PCC D46-10-02-01

23KS20000 BLACK BRANT ROCKET ENGINE

OPERATION AND HANDLING INSTRUCTIONS

ISSUE No. 1

Compiled by H. Rojeska

DEFENCE RESEARCH BOARD

CANADIAN ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

Valcartier, Quebec

CARDE TECHNICAL NOTE: 1629

UNCLASSIFIED

PCC D46-10-02-01

Project

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FOREWORD

1. The 23KS20000 Black Brant Rocket Engine was designed and developed by Canadian Armament Research and Development Establishment of the Defence Research Board of Canada, Valcartier, P.Q. All enquiries relative to this engine should be forwarded to Chief Superintendent, Canadian Armament Research and Development Establishment, P.O. Box 1427, Quebec, P.Q., Canada.

2. This handbook was compiled from data supplied by Test and Evaluation, Process Engineering, and Rocket Motor Sections, Propulsion Wing, C.A.R.D.E.

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For: Chief Superintendent
Canadian Armament Research
and Development Establishment

15 July 1964

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SECTION I

1.0 THE 23KS20000 BLACK BRANT ROCKET ENGINE

1.1 GENERAL

1.1.1 This handbook provides a description and instructions for handling, storage, and transportation of the assembled 17-inch diameter 23KS20000 Black Brant rocket engine. This engine was designed and developed at CARDE.

1.1.2 Details of variation in the model design of the 23KS20000 series of engines are to be provided for by the issue of supplementary data. (See Appendix I - Supplementary Data Record Sheet).

1.1.3 Procedures for the installation of the engine to the vehicle airframe are provided for separately. Refer to CARDE Black Brant IIB Data Booklet.

SECTION II

1.0 PURPOSE OF 23KS20000 BLACK BRANT ENGINE

1.1 This engine is used as a propulsion unit for the 17-inch diameter Black Brant upper atmosphere research vehicle and is designed to deliver a total impulse of approximately 449,000 lb-sec over a period of 28 seconds when operated at 60°F at sea level.

1.2 The thrust and duration of thrust are dependent upon the temperature of the propellant grain at the time of firing. (See Figs. 5A and 5B).

SECTION III

1.0 DESCRIPTION OF 23KS20000 BLACK BRANT ROCKET ENGINE

1.1 ENGINE DESIGNATION

1.1.1 The 23KS20000 Black Brant rocket engine is one production model of a series developed for upper atmosphere research. The model designation and nomenclature of the design are as follows:

23	duration of thrust in seconds
K	oxidizer and fuel code
S	solid propellant charge
20000	thrust, in pounds, at sea level

SECTION III - continued

1.0 DESCRIPTION OF 23KS20000 BLACK BRANT ROCKET ENGINE

1.2 EXTERNAL CHARACTERISTICS

1.2.1 The Black Brant rocket engine has a thin-walled steel chamber 17.2 inches in outer diameter with an over-all length of about 209.4 inches. The forward end of the engine is provided with a radially drilled attachment ring for mounting the nose cone, and a flanged boss for the installation of the igniter assembly. The aft end of the engine terminates in an expanded angle nozzle. The nozzle expands from about 8.24 inches at the throat to a maximum of about 13.475 inches at the exit in outer diameter. (See Figs. 1A and 1B). The principal data of the engine assembly are detailed in Table I and Fig. 2.

TABLE I

23KS20000 BLACK BRANT ROCKET ENGINE DATA

ENGINE		
Length of engine (complete with nozzle)	209.4	in.
Outer diameter of engine	17.2	in.
Total weight of engine	2616.5	lb
IGNITER		
Squib: M-56 MOD VI		
Minimum firing current, amps	1.6	
Recommended firing current, amps	5.0	
No fire current, amps	0.4	
Squib resistance, ohms	1.0	
TEMPERATURE		
Engine firing temperature limits, $\pm$ 5°F	14 to 100	°F
Engine storage temperature limits (See Note)	0 to +150	°F
Preferred storage temperature limits	+60 to + 90	°F
Igniter storage temperature limits	-20 to +150	°F
Propellant flame temperature	4220	°F

NOTE: Before firing, the engine must be conditioned for at least 12 hours within the firing temperature limits.

/continued

SECTION III - continued

1.0 DESCRIPTION OF 23KS20000 BLACK BRANT ROCKET ENGINE

1.2 EXTERNAL CHARACTERISTICS

1.2.2 Referring to Fig. 2, the nozzle dimensions for 23KS20000 Black Brant IIB are:

Reference	Dimensions
"X"	8.24 in.
"Y"	13.475 in.
"Z"	20.94 in.

1.3 INTERNAL CHARACTERISTICS

1.3.1 The engine consists essentially of a thin-walled, steel chamber lined with a mica-filled polyurethane which acts as a liner and grain bonding agent.

1.3.2 The igniter assembly consists of a flanged plug, a scroll flash charge tube, a pressure squib, and a latex-sleeved wire basket for the pellets, (see Figs. 3A and 3B). The igniter assembly is attached to the forward end of the engine by means of a flanged boss.

1.3.3 The ceramic lined nozzle is attached to the aft end of the chamber by means of a ring of bolts.

1.4 CHAMBER ASSEMBLY

1.4.1 The 17-inch diameter chamber assembly is fabricated from stretch-formed, 0.104 $\pm$ 0.020 inch thick steel of Specification AISI 4130 and is designed to withstand a working pressure of 1420 psi.

1.4.2 The chamber lining is of mica-filled polyurethane which functions as a grain restrictor and ablating coolant for the steel. A radially drilled ring for the attachment of the instrumented nose cone is provided at the forward end, while the aft end has a drilled flange for the attachment of the nozzle. A flanged boss is provided in the forward end of the chamber for the installation of the igniter assembly.

