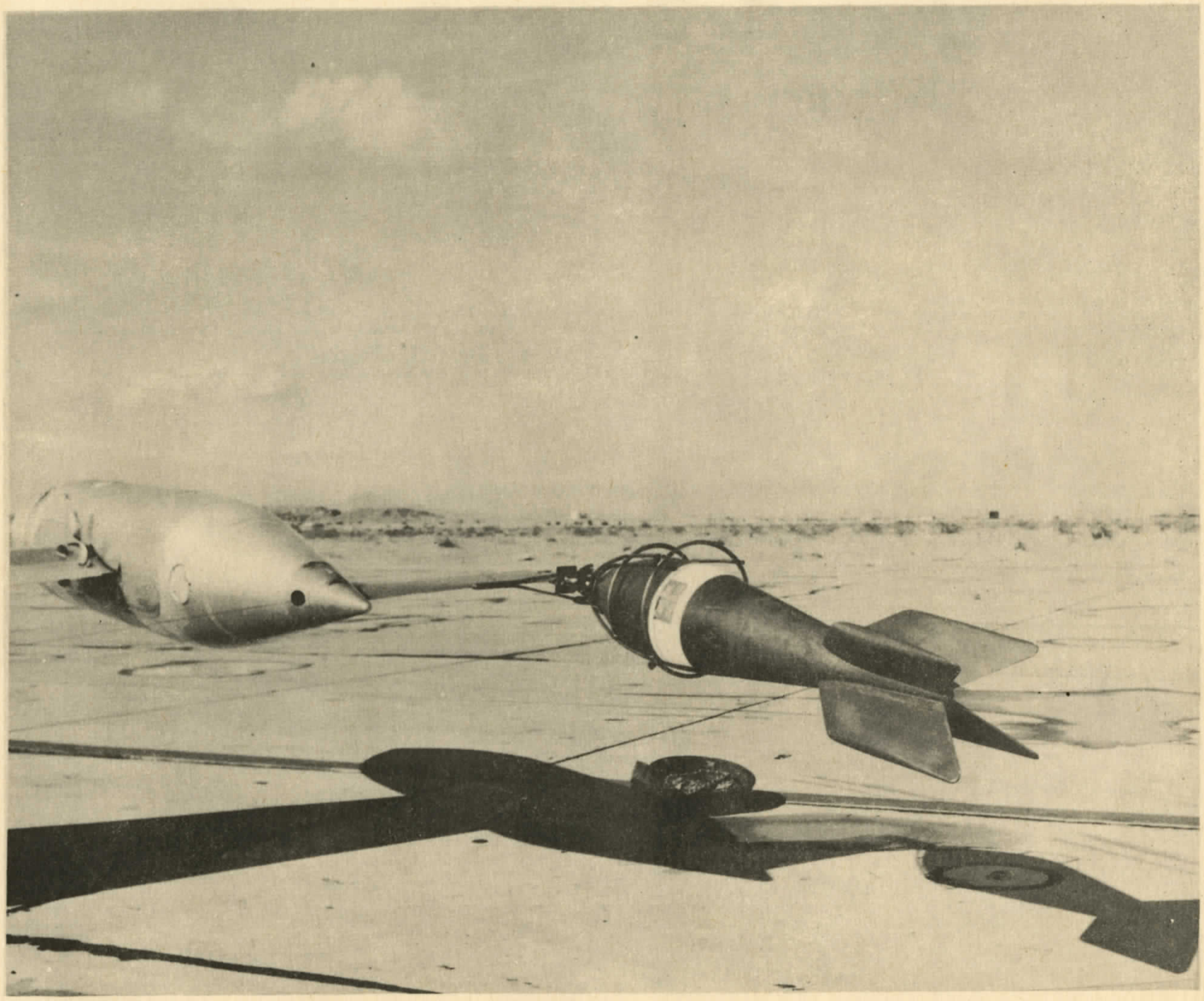


Fig. 14 Del Mar DF-2R Target and Receptacle Mounted on Tip Tank Stabilizer Fin of T-33 Aircraft.

