

CARDE T.N. 1525/63

PROJECT No.
D46-10-02-01

UNCLASSIFIED

CARDE T.N. 1525/63

**SUMMARY OF PERFORMANCE OF THE 15KS25000 ROCKET ENGINE
USED IN THE FIRST SIXTEEN BLACK BRANT VEHICLES**

by

C.D. Martin and A. Ouellet



DEFENCE RESEARCH BOARD

CANADIAN ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

Valcartier, Quebec

UNCLASSIFIED

April, 1963

✓
CARDE TECH. Note 1525/63

UNCLASSIFIED

✓
(Project No. D46-10-02-01)

Summary of Performance of the
15KS25000 Rocket Engine Used in the
First Sixteen Black Brant Vehicles (U)

by

C.D. Martin and A. Ouellet

✓
CANADIAN ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT
Valcartier, P.Q.

April 1963

ABSTRACT

The performance of the CARDE developed 15KS25000 rocket engine used in the launching of the first sixteen Black Brant vehicles is outlined. Relevant data on the engine and vehicle are presented for each of the launchings and explanatory comments are given for apparent deviations from normal performance. Results indicate some lack of reproducibility in the engine but a generally acceptable performance. A postscript adds some information on seven subsequent launchings.

TABLE OF CONTENTS

	Page No.
ABSTRACT	i
INTRODUCTION	1
PERFORMANCE DATA	1
DISCUSSION OF DATA	4
CONCLUSIONS	5
ACKNOWLEDGEMENT	5
REFERENCES	5
POSTSCRIPT	6

INTRODUCTION

After two and a half years use it is desirable now to summarize the results of all the launchings of the Black Brant vehicles from September 1959 to January 1962 as they relate to the performance of the 15KS25000 rocket engine used in the vehicles. Although some of the data presented here have been previously published (1 to 10) they are not complete enough for comparison purposes. In the references as many relevant publications as possible have been included to provide an up-to-date information source on the rocket engine. It should be noted that the vehicles one to twelve were generally known as Black Brant I vehicles and the last four as Black Brant II vehicles but the engines were similar with only minor changes to the nozzle expansion cone to suit the different fin attachments.

PERFORMANCE DATA

Included in the performance data for the 15KS25000 rocket engine given in Table I are many relevant data listings for the engine and vehicle. Definitions for some of the parameters follow:

1. Burning time, t_b , is obtained by taking the time difference when initially the engine pressure reaches 100 p.s.i.g. and when it finally reaches 98% of the value where the tangent leaves the final equilibrium portion of the curve.
2. Action time, t_a , is obtained by taking the time difference where initially the pressure reaches 100 p.s.i.g. and when it finally reaches 30 p.s.i.g.
3. Maximum pressure is the value occurring during firing excluding ignition peak. In the 15KS25000 engine this point is reached after approximately one second of burning.
4. C^* , characteristic velocity, is a parameter expressing propellant performance. Since the thrust of the rocket engine can only be measured indirectly in flight, overall engine performance must be assessed by measuring propellant performance and provided no significant changes occur in the nozzle no error is introduced. C^* is obtained from measured values of pressure-time, nozzle throat area and propellant weight.

The overall accuracy of the reduced data from the engine firing via pressure transducer, telemetry, ground station and analogue to digital conversion is not expected to be better than $\pm 3\%$. For some unknown reason it appears that there is a bias towards high values of C^* .

In Table II comparative data are given for typical values obtained from prototype engines fired statically during the final development phase of the 15KS25000 rocket engine.

