

TECHNICAL REPORT

1969 CAMARO - 302 CID
ENGINE PERFORMANCE EVALUATION



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TECHNICAL REPORT		DATE 10-19-70	DEPT. NO. 7480	REPORT NO. 4405.120
SUBJECT 1969 CAMARO - 302 CU. IN. ENGINE PERFORMANCE EVALUATION				
PROJECT OR CHARGE NO. 7480400		DATE OPENED 9-69 CLOSED 4-70	MODELS AFFECTED 1969 CAMARO	
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ABSTRACT <i>including the objective of the project</i> This report covers a brief performance evaluation of a 1969 Z-28 Chevrolet Camaro V-8 engine of 302 cubic inch displacement (4.00 bore and 3.00 stroke) at 11:1 compression ratio. WOT and part throttle rating data, air consumption, octane requirements, and heat rejection data was obtained. Also included in this report are results of performance tests of an optional "Service Pack" camshaft and 2-4 bbl. cross ram intake manifold.				

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS:

A - A 1969 Chevrolet Camaro Z-28 V-8 engine at 10.8:1 compression ratio, as tested, and 302 cubic inches produced the following WOT outputs:

- 1 - Laboratory Gross: Air cleaner installed, standard Holley 4-bbl. 800 CFM fixed jet carburetor, maximum power spark advance set at each speed, normal heat to intake manifold (Type of heat - exhaust), no exhaust heat valve, standard car oil pan with baffles and windage tray, and laboratory exhaust system:

Torque @1600 rpm (lb. ft.)	239.5
Torque, maximum (lb.-ft. @ rpm)	302.7 @ 4800
BHP, maximum (@ rpm)	308.8 @ 6000 *
BHP per cubic inch	1.056
FHP @ 4000 rpm	38.7
BMEP, maximum (psi @ rpm)	150.0 @ 4800
IMEP, maximum (psi @ rpm)	183.4 @ 5200
FMEP @ 4000 rpm (psi)	25.3
Mechanical Efficiency @ 1200 rpm	89.6
Mechanical efficiency @ 4000 rpm	84.0

Curve Sheet No.

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* Note: Dynamometer limited to 6000 rpm

- 2 - Cold Bare Gross: No air cleaner, as released mixture, 800 CFM Holley 4-bbl. carburetor, intake manifold heat passage blocked off, maximum power spark advance set at each speed, laboratory exhaust system installed, and no heat valve:

Torque, maximum (lb. ft. @ rpm) 312.9 @ 4400
 BHP, maximum (@ rpm) 318.9 @ 6000 *

Curve Sheet No.

1

- 3 - Full Net: Air Cleaner installed (1.1 inches of H₂O restriction @ 400 cubic feet per minute), fixed jet carburetor (4-bbl. Holley - 800 CFM), normal heat on the intake manifold (Type of heat - exhaust), no heat valve, automatic spark advance set manually at each speed, basic setting 4° B, car cooling viscous drive fan and dual exhaust system installed.

Torque, maximum (lb.-ft. @ rpm) 246.0 @ 4400 - 56.7 - 66.9
 BHP, maximum (@ rpm) 235.8 @ 5600 - 73.0 - 83.1

Curve Sheet No.

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- B - The following air consumption data were obtained with Hot Bare Gross operating conditions (Same as Cold Bare Gross except intake manifold heat is used).

Maximum Brake Horsepower 313.8 hp @ 6000 * - 6.1
 Maximum Torque 301.4 ft.-lb. @ 4800 rpm - 16.5
 Torque @ 2000 rpm 255.7 ft.-lb.
 Friction Horsepower @ 4000 rpm 40 hp.
 Volumetric Efficiency @ 4000 rpm 84.9%
 Maximum Volumetric Efficiency 88.0% @ 4400 rpm
 Indicated Specific Air Consumption 6.27 lbs. / IHP. Hr.
 @ 1200 rpm
 Minimum Indicated Specific Air Consumption 4.85 lbs. @ 5600 rpm / IHP.Hr.
 Maximum Brake Mean Effective Pressure (Corrected) 152 psi @ 4800 rpm
 Maximum Indicated Mean Effective Pressure (Corrected) 185.0 psi @ 5200 rpm
 Friction Mean Effective Pressure @ 4000 rpm 25.8 psi
 Mechanical Efficiency @ 1200 rpm 89.5%
 Mechanical Efficiency @ 4000 rpm 85.0%

Note: * Dynamometer limited to 6000 rpm.