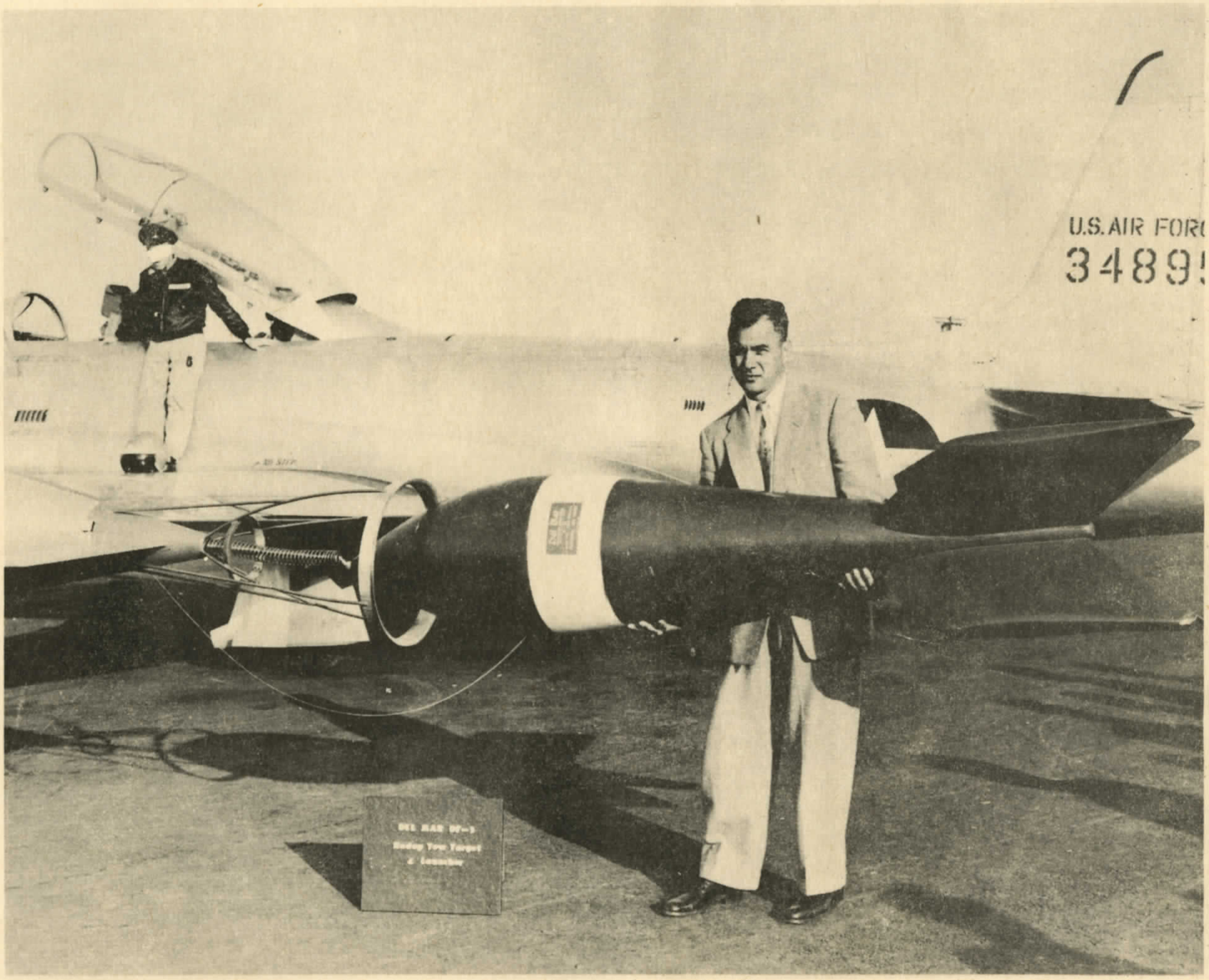


Fig. 15 Del Mar DF-3R Target and Receptacle (showing extended centering probe) Mounted on Tip Tank of T-33 Aircraft.