1.5 PROPELLANT GRAIN

1.5.1 The solid propellant is cast in the form of a modified, tapered, three-leaf clover, internal burning, ammonium perchlorate-polyurethane-aluminum charge weighing approximately 2085 pounds. The gaseous and liquid-solid combustion products are:

SECTION III - continued

1.0 DESCRIPTION OF 23KS20000 BLACK BRANT ROCKET ENGINE

1.5 PROPELLANT GRAIN

H_2O, H_2, CO_2, CO, N_2, HCl, Al_2O_3, H, OH, NH_3, CHO, HCN, Cl, $AlCl_3$, $AlCl_2$, $AlCl$, Cu, and Cr_2O_3. The forward and aft ends of the grain are restricted with a mica-filled polyurethane.

1.6 NOZZLE ASSEMBLY

1.6.1 The nozzle is precision machined from aircraft-quality AISI 4340 steel and the inner surface of the expansion cone is lined with flame-sprayed ceramic which functions as a heat barrier. The approach and exit of the nozzle throat is fitted with a graphite insert which insulates the steel from hot gases of the burning propellant.

1.7 IGNITER ASSEMBLY

1.7.1 The igniter assembly consists of a flanged plug, a scroll flash charge tube, an M-56 MOD VI pressure squib, and a latex-sleeved wire basket containing approximately 200 grams of SR 371 pellets.

1.7.2 When the vehicle is mounted on the launcher arming of the igniter is carried out. This requires removing the shipping plug and installing the M-56 pressure squib at the external end of the igniter flash tube. (See Section VIII).

SECTION IV

1.0 STORAGE AND SHIPPING PROTECTION DEVICES

1.1 A light alloy closure for the igniter boss and a light alloy plate, bolted to the engine chamber flange at the nozzle end protect the propellant grain during temperature cycling, long term storage and shipping. The use of these protection devices prevents accidental ignition and entrance of moisture to the propellant grain.

1.2 The nozzle is shipped separately from the engine. A special light alloy mounting plate is used to protect the graphite extension of the nozzle and to anchor the nozzle to the shipping crate. Use care in removing the mounting plate from the nozzle to prevent damage to the graphite.

SECTION V

1.0 SHIPPING AND STORAGE CLASSIFICATION

1.1 THE ROCKET ENGINE

1.1.1 The storage classification of the 23KS20000 Black Brant engine is GROUP 6 in accordance with R.C.O.C. Manual. With respect to shipment the engine is crated as 'BLACK BRANT ROCKET ENGINE, JET THRUST UNIT' and designated as 'CLASS "B" EXPLOSIVE', (see Fig. 4), in accordance with the Canadian Board of Transport Commissioners regulations. Under the U.S. Interstate Commerce Commission Regulations and the U.S. Navy Bureau of Ordnance involving a flammable hazard, the designation is 'CLASS "B" EXPLOSIVE'.

1.2 THE IGNITER

1.2.1 The storage classification of the igniter for the 23KS20000 engine is GROUP 6 in accordance with R.C.O.C. Manual. With respect to shipment the igniter is crated and marked 'IGNITER, JET THRUST, CLASS "B" EXPLOSIVE' in accordance with the Canadian Board of Transport Commissioners regulations. Under the U.S. Interstate Commerce Commission Regulations and the U.S. Navy Bureau of Ordnance involving a flammable hazard, the designation is 'CLASS "B" EXPLOSIVE'.

2.0 METHOD OF SHIPPING

2.1 AIR TRANSPORT

2.1.1 Transportation by Air is, to date, the only method which has been qualified.

2.2 RAILWAY TRANSPORT

2.2.1 Release of the engine for shipment by rail has not been investigated.

SECTION VI

1.0 STORAGE OF ROCKET ENGINE AND IGNITER

1.1 STORAGE OF ROCKET ENGINE

1.1.1 The rocket engine should be stored under explosives magazine regulations.

1.2 STORAGE OF IGNITER

1.2.1 The igniter storage temperature may be from -20° to +150°F. Igniter assemblies will be stored in moisture-proof containers.

SECTION VII

1.0 INSPECTION OF 23KS20000 BLACK BRANT ROCKET ENGINE AFTER REMOVAL FROM STORAGE

1.1 After removing the engine from storage and prior to use, inspect the engine as follows:

(a) Visually inspect the engine for any evidence of damage or deformation. Reject the engine if damaged.

(b) Remove the light alloy closure from the igniter boss and visually inspect the interior for condensation of moisture on the propellant grain and for gross surface defects in grain and inhibitor. Replace the closure immediately after inspection and leave in place until ready to install the igniter. Similarly, inspect the propellant grain from the aft end of the engine.

> WARNING
>
> If artificial light is required for inspection use a safety flash light only. Do not bring power lights or power cords near the engine. Do not insert anything into either the forward or aft end of the engine.

SECTION VIII

1.0 INSPECTION AND INSTALLATION OF IGNITER ASSEMBLY

1.1 To install the igniter proceed as follows:

(a) In general, select the igniter shipped with the engine.

(b) Remove the igniter assembly from its moisture-proof container and visually inspect the wire basket and the latex sleeve for damage. If damaged, reject the igniter.

(c) Remove the closure from the igniter boss of the rocket engine.

(d) Inspect the "O" ring on the igniter housing and apply a light coating of silicone grease, such as DC-4, to the

SECTION VIII - continued

1.0 INSPECTION AND INSTALLATION OF IGNITER ASSEMBLY

1.1 (d) "O" ring. Locate the igniter so that the flash tube is in line with the access door in the nose cone. Make sure that the copper gasket is properly located before tightening up the bolts in the engine igniter boss. Use a torque of 12 foot-pounds on the 1/4 - 0.28 x 0.75 inch long bolts.

(e) When ready to arm the engine, remove the shipping plug from the scroll flash charge tube and place the "O" ring on the M-56 squib. Tighten the M-56 squib with 60 inch-pounds torque. A spare "O" ring for the M-56 squib is obtainable from the shipping plug.