The data appear on Engine Performance Summary Sheet (I), Curve Sheet No. 21 and is plotted on Curve Sheet No. 20.

C - Optimum Fuel Loops Were Not Obtained With The Z-28 Engine.

The Minimum Brake Specific Fuel Consumption observed under Full Net (Less car cooling fan) operating conditions was:

0.499 $\frac{\text{Lbs.}}{\text{BHP Hr.}}$ @ 3200 rpm

The data appears on Engine Performance Summary Sheet (II), Curve Sheet No. 22, and is plotted on Curve Sheets 7 thru 14. The data was obtained with the carburetor adjusted to maximum intake vacuum at idle.

D - The corrected octane requirements of the 1969 Z-28 Camaro engine at WOT were:

<u>Octane Number</u> <u>(Primary Reference Fuels)</u>	<u>RPM</u>	<u>Spark Advance</u>
99.8	1600	Maximum Power
96.5	1600	2% Power Loss
86.0	1600	Governor Spark Adv.
93.8	3200	Maximum Power
90.5	3200	2% Power Loss
87.2	3200	Governor Spark Adv.

Octane Number
(Full Boiling Range Fuels)

86.0	1600	Automatic
89.4	3200	Automatic

Curve Sheets No. 23 and 24

E - Minimum Specific Heat Rejection to the engine coolant at WOT was:

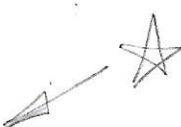
23.4 BTUs/Minute/Obs. Hp. @ 4000 rpm. Engine water flow at 4000 rpm was 329 Lbs./Minute.

Curve Sheets No. 25 thru 28

RECOMMENDATIONS:

This report is for record purposes.

PARTS TESTED:A - Engine Specifications:

Engine	1969 Chevrolet RPO Z-28
Type	OHV V-8
Bore and Stroke	4.00" X 3.00"
Displacement	302 Cu. In.
Weight	Not Available
Compression Ratio	11.0:1 (<u>10.8:1</u> As Tested) 
Firing Order	1-8-4-3-6-5-7-2 (GM and Chrysler designation)
Spark Plugs	Released AC 44 WOT Performance: J-4 (Champion)

Refer to photographs No. 7070-305, 306, and 307.

B - Combustion Chamber Design:

A wedge combustion chamber is used. Refer to photographs Nos. 7070-314 and 311.

C - Carburetor:

Type - 4-Barrel Holley #3923289 (R4053A)

Venturi Diameter - 1-3/8" primary and 1-9/16" secondary

Throttle Bore - 1-11/16" (primary and secondary)

D - Intake Manifold:

An aluminum high rise, conventional two-level intake manifold is used. Refer to photographs Nos. 7070-309 and 322.

E - Exhaust Manifold:

The exhaust manifolds are of four port, cast iron, W shaped design. The right has a rear outlet and the left outlet is between cylinders 5 and 7. Refer to photographs Nos. 7070-316 and 310.

F - Camshaft:

	<u>Intake</u> <u>Advertised/Chrysler</u>	<u>Exhaust</u> <u>Advertised/Chrysler</u>
Opens	60°50' / 38° BTC	108°50' / 85° BBC
Closes	105°23' / 78° ABC	57°23' / 31° ATC
Apparent Dur.	346°13' / 296°	346°13' / 296°
Overlap	118°13' / 69°	
Cam Centerline	108°50' / 110° ATC	115°44' / 117° BTC

The valve train is shown in photograph No. 7070-317

G - Valve and Port Data:

	<u>Intake</u>	<u>Exhaust</u>
Rocker Arm Ratio - Nominal	1.50	1.50
Valve Diameter	2.02	1.60
Maximum Valve Lift - Nominal (From base circle)	.485	.485
- Actual	.478	.480
Maximum Valve Lifted Area	2.561 in. ²	1.909 in. ²
<u>Maximum Valve Lifted Area</u> <u>One cylinder's displacement</u>	.0678 in. ⁻¹	.0506 in. ⁻¹
Basic Intake Branch and Port Area	2.2 in. ²	
Intake Runner Area	3.1 in. ²	
Exhaust Port Area at Face	1.6 in. ²	
Valve Lash - Set hot at:	.030	.030

Photograph 7070-317 shows the cam and valve train used in the Z-28 engine.

