PB80-159601

EPA-AA-TAEB 76-20

An Evaluation of the Morse Constant Speed Accessory Drive

June 1976

Technology Assessment and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Environmental Protection Agency

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-AA-TAEB 76-20	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE An evaluation of the morse constant speed accessory drive		5. REPORT DATE June 1976
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) (no author)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Technology Assessment & Evaluation Branch Emission Control Technology Division Office of Mobile Source Air Pollution Control U.S. Environmental Protection Agency Ann Arbor, MI 48105		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS		13. TYPE OF REPORT AND PERIOD COVERED Technical
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The EPA receives information about devices for which emission reduction or fuel economy improvement claims are made. In most cases, these devices ar are being recommended or promoted for retrofit to existing vehicles although some represent advanced systems for meeting future standards. The EPA is interested in evaluating the validity of the claims and invites proponents of such devices to provide to the EPA complete technical data on the device's principle of operation, together with test data on the device made by independent laboratories. The conclusions drawn from the EPA confirmatory tests are necessarily of limited applicability. Morse Chain has developed a variable-ratio drive to replace the fixed-ratio waterpump drive conventionally used on automobiles. Information and data supplied to the EPA by Morse indicated that the Morse variable-ratio drive had potential for fuel economy improvement when compared to conventional fixed-ratio drives. The fuel economy improvement is due to reducing the horsepower used to drive the water pump, and hence the engine-powered accessories. To attempt to quantify this potential fuel economy improvement an evaluation of the Morse drive was scheduled.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Fuel economy Emission	Morse chain Emission control device	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 15p.
RELEASE UNLIMITED	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

Background

The Environmental Protection Agency receives information about many systems which appear to offer potential for emission reduction or fuel economy improvement compared to conventional engines and vehicles. EPA's Emission Control Technology Division is interested in evaluating all such systems, because of the obvious benefits to the Nation from the identification of systems that can reduce emissions, improve economy, or both. EPA invites developers of such systems to provide to the EPA complete technical data on the system's principle of operation, together with available test data on the system. In those cases in which review by EPA technical staff suggests that the data available show promise, attempts are made to schedule tests at the EPA Emissions Laboratory at Ann Arbor, Michigan. The results of all such test projects are set forth in a series of Technology Assessment and Evaluation Reports, of which this report is one.

The conclusions drawn from the EPA evaluation tests are necessarily of limited applicability. A complete evaluation of the effectiveness of a system in achieving performance improvements on the many different types of vehicles that are in actual use requires a much larger sample of test vehicles than is economically feasible in the evaluation test projects conducted by EPA. For promising systems it is necessary that more extensive test programs be carried out.

The conclusions from the EPA evaluation test can be considered to be quantitatively valid only for the specific test car used, however, it is reasonable to extrapolate the results from the EPA test to other types of vehicles in a directional or qualitative manner, i.e., to suggest that similar results are likely to be achieved on other types of vehicles.

Morse Chain, Division of Borg Warner Corporation, has developed a variable-ratio drive to replace the fixed-ratio waterpump drive conventionally used on automobiles. Information and data supplied to the EPA by Morse indicated that the Morse variable-ratio drive had potential for fuel economy improvement when compared to conventional fixed-ratio drives. The fuel economy improvement is due to reducing the horsepower used to drive the waterpump, and hence the engine-powered accessories.

To attempt to quantify this potential fuel economy improvement, an evaluation of the Morse drive was scheduled at the EPA's Ann Arbor, Michigan laboratory.

Test Vehicle Description

The vehicle (furnished by Morse) used in the test program was a 1975 Chevrolet Nova powered by a 1976 305 cu. in. engine, and equipped with a three speed automatic transmission. The Nova was tested at an inertia weight of 4000 lbs.

In the standard production configuration, the waterpump is driven at 1.25 times crankshaft speed by means of pulleys and V-belt. Accessories (alternator, air conditioning and power steering) are driven from the waterpump shaft with V-belts and pulleys. The drive ratios for the accessories must be such that adequate output can be obtained from the accessories at low engine speeds (idle, stop-and-go driving, etc.). Consequently, at high engine speeds, the accessories may be driven faster than is necessary to provide required outputs, and thus absorb more power than is necessary.

The Morse Controlled Speed Accessory Drive (CSAD) is designed to reduce this energy loss by using a variable-ratio drive between the crankshaft and waterpump. The Morse CSAD replaces the fixed pulleys on the crankshaft and waterpump with pulleys whose effective diameter is controlled by engine speed (rpm). The waterpump and crankshaft pulleys are connected by a variable speed belt.