SECTION IX

1.0 INSPECTION AND INSTALLATION OF NOZZLE ASSEMBLY

1.1 The inspection and installation of the nozzle assembly will be carried out as follows:

1.1.1 NOZZLE INSPECTION

(a) Inspect the nozzle for signs of damage to the ceramic lining.

(b) Inspect the nozzle mating surface.

(c) Inspect the nozzle mating "O" ring and gasket.

(d) Any significant damage to the nozzle will require rejection of the nozzle.

1.1.2 NOZZLE INSTALLATION

(a) Remove the light alloy sealing plate from the aft end of the engine.

(b) Lubricate the nozzle "O" ring with a suitable lubricant, such as DC-4, and install in the nozzle mating surface "O" ring groove.

(c) Install the nozzle gasket over the graphite projection and up against the grooved mating surface on the nozzle.

SECTION IX - continued

1.0 INSPECTION AND INSTALLATION OF NOZZLE ASSEMBLY

1.1.2 NOZZLE INSTALLATION

(d) Align the nozzle attach-holes with the attach-holes of the engine. Use any alignment marks indicated.

(e) Secure the nozzle with the sixteen (16) Allen-head screws provided. Torque screws to 20-25 foot-pounds.

(f) Check that there is a uniform gap of approximately 0.025 inch between the nozzle bolt flange and the engine flange. The gap indicates that the nozzle gasket was not omitted.

(g) Temporarily install a Styrofoam closure in the expansion cone of the nozzle to provide protection for the propellant grain until the engine is ready to be fired. It will be removed before firing.

SECTION X

1.0 HANDLING OF ROCKET ENGINE AND IGNITER ASSEMBLY

1.1 GENERAL

1.1.1 The rocket engine is designed as a vehicle power unit and it must be given the same care as other parts of the vehicle.

1.2 ROCKET ENGINE HANDLING LIMITS

1.2.1 The rocket engine is designed to withstand loads associated with acceleration of 25 g longitudinally and 5 g across the diameter. Dropping the engine on any hard surface even from a low height will give excessive loads and cause damage.

1.2.2 Damage to the drilled forward end attachment ring of the engine will preclude proper installation of the nose cone. Damage to the machined shoulder and drilled flange at the aft end will preclude proper installation of the nozzle to the engine.

1.3 IGNITER ASSEMBLY HANDLING

1.3.1 The igniter assembly must be handled with the same care as the rocket engine. Damage to the igniter due to dropping will result

SECTION X - continued

1.0 HANDLING OF ROCKET ENGINE AND IGNITER ASSEMBLY

1.3 IGNITER ASSEMBLY HANDLING

in broken pellets or torn latex sleeve. Broken pellets may cause an unacceptably high ignition pressure.

1.3.2. Do not remove the igniter assembly from the moisture-proof container until ready for installation in the rocket engine.

SECTION XI

1.0 CRATING AND TRANSPORTING THE ROCKET ENGINE AND IGNITER

1.1 The rocket engine and igniter are protected by suitable packaging to prevent damage caused by normal handling while being transported.

1.2 For transportation by rail in Canada the Canadian Armament Research and Development Establishment has authority, under Special Permit No. 520 from the Board of Transport Commissioners for Canada, to ship the 23KS20000 engine in the crate manufactured to CARDE Drawing No. 61052306, (see Fig. 4). (Release of the engine for firing after rail transport has not yet been approved.)

SECTION XII

1.0 TEMPERATURE CYCLING OF ROCKET ENGINE

1.1 STORAGE

Temperature cycling of the rocket engine during storage, i.e., from hot to cold to hot or vice versa, must be avoided.

1.2 FIRING

1.2.1 A typical temperature cycle consists of the engine casing temperature commencing above $32^{\circ}F$, going below $32^{\circ}F$ to any temperature between $32^{\circ}F$ and $10^{\circ}F$ and returning to some temperature above $32^{\circ}F$.

SECTION XII - continued

1.0 TEMPERATURE CYCLING OF ROCKET ENGINE

1.2 FIRING

1.2.2 Two temperature cycles are permissible. If the engine is not fired during the third cycle, further attempts to use the engine to launch a vehicle should not be made without referring the engine to CARDE. Suitable temporary insulation on the rocket engine will considerably prolong the "hold times" which may be accepted under cold weather conditions.

SECTION XIII

1.0 FIRING THE ROCKET ENGINE

1.1 RANGE REGULATIONS

1.1.1 Range regulations for the firing of engines and handling of misfires will govern the use of the recommendations of Section XIII.

1.2 FIRING CIRCUIT CHECK

1.2.1 To prevent misfires caused by an incorrect firing circuit, a resistance check should be made after the engine is armed. Use an approved, accurate, squib tester at the closest point feasible to the firing switch in the blockhouse.

1.3 HANDLING OF MISFIRES

1.3.1 A misfire may be the result of:

(a) Improper firing circuit.

(b) Squib failure.

(c) Igniter failure.

(d) Failure of propellant to ignite.

(e) Hangfire, in which the propellant partially ignites or smoulders.

1.3.2 In the event of a misfire check for proper firing circuit from the blockhouse. If squib circuit is open or shorted wait at least 10 minutes if igniter discharge from the nozzle was not observed; wait 30 minutes if igniter discharge was observed.

SECTION XIII - continued

1.0 FIRING THE ROCKET ENGINE

1.3 HANDLING OF MISFIRES

1.3.3 Disconnect firing leads and remove squib. If squib has not fired replace with a new squib and proceed with firing.

1.3.4 If squib or igniter has fired no further attempts should be made to fire the engine. Request disposal instructions for the engine from CARDE.