PROCEDURE AND RESULTSA - Performance Run-in:

A standard 13-1/2 hour Engine Development Laboratory run-in was completed with no problems arising. The following Laboratory Performance Evaluation was then performed.

PROCEDURE AND RESULTS: (Continued)

B - Heat Rejection: The heat rejection data was obtained by Department 7740, Cooling Laboratory. The data are plotted on Sheets 25 through 28. A summary follows:

<u>RPM</u>	<u>Water Flow</u> <u>(Lbs./Minute)</u>	<u>Total Heat Rej.</u> <u>BTUs/Minute</u>	<u>Specific Heat Rej.</u> <u>BTUs/BHP-Minute</u>
2000	150	2900	32.2
2800	223	3450	27.3
4000	329	4840	23.4

C - Octane Requirements: Spark and Octane requirements were run according to Department 7480's standard procedures. Results are shown on Curve Sheets 23 and 24. These results are reported at three different spark advance settings:

1. Automatic Spark Advance (set manually).
2. Spark advance giving a 2% power loss.
3. Maximum power spark advance (set at each speed).

Power loss to spark advance for this 302 cu. in. 11:1 compression ratio engine is approximately 5% from 2000 through 4000 rpm. Power loss at higher speeds is much lower (1.4% at 4400 rpm, which was the highest speed at which WOT spark loops were run).

Fuel requirements are very low in the low speed range but are in the premium fuel range at the high speeds at which this engine is designed to run.

Photographs No. 7070-311, 313, and 314 show combustion chambers and piston tops.

D - Fuel Consumption

- 1 - Optimum Fuel Loops, were not obtained with the Z-28 engine.
- 2 - Part Throttle Fuel Economy - These runs were made using the standard Z-28 Holley 4-bbl. carburetor (idle set to maximum intake vacuum @ 900 rpm.) on a Full Net (Less Car Cooling fan) basis at 1200, 1600, 2000, 2400, 2800, 3200, 3600, and 4000 rpms. The throttle angle was varied to obtain certain specified loads at each of these speeds. Spark advance was set manually to the

released spark advance curve at each speed and load combination. Plots of BMEP vs. BSFC can be seen on Sheets 7 thru 14, and a flow curve of the carburetor used is on Sheet 15.

Results of the part throttle fuel economy tests shown the engine to be very rich at low speeds and rich on higher speeds. The following brief table shows BSFC data for the Z-28 and the 340 engine (rating data with AVS carburetor).

Engine	RPM	B.S.F.C. Lb/BHP-Hr.		
		20 BMEP	30 BMEP	50 BMEP
Z-28	1600	1.32	1.08	.760
	2400	1.03	.770	.640
	3600	.970	.775	.630
340	1600	.775	.630	.520
	2400	.815	.670	.525
	3600	.860	.685	.545

Part throttle distribution was also checked (oxygen meter). Results show poor F/A distribution with front rich (.080 F/A) to rear lean (.060 F/A) being a typical pattern. Curve Sheets 16, 17, 18, and 19 show this distribution.

The Z-28 engine uses an air pump (photograph 7070-318) for emission control. This method of control requires P/T mixtures richer than normal Chrysler practice but not as rich as the particular carburetor tested (.070 to .075 F/A part throttle mixtures). Thus, the carburetor was flowed and checked to see if it is typical of Z-28 production. Curve Sheet No. 15 shows the Z-28 flow curve as received. A comparison of this data to a production flow curve borrowed from Holley shows our carburetor to be at or slightly above the rich limit throughout the part throttle range and within limits at WOT.

E - Standard Rating Series - This series of runs was made according to the standard procedures of Department 7480. The plotted data from these runs may be found on Curve Sheets 1 thru 5, and an accessory breakdown of losses in the rating series are shown on Curve Sheet No. 6. The data is also tabulated on Engine Performance Summary Sheets II and III, Curve Sheets 22 and 22A.