PERFORMANCE DATA FOR 15KS25000 ENGINE IN FLIGHT VEHICLES

TABLE I

Reference No.	1	2	3	4	5	6	7	8
Vehicle Designation	PTV 1	PTV 2	PTV 3	PTV 4	PTV 5	PTV 6	PTV 7	PTV 8
Vehicle Symbol No.	CC I 1	CC I 2	CC I 3	CC I 4	CC I 5	CC I 6	CC I 7	CC I 8
Vehicle Sponsor	CARDE	CARDE	CARDE	CARDE	CARDE	CARDE	CARDE	CARDE
Nose Cone Experiment	(.....)	(.....)	Engine & Vehicle Performance	(.....)	(.....)	(.....)	(.....)	NO
Launch Site	CRR	CRR	CRR	CRR	CRR	CRR	CRR	CRR
Launch Date	5/9/59	5/9/59	8/9/59	10/9/59	18/5/60	24/5/60	28/5/60	23/9/60
Launch Time, hrs	0927	1624	0914	1548	1540	1144	1227	0040
Launch Elevation Angle, °	70	70	70	70	80	81	80	75
Engine Filling No.	D-226	D-227	D-228	D-229	D-302	D-303	D-304	D-316
Engine Case No.	WAF-103	WAF-105	WAF-107	WAF-111	WAF-113	WAF-115	WAF-117	WAF-143
Nozzle Type	BBI	BBI	BBI	BBI	BBI	BBI	BBI	BBI
Nozzle Throat Diam., in.	5.18	5.17	5.18	5.18	5.20	5.20	5.20	5.20
Igniter Type	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)	(.....)
Igniter Squib	(.....)	(.....)	Carton	(.....)	(.....)	(.....)	(.....)	(.....)
Bourns Transducer, No.	2	2	2	2	2	2	2	1
Engine Temp., °F	70	65	103	100	5	14	-13	45
Propellant Weight, lb	1757	1760	1748	1761	1757	1759	1760	1758
Burning Time, t _b , sec	14.39	13.58	13.22	12.95	15.00	14.53	13.70	13.27
Action Time, t _a , sec	18.00	17.68	15.31 (a)	16.79	15.54 (a)	20.49	19.08	17.56
Max. Pressure, P _{max} , psia	865	908	950	1002	754	779	836	941
Avg. Pressure over t _b , psia	816	860	896	905	732	754	804	883
Characteristic Velocity	4921	5027	4823	5020	4412	4979	4987	5051
C, ft/sec								

- Notes:
1. Items marked with an (a) are commented on in the discussion
 2. C*, theoretical, at 70°F is 4900 ft/sec
 3. NO - Nitric oxide point seeding
 4. CRR - Churchill Research Range (previously called Fort Churchill Rocket Research Facility)
 5. WS - NASA Wallops Station, Wallops Island, Virginia

TABLE I (Continued)

Reference No.	9	10	11	12	13	14	15	16
Vehicle Designation	PTV 9	DRTE 03	DRTE 04	DRTE 05	Black Brant II 01	Black Brant II 02	Black Brant II A	Black Brant III A
Vehicle Symbol No.	CC I 9	BB I 10	BB I 11	BB I 12	CC II A 13	CC II A 14	CC II A 15	CC II A 16
Vehicle Sponsor	CARDE	DRTE	DRTE	DRTE	CARDE	CARDE	CARDE	CARDE
Nose Cone Experiment	NO	(. . . Ionosphere . . .)	(. . . Ionosphere . . .)	(. . . Ionosphere . . .)	(. . . Vehicle Performance . . .)	(. . . Vehicle Performance . . .)	(. . . Vehicle Performance . . .)	(. . . Vehicle Performance . . .)
Launch Site	CRR	CRR	CRR	CRR	CRR	CRR	WS	WS
Launch Date	30/9/60	20/10/60	8/10/60	28/10/60	12/10/60	12/10/60	22/11/61	30/11/61
Launch Time, hrs	0017	1350	0845	0621	1036	1527	0700	1830
Launch Elevation Angle, °	82.5	75	82.5	80	82.5	82.5	75	74.5
Engine Filling No.	D-317	D-313	D-314	D-315	D-413	D-412	D-659	D-658
Engine Case No.	WAF-151	WAF-147	WAF-119	WAF-141	WAF-157	WAF-135	BAW MT2	BAW MT6
Nozzle Type	BB1	BB1	BB1	BB1	BB1A	BB1A	BB1A	BB1A
Nozzle Throat Diam., in.	5.20	5.20	5.20	5.20	5.14	5.13	5.15	5.14
Igniter Type	(. . .)	(. . .)	(. . .)	(. . .)	Basket . . .	(. . .)	(. . .)	(. . .)
Igniter Squib	(. . .)	(. . .)	(. . .)	(. . .)	M45 mod II	(. . .)	(. . .)	(. . .)
Bourns Transducer, No.	1	1	1	1	2	2	2	2
Engine Temp., °F	55	(15)	(50)	(60)	60	65	61	56
Propellant Weight, lb	1767	1754	1762	1766	1759	1762	1764	1754
Burning Time, tb, sec	13.31	14.85	15.29	12.55(a)	13.83	12.76(a)	13.53	13.69
Action Time, ta, sec	18.14	20.40	20.07	16.90(a)	18.05	17.33	15.28(a)	17.81
Max. Pressure, pmax, psia	880	757	838	942	931	960	885	871
Avg. Pressure over tb, psia	838	738	748	873	845	896	844	809
Characteristic Velocity C*, ft/sec	4949	4931	4958	4802	5082	4968	4662	4804

Notes:

1. Items marked with an (a) are commented on in the discussion
2. C*, theoretical, at 70°F is 4900 ft/sec
3. NO - Nitric oxide point seeding
4. CRR - Churchill Research Range (previously called Fort Churchill Rocket Research Facility)
5. WS - NASA Wallops Station, Wallops Island, Virginia

PERFORMANCE DATA FOR 15KS25000 ENGINES FIRED STATICALLYTABLE II

Temperature	0°F	+70°F	+120°F
Burning time, t_b , sec.	14.3	12.7	11.9
Action time, t_a , sec.	19.7	17.3	16.2
Avg. Pressure over t_b , psia	770	875	920
Characteristic Velocity C*, ft/sec	4770	4860	4910

DISCUSSION OF DATA

Reference numbers 1 and 2 - These two engines and vehicles gave satisfactory performance and the data obtained are in most respects considered normal values for the rocket engine.