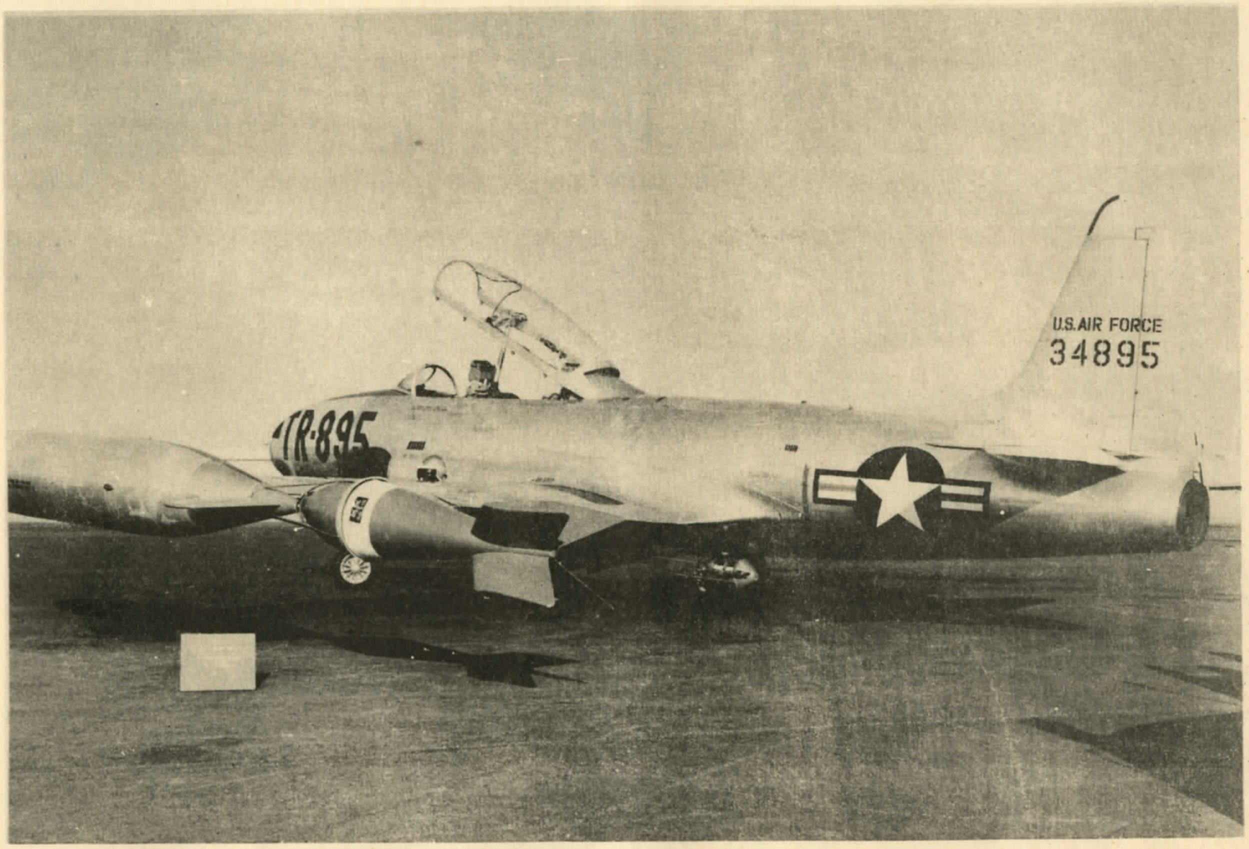


Fig. 16 Del Mar DF-3R Target and Receptacle Mounted on Tip Tank of T-33 Aircraft.