A Hot Bare Gross with Air Consumption run was made using a Cox Air Flow Meter No. 3 to measure air flow. The data appears on Engine Performance Summary Sheet I, Sheet 21, and plotted on Curve Sheet No. 20.

Results of WOT rating data are tabulated below with laboratory gross power used as a baseline:

<u>Z-28 Chevy</u>	<u>Peak Torque @ 4400 RPM</u>	<u>BHP @ 6000 RPM</u>
	+10.2	+10.1
Cold Bare Gross	+12 lb.ft. (4%)	+6* (2%)
Laboratory Gross	- Baseline -	-
Full Net	-55 lb.ft. (18%) -56.7	-79 (25%) -73

The high gross to net loss for the Z-28 engine is due to exhaust system losses (68 BHP @ 6000 rpm). The exhaust system used is a dual system with a single transverse muffler. A sketch of the muffler is shown on Curve Sheet No. 30. Photograph 7070-323 shows the system.

As a comparison, the 340 AVS four-barrel laboratory gross rating shows 52 lb.ft. more peak torque and 9 BHP higher peak power. Peak torque for the 340 occurs @ 3600 rpm, and peak power at 5600 rpm.

The Z-28 engine has a windage tray and baffled pan for oil control. Because of this and the time required to build a deep pan all performance work was done with standard car oil and windage tray. Photograph 7070-313 shows the tray and oil pan.

DISCUSSION:

A - Z-28 Engine:

The 1969 Z-28 Chevrolet Camaro is a 5-liter (302 cu. in.) optional engine and car package made available by Chevrolet to make the engine and car eligible for Trans-Am Sedan racing. In keeping with the racing background, the production engine is performance oriented, with mechanical lifter camshaft, large carburetor, low restriction air cleaner, etc. The car package is also race-oriented with spoilers, special hood scoops, etc.

To summarize, the 1969 Z-28 engine is a high specific output engine which with a high numerical rear axle (3.7:1 std.) successfully meets the Trans-Am street and racing image.

As a comparison to the 1969 engine, Trans-Am rules were relaxed in 1970, no longer requiring manufacturers to build an engine of exactly 5-liters displacement. Instead, this displacement would be arrived at by modifying an existing engine--i.e. by deboring or destroking. Consequently, the 1970 Z-28 Camaro engine is a 350 cu. in. engine with a shorter duration camshaft, making a much more streetable package.

* Note: Gross power peak is higher than 6000 rpm.

Also included in this report is a table comparing the 1969 Z-28 302 cu. in. engine, the 1970 340 cu. in. Chrysler engine, and a 1966 350 Bhp, 327 cu. in. engine. (Curve Sheets 33, 34 and 35).

B - 2-4-Bbl. Z-28 Engine:

Optional pieces available for the Z-28 engine, both for street and Trans-Am racing, include a 2-4 Bbl. cross ram intake manifold and a special "Service Pack" camshaft, photograph No. 7070-308. As these pieces were available, WOT power runs were made to evaluate their effect on performance. Results are shown on Curve Sheet 29 and tabulated below:

	Torque Peak @ 4800 rpm.	Power @ 6000 *
Laboratory gross		Baseline
Service Pack cam	+ 7 lb.-ft.	+ 1 BHP
2-4 Bbl. intake (cold) and service pack cam	+16 lb.-ft.	+24 BHP

The "Service Pack" cam is slightly "hotter" than the standard cam and presumably has better valve dynamics. A comparison follows:

Camshaft	Chevrolet	Chrysler	Lift (int./exh.)	
			Advertised	Actual
R.P.O. Z-28	346°13'-346°13'-112°17'	296-296-69	.485/.485	.478/.480
Service Pack	299°50'-313°94'- 83°24'	300-308-81	.485/.503	.493/.512

Camshaft plots are shown on Curve Sheets 31 and 32. *(REVERSED)*

The intake manifold is aluminum, cross-ram type with a removable plenum cover, photographs 7070-319 and 320. Two 600 CFM Holley 4-Bbl. carburetors are used.

* Note: Power peak higher - dyno limit 6000 rpm.