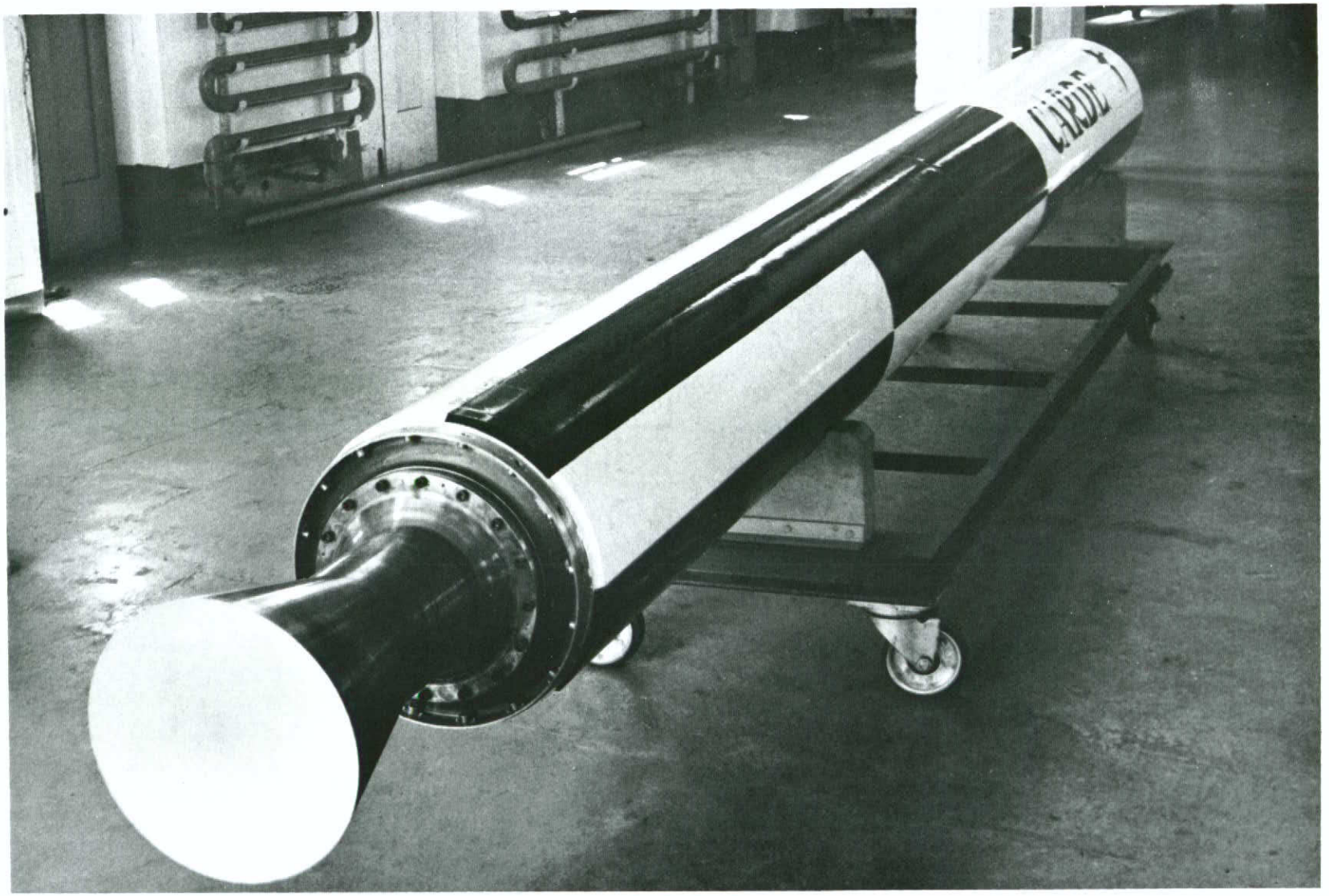

FIGURE 1A - Aft end view of 23KS20000 Black Brant engine

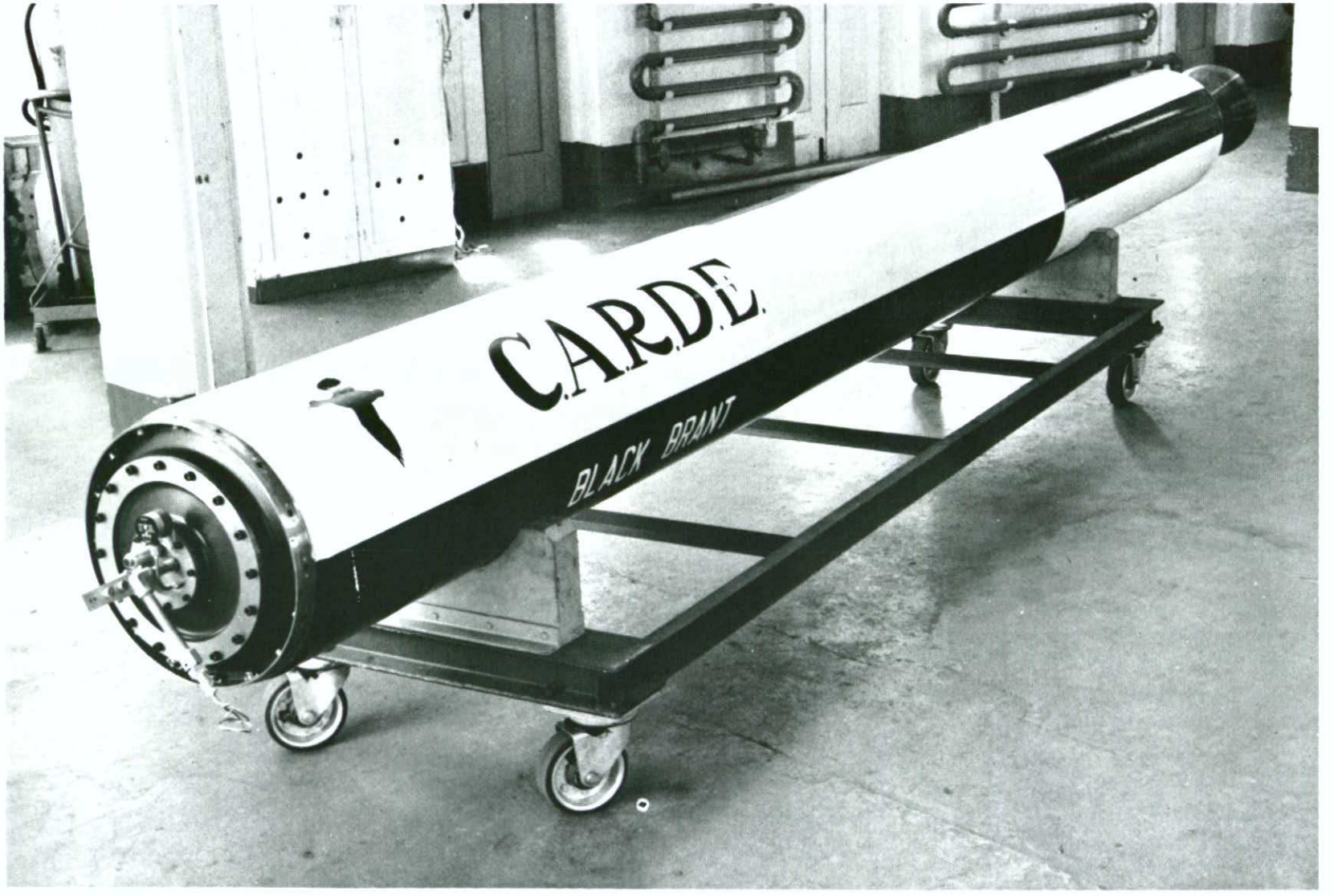

FIGURE 1B - Head end view of 23KS20000 Black Brant engine

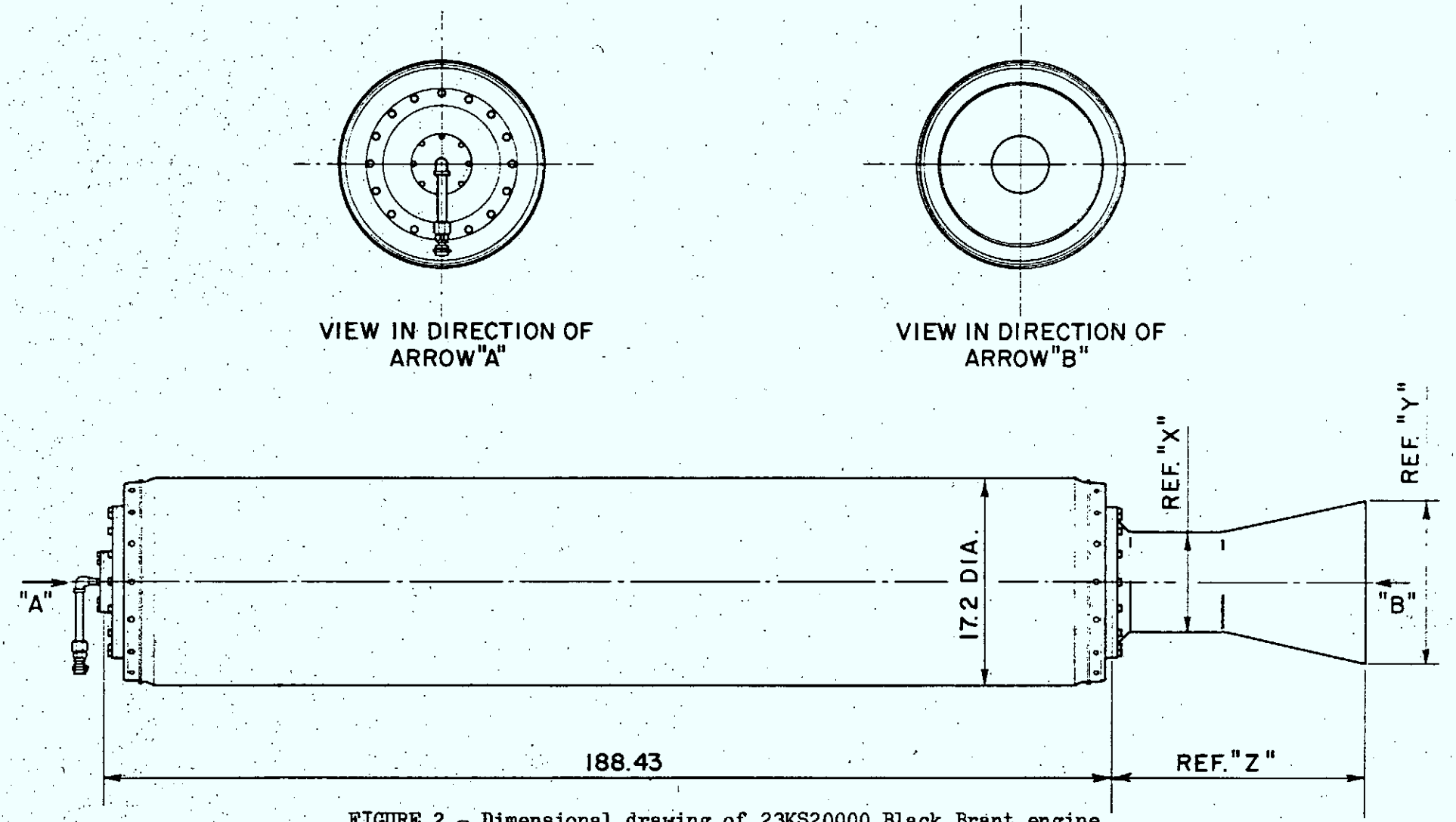