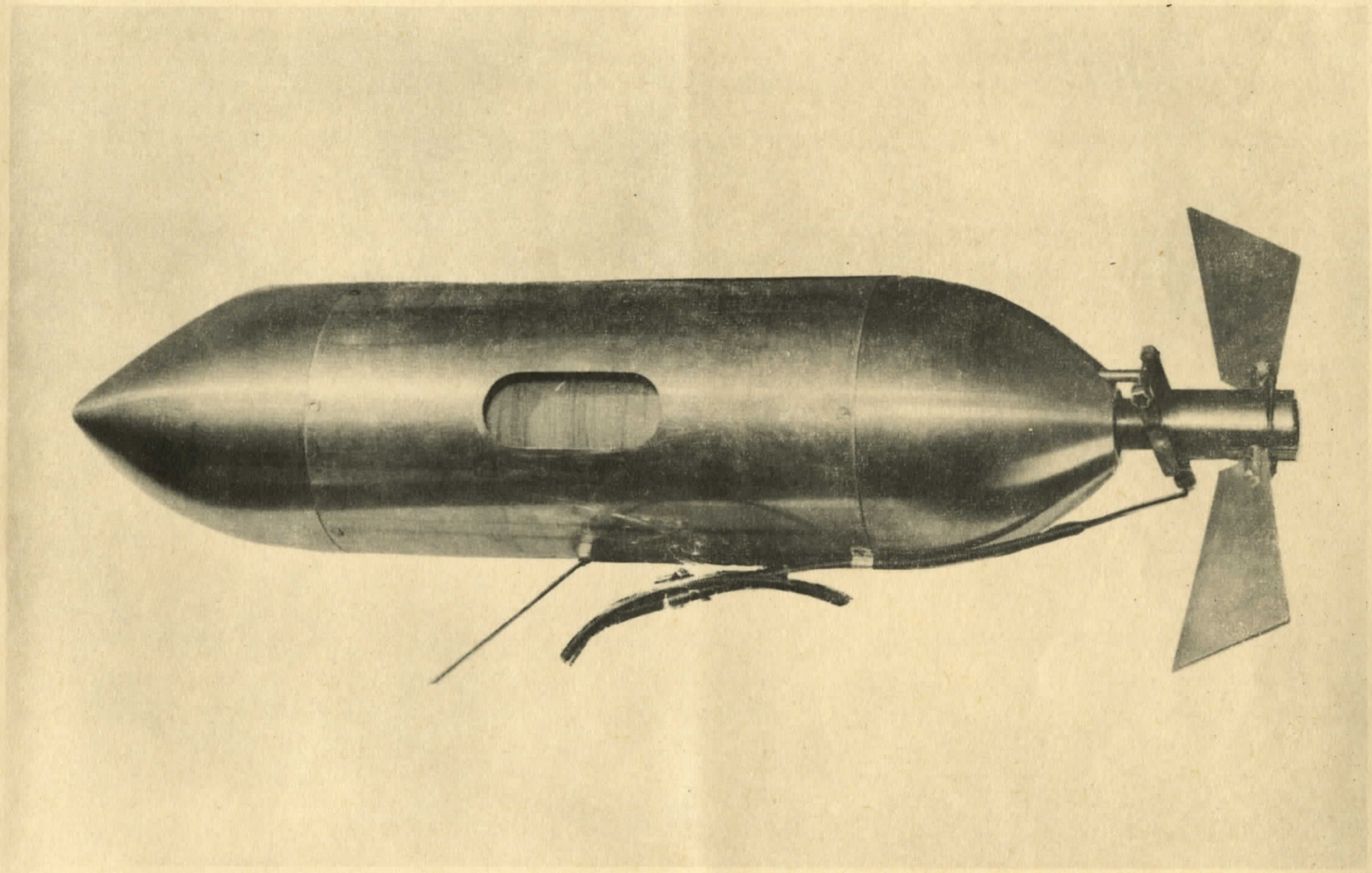
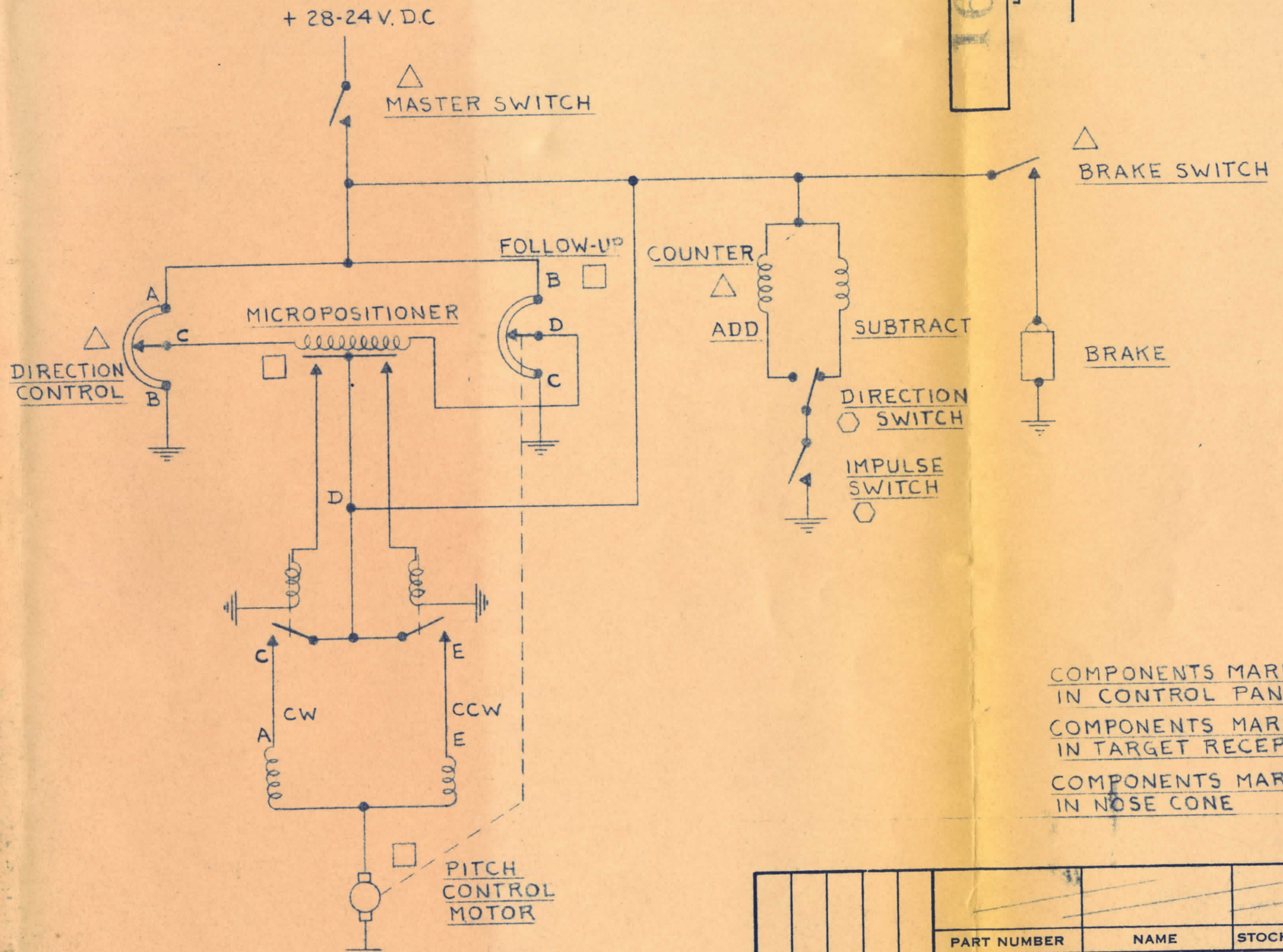