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- 3 Laboratory Gross
- 4 Laboratory Gross Distribution
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- 6 WOT Rating Breakdown

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- 8 Part Throttle Fuel Economy - 1600 rpm
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- 10 Part Throttle Fuel Economy - 2400 rpm
- 11 Part Throttle Fuel Economy - 2800 rpm
- 12 Part Throttle Fuel Economy - 3200 rpm
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- 14 Part Throttle Fuel Economy - 4000 rpm
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③

COMPETITIVE ENGINE COMPARISON

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	Z-28 CHEVY 1969 CAMARO	CHEVY II 1966	340-4 BBL 1970	
AIR CLEANER	UNSILENCED, PAPER 3 x 13 7/8 OD	DOUBLE SNORKEL PAPER 3 1/2 x 11 1/2 OD	SEMI-SILENCED (DUAL SNORKEL CLR PAPER 2 1/2 x 12 3/4 OD, w/o SNORKELS)	
CARBURETOR - PRI. VENT/T.B.	1 3/8 x 1 1/16	1 1/4 x 1 9/16	1 3/16 x 1 7/16	
SEC. VENT/T.B.	1 9/16 x 1 1/16	1 5/16 x 1 9/16	1 1/16 AIR VALVE	
INTAKE MANIFOLD - RUNNER, H x W	1.75 x 1.75	x	1.50 x 1.98	
AREA (IN ²)	3.1	2.9	2.9	
- BRANCH, AREA (IN ²)	2.2	2.2	2.1	
- MATERIAL	ALUMINUM	ALUMINUM	CAST IRON	
CYLINDER HEAD - INT. PORT, AREA (IN ²)	2.2	2.2	2.2	
, AREA/IN ³	.058	.054	.055	
- INT. VALVE DIA.	2.02	2.02	2.02	
- EXH. VALVE DIA.	1.60	1.60	1.60	
- EXH. PORT, AREA (IN ²)	1.6	1.6	1.7	
, AREA/IN ³	.042	.039	.041	
EXHAUST MANIFOLD - TYPE	"W" SHAPE	RAM'S HORN	STREAMLINED	
- BRANCH AREA (IN ²)	1.9	1.6	2.1	
- OUTLET DIA (IN)	1.85 I.D.	1.9 I.D.	2.3 I.D.	

COMPETITIVE ENGINE COMPARISON

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	Z-28 CHEVY 1969 CAMARO	CHEVY II 1966	340-4 BBL 1970 "A" BODY
EXHAUST SYSTEM - PIPE	2 1/4	2 1/2	2 1/4
- MUFFLER	SINGLE TRANSVERSE 2 1/4 IN X 2 OUT	2 1/8 IN X 2 OUT	2 1/4 X 2 1/4 X 2 1/4
- TAIL PIPE	2	2" / RESONATOR	2 1/4
- BACK PRESS. @ 4100	9.5" HG	8.8" HG	9.8" HG
- " " @ 5200	11.8" HG	11.4" HG	11.4" HG
CAM SHAFT - DURATION, INT-EXH-O'LAP	296-296-69	276-276-48	268-276-111
- LIFT, INT-EXH, (IN)	.478 - .480	.434 - .431	.430 - .445
- ϕ INTAKE (ATC)	110°	111°	112°
- ϕ EXHAUST (BTC)	117°	117°	116°
TAPPET	MECH	HYD	HYD
ST. GOOD SPEED - DYNAMOMETER	6000 PLUS	5500	5600
DISTRIBUTOR	SINGLE BREAKER (OPTIONAL MAGNETIC TRIGGER AXIS)	SINGLE BREAKER	MAN TRANS M - DOUBLE BREAKER A - SINGLE BREAKER L - AUTO TRANS
SPARK PLUG	AC44	AC44	NGY
LOSS TO S/A - % @ 3200 / 4400 rpm	5.7 / 1.4	2.2 / 1.2	4.1 / 7.8
OCTANE NUMBER - PRI. REF. - MAX @ WOT	99.8 @ 1600	97.2 @ 1200	101.3 @ 1200
OIL PAN BAFFLE	WINDAGE TRAY 4 OIL PAN BAFFLE	SUSPENDED	WINDAGE TRAY
FAN SIZE	18" D, 7 B, 2 PH	18" D - 5 BLADE	18" D, 7 B, 2 1/4 PH
DRIVE	VISCOUS	VISCOUS	VISCOUS