FIGURE 2 - Dimensional drawing of 23KS20000 Black Brant engine

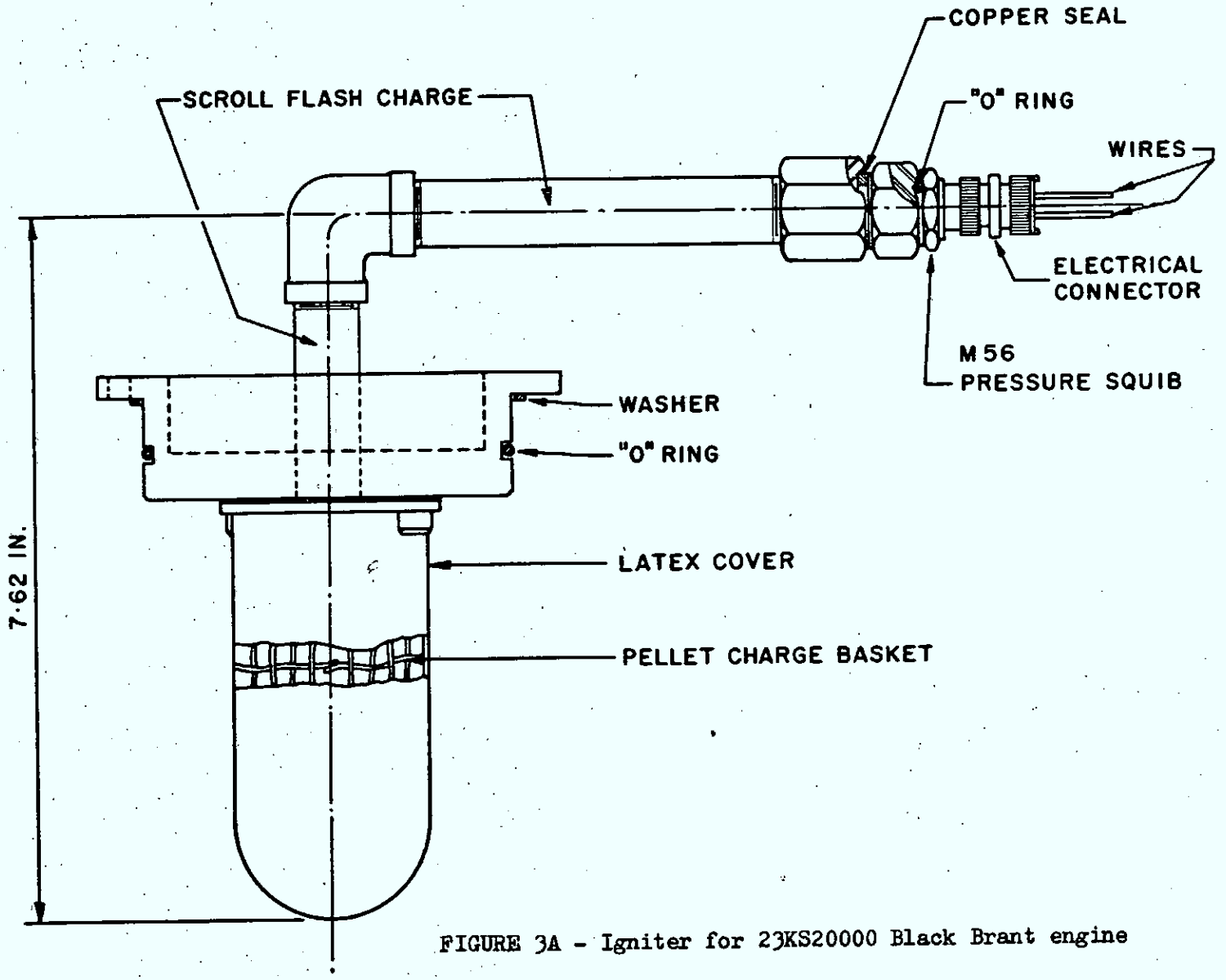

FIGURE 3A - Igniter for 23KS20000 Black Brant engine

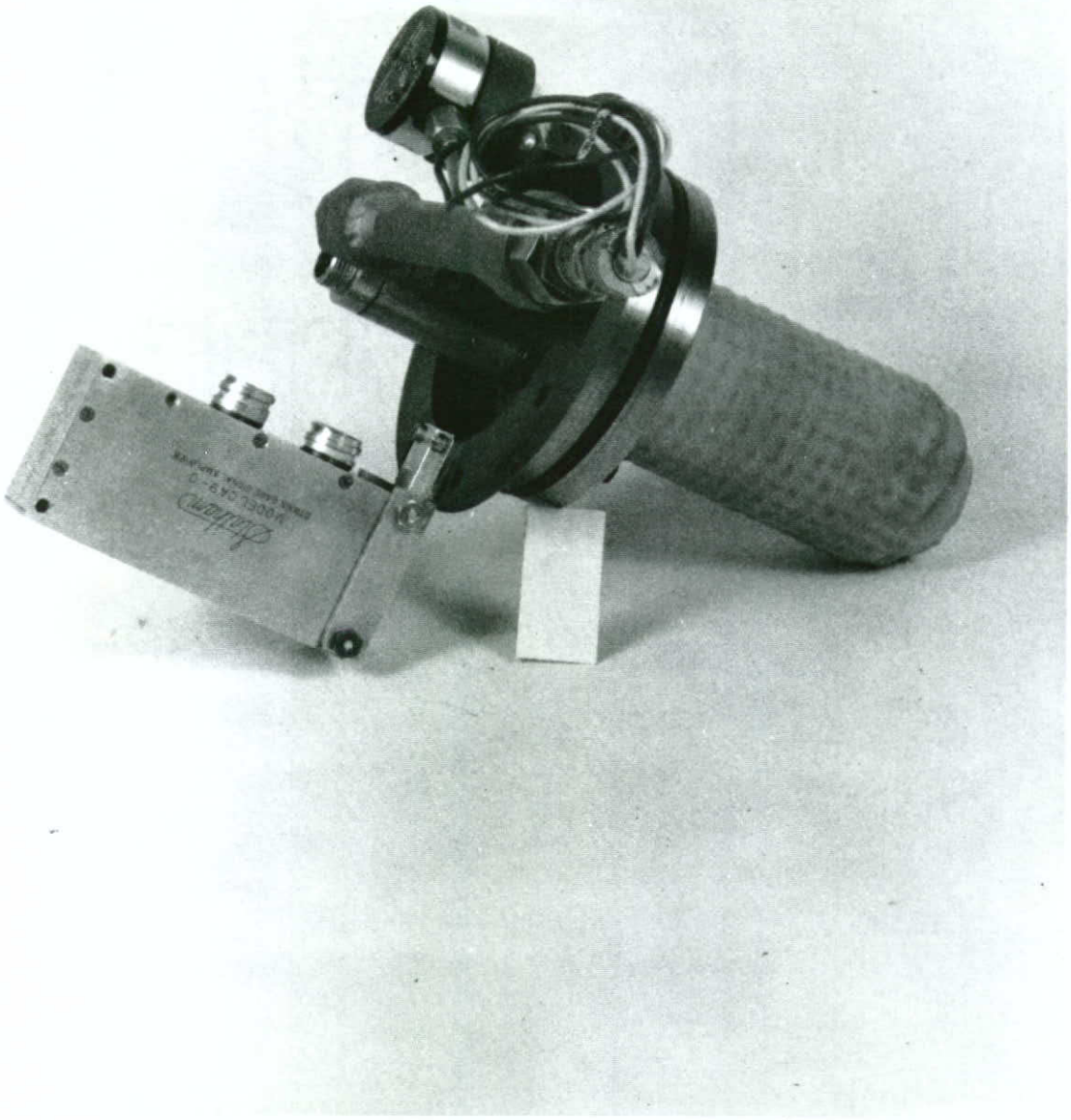

FIGURE 3B - Igniter equipped with engine pressure transducers

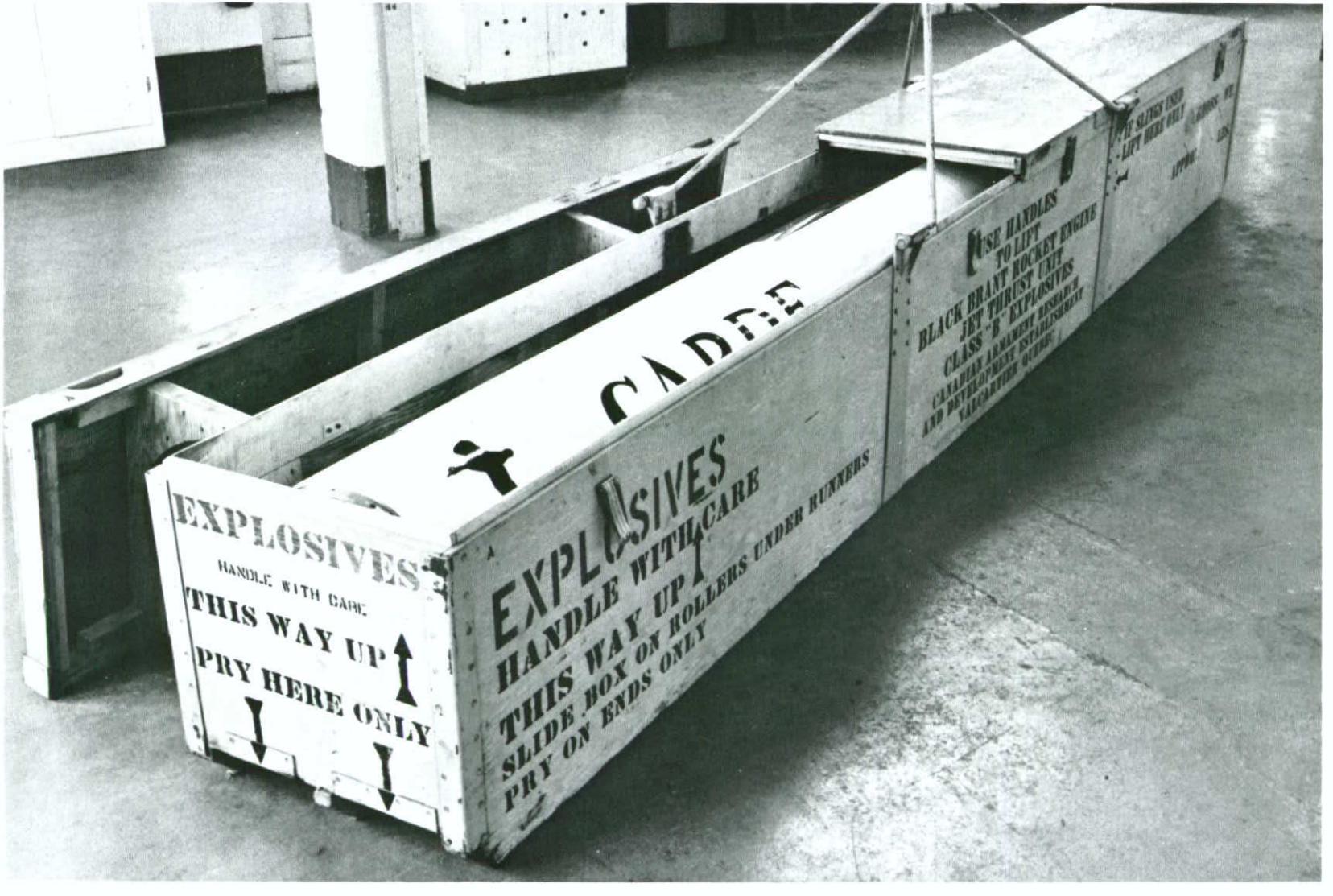