Reference No. 3 - Telemetry became unintelligible during the final tail-off portion of the engine burning. Loss of telemetry may have been owing to excessive lateral acceleration but vehicle break-up is not suspected. The partial loss of the pressure record gives an action time and C* lower than normal.

Reference No. 4 - Both engine and vehicle gave normal performance to impact.

Reference No. 5 - There is some evidence of partial failure of the engine at the nozzle end since there was a rapid loss of chamber pressure during tail-off and both lateral accelerometers went off scale for fifteen seconds. Action time and C* are lower than normal because of apparent partial engine failure. The vehicle became unstable but did not break up. The instability may have been caused by burn-through at the nozzle end of the engine or by structural failure of the fins causing damage of the aft end of the engine.

Reference Nos. 6, 7, 8 and 9 - These four engines and vehicles operated in a normal manner including one engine with propellant conditioned to minus 13°F.

Reference Nos. 10, 11 and 12 - These three vehicles were launched by the Churchill Range crew and no accurate propellant temperature is available. From some relative data approximate temperatures have been assigned. Engine

performance on 10 and 11 appears normal but for some unknown cause No. 12 has a propellant burning rate higher than normal and a relatively short tail-off. It is conceivable that minor cracks in the propellant grain may have provided an increase in the burning surface.

Reference Nos. 13 and 14 - These two engines were used in the first launching of the IIA vehicle which employed modified nose cone and fins. With the exception of an unexplained shorter burning time for No. 14 both engines gave acceptable performance values.

Reference Nos. 15 and 16 - These two engines were used in confirmatory launchings of the IIA vehicle. Number 15 vehicle broke up about 15 seconds after launch apparently owing to a structure failure of some part of the fin assembly. As a result of some telemetry loss because of vehicle malfunction the action time and C are low for this engine. Number 16 vehicle went into a flat spin about 27 seconds after launch but did not break up.

CONCLUSIONS

From the evidence obtained from the first sixteen launchings with the 15KS25000 engine it may be concluded that fairly reliable functioning of the engine can be expected over an engine temperature range of 0°F to 100°F. There is no conclusive evidence to say that any of the engines failed during propellant burning but one of the engines, reference number 5, has some suspicion attached to it. There is evidence of somewhat less reproducibility in burning time than desirable but it is believed to be quite adequate for the purpose of the vehicle. It would have required considerably more time and effort to develop an engine of this size with much better reproducibility.

ACKNOWLEDGEMENT

The authors acknowledge the work of Mr. C. Lafond of Systems Wing in providing data from the telemetry records.

REFERENCES

1. Dickinson L.A. and Odgers A.L. The Development of a 15KS25000 Rocket Engine (U) CARDE Report 328/60 (CONFIDENTIAL)
2. Martin C.D., Cameron I.R. and Blake R.P. CARDE Black Brant I Vehicle Trial Fort Churchill Rocket Range (U) September 1959 CARDE Tech. Memo 343/60 (UNCLASSIFIED)
3. Gouge R. Data Reduction Results of Black Brant Trials at Churchill in September 1959 CARDE Tech. Letter 1271/60 (RESTRICTED)

REFERENCES (Cont'd)

4. Kane J., Gouge R. and Johnson C. Data Reduction Results of Black Brant Trials at Churchill in May 1960 (U) CARDE Tech. Letter 1319/60 (RESTRICTED)
5. Kane J, and Gouge R. Data Reduction Results of Black Brant Trials at Churchill in September and October 1960 (U) CARDE Tech. Letter 3016/61 (RESTRICTED)
6. Delisle J.R., Flight Test Results of Black Brant IIA (CCII15&16) Firings at Wallops Island Va., November 1961 CARDE Tech. Note 1467/62 (UNCLASSIFIED)
7. Rojeska H., Dickinson L.A. and Martin C.D. 15KS25000 Black Brant Engine (U) Operation and Handling Instructions CARDE Issue No. 1 Tech. Note 1440/62 (UNCLASSIFIED)
8. Rojeska H., Jackson F. and Martin C.D. 15KS25000 Black Brant Engine (U) Operation and Handling instructions CARDE Issue No. 2 Tech. Note 1528/62 (UNCLASSIFIED)
9. U.S. Army Signal Missile Support Agency, Meteorological Data Report Black Brant I DRTE 03, 04 and 05, December 1960 (UNCLASSIFIED)
10. U.S. Army Signal Missile Support Agency, Meteorological Data Report Black Brant I CARDE 08 and CARDE 09, and Black Brant II CARDE 01 and CARDE 02, January 1961 (UNCLASSIFIED)