Fig. 17 Prototype Del Mar DF-2 Tow Reel.

NOTICE OF CHANGE		
1 May Be Reworked	3 Record Change	5 Parts Made OK
2 Cannot Be Reworked	4 Now Shop Practice	DISPOSITION & REFERENCES / ZONE
EFFECTIVE ON		

LAST ISSUE 1661

DEL. REPORT 547
FIG. 18



COMPONENTS MARKED "△" ARE LOCATED IN CONTROL PANEL

COMPONENTS MARKED "⬡" ARE LOCATED IN TARGET RECEPTACLE

COMPONENTS MARKED "□" ARE LOCATED IN NOSE CONE

PART NUMBER	NAME	STOCK SIZE	MATL. DESCR.	MATL. SPEC.	ZONE	NEXT ASSEMBLY	NO. REQ. PER MODEL

REQUIREMENTS ARE PER NOTED ASSEMBLY

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED
DIM. LIMITS ARE:
ANGULAR ± 1/2°
DECIMAL ± .010
FRACTIONAL ± 1/32
BREAK ALL SHARP EDGES

ODD DASH NOS. SHOWN
EVEN DASH NOS. OPP.
FINISH

UNIT WT. CALC. / ACTUAL
SECT.

DEL MAR ENGINEERING LABORATORIES
LOS ANGELES 64, CALIFORNIA
AERONAUTICAL PROJECTS

Utzschneider 3-30-55
Lohmaugh 3-30-55
JH 3-30-55

PREPARED FOR DF-4

SCHEMATIC WIRING DIAGRAM

SCALE NONE | FIRST ISSUED

DWG. SIZE B | 1661

SHEET 1 OF 1