FIGURE 4 - Transit crate for Black Brant engine

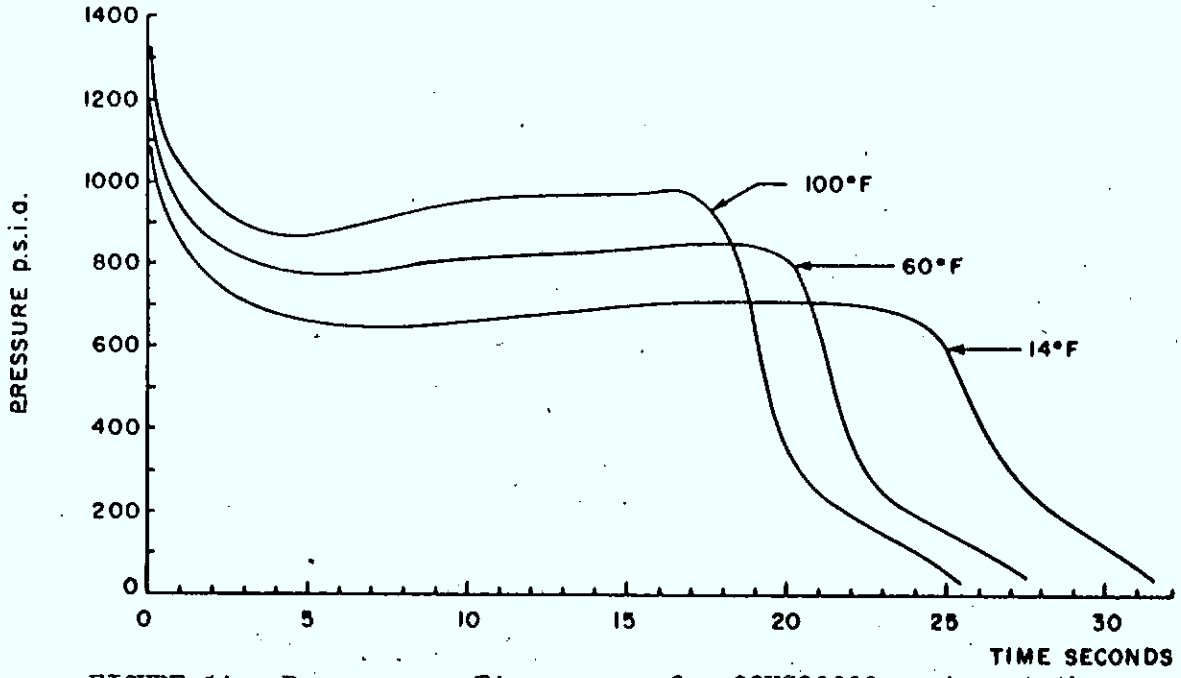

FIGURE 5A - Pressure vs Time curves for 23KS20000 engine at three temperatures.

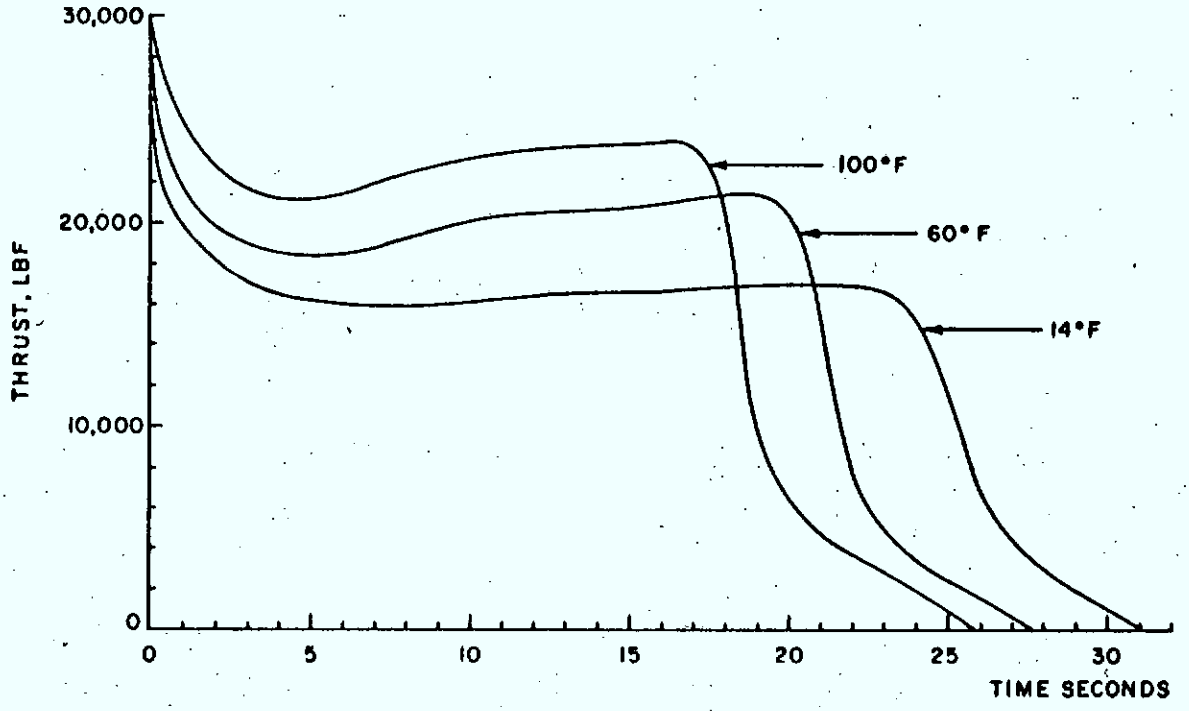

FIGURE 5B - Thrust vs Time curves for 23KS20000 engine at three temperatures.

APPENDIX I

REVISION AND SUPPLEMENTARY DATA RECORD SHEET

Engine Designation	Series	Subject of Supplementary Data	Data Description	Section	Date of Issue	Added Supplement

REPORT NO:	CARDE T.N. 1629/64	UNCLASSIFIED
PROJECT NO:	D46-10-02-01	
TITLE:	23KS20000 Black Brant Rocket Engine Operation and Handling Instructions - Issue No.1	
AUTHOR:	Compiled by H.Rojeska	
DATED:	August, 1964	
SECURITY GRADING:	UNCLASSIFIED	
INITIAL DISTRIBUTION:	September, 1964	

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