POSTSCRIPT

It is worth adding that two launchings of the IIA vehicle with modified fins gave very satisfactory results in August 1962 at Wallops Island. Also in November 1962 a BBI vehicle carrying an NO seeding experiment was successful at the U.S. range. In 1963 the 15KS25000 engine fired satisfactorily at the reopened Churchill Research Range in four BBI vehicles, two for NO seeding experiments in March and two for upper atmosphere experiments by the National Research Council in April.

8 - DSIS Circ: UK Liaison Officer

DISTRIBUTION

- 1 - Reference File
- 1 - DWER
- 1 - SES
- 1 - DRCL
- 1 - NRE

8 - Advisory Committee on Explosives and Propellant Research

- 1 - DSS/N
- 1 - DEE/TL
- 1 - Sec. CSAC
- 2 - DGFE
- 1 - NAE
- 3 - Canadian Arsenals, Director, Chemicals and Explosives Production
- 3 - Controller General, Inspection Services
- 2 - DRM London (1 for Canadian Armed Forces Ordnance Board Rep.)
- 1 - D Arm Eng. Library
- 1 - AFHQ/TL
- 1 - AMTS

21 - UK Distribution

5 - Admiralty for:

- 2 - Admiralty Centre for Scientific Information and Liaison
- 1 - Admiralty Director of Physical Research
- 1 - Chief Inspection of Naval Ordnance
- 1 - NOIL (Caerwent) Attn: Dr. J.W. Wight

3 - War Office, EP Interdependence for:

- 1 - Scientific Adviser to the Army Council
- 1 - Army Operational Research Group
- 1 - Director, Armament Research and Development Establishment

1 - Air Ministry for:

- 1 - Scientific Adviser to the Air Ministry

12 - Ministry of Aviation for:

- 4 - Technical Information and Library Services
- 1 - Director, Explosives Research and Development Establishment
- 1 - Director, Rocket Propulsion Establishment
- 1 - Director, Guided Weapons Research and Development (For ADGW (P&W)
- 1 - Chief, Inspector of Armament
- 1 - Director, Chemical Inspectorate
- 1 - Director General of Artillery (DG of A)
- 2 - Director, Royal Aircraft Establishment (1 - RAE/RPO)

9 - Naval Attache, US Embassy

SUGGESTED DISTRIBUTION:

- 1 - Naval Ordnance Lab., Technical Library
- 1 - US Naval Ordnance Test Station, Inyokern, Calif.
- 1 - US Naval Powder Factory Technical Library, Indian Head, Md.
- 2 - Bureau of Ordnance (1 - Tech. Library, 1 - Re2C)

65 - Senior Standardization Representative, US Army (625)

SUGGESTED DISTRIBUTION:

- 6 - Office of Chief of Ordnance (1 - ORDTB, 1 - ORDTM, 1 - ORDTU) (6)
- 1 - Secretary US Ordnance Committee (52)
- 1 - Ballistics Research Labs., APG (64)
- 1 - Picatinny Arsenal Technical Library, Dover, N.J. (155)
- 30 - Solid Propellant Information Agency (551)
- 1 - Redstone Arsenal
- 1 - Frankford Arsenal (151)
- 1 - Jet Propulsion Lab., California Institute of Technology (6)
- 1 - Poulten Labs., Stanford Research Institute (6)
- 4 - NASA Hqs. (2 - Solid Propellants Rockets Division (563)

19 - Air Attache, US Embassy

SUGGESTED DISTRIBUTION:

- 10 - Defence Documentation Centre
- 1 - Air Research and Development Command
- 1 - Air University, Maxwell Air Force Base
- 1 - Armament Center and Proving Ground, Eglin Air Force Base
- 1 - Aeronautical Systems Division

1 - UK Tech Rep., for British Defence Staff (Munitions/XP)

2 - Mr. Rolfe Kingsley, US Embassy

3 - Miss White, NRC/CB Library

UNCLASSIFIED

REPORT NO: CARDE T.N. 1525/63
PROJECT NO: D46-10-02-01
TITLE: Summary of performance of the 15KS25000 rocket engine used in the first sixteen Black Brant Vehicles.
AUTHORS: C.D. Martin and A. Ouellet
DATED: April, 1963
SECURITY GRADING: UNCLASSIFIED
INITIAL DISTRIBUTION: October, 1963

(NON-CONTROLLED GOODS)
DMC A
REVIEW: GCEC December 2012