The CSAD is designed to maintain a fixed ratio between crankshaft and waterpump up to about 1100 rpm (engine speed). As the engine speed increases above 1100 rpm, the CSAD changes the drive ratio to maintain constant output up to 2100 rpm (engine speed). Above 2100 rpm, the ratio of the CSAD is fixed, so further increases in engine speed result in increased accessory speeds. However, the rate of increase in accessory speeds is less than the rate of increase in engine speed.

In the production configuration, the test vehicle is equipped with a flex-fan. The flex-fan is also used in the Morse CSAD installations, and is driven on the waterpump shaft.

Test Program

Exhaust emissions and fuel economy were measured in accordance with the 1975 Federal Test Procedure ('75 FTP). Emissions and fuel economy were also measured during the EPA Highway Fuel Economy Test and under several steady state conditions. One exception to the '75 FTP was the ambient temperature maintained during the test program. The test cell temperature was maintained between 86 and 91°F during all tests. This was done to provide additional load on the engine accessories during certain portions of the test program.

One of the problems of this test program was to generate sufficient accessory loads during a chassis dynamometer emission test to demonstrate the effects of the Morse CSAD. It was anticipated that the CSAD would show its greatest benefit under conditions of high accessory loading. Of the accessories installed on the test vehicle, the alternator and air conditioning compressor could provide the most easily adjustable loads on the engine.

Tests were conducted under two accessory loads. For the first test condition, no additional accessory loads were imposed on the engine. The benefits of the CSAD were expected to be minimal under this condition. For the second test condition, the air conditioning system was operated with driver controls set at maximum air conditioner settings, and the high-beam headlights were turned on. Operating the air conditioning at maximum output kept the air conditioning compressor operating continuously during the test. Additional load was imposed on the air conditioning system by the higher-than-normal ambient temperature maintained throughout the test program. No attempt was made to vary the power steering pump load.

Tests were conducted with and without (baseline) the CSAD installed on the test vehicle. For each vehicle configuration, tests were conducted with and without increased accessory load.

Test Results

Test results, summarized below, show the effect of the Morse CSAD on exhaust emissions and fuel economy during the '75 FTP.

'75 FTP*
Mass emissions in
grams per mile
(grams per kilometer)
No accessory load

	HC	CO	NOx	Fuel Economy (Fuel Consumption)
Baseline-avg. of 2 tests	0.60 (0.37)	6.3 (3.9)	2.20 (1.37)	14.7 miles/gal. (16.0 liters/100km)
CSAD-avg. of 2 tests	0.69 (0.43)	8.0 (5.0)	2.20 (1.37)	14.6 miles/gal. (16.1 liters/100km)
% Change	+15%	+27%	0	-1% (+1%)

* Ambient temperature between 86-91°F.

'75 FTP*
Mass emissions in
grams per mile
(grams per kilometer)
AC-lights on

	HC	CO	NOx	Fuel Economy (Fuel Consumption)
Baseline-avg. of 2 tests	1.05 (0.65)	21.9 (13.6)	3.13 (1.95)	12.6 miles/gal. (18.7 liters/100km)
CSAD-avg. of 2 tests	0.88 (0.55)	15.6 (9.7)	2.88 (1.79)	13.3 miles/gal. (17.7 liters/100km)
% change from baseline	-16%	-29%	-8%	+6% (-5%)

Similarly, the results obtained during the Highway Fuel Economy Test are summarized below.

HFET*
Mass emissions in
grams per mile
(grams per kilometer)
No accessory load

	HC	CO	NOx	Fuel Economy (Fuel Consumption)
Baseline-avg. of 2 tests	0.14 (0.09)	5.6 (3.5)	1.88 (1.17)	20.1 miles/gal. (11.7 liters/100km)
CSAD-avg. of 2 tests	0.43 (0.27)	17.8 (11.1)	1.72 (1.07)	20.3 miles/gal. (11.6 liters/100km)
% change from baseline	+207%	+218%	-9%	+1% (-1%)

* Ambient temperature between 86-91°F.

HFET*
Mass emissions in
grams per mile
(grams per kilometer)
AC-lights on

	HC	CO	NOx	Fuel Economy (Fuel Consumption)
Baseline-avg. of 2 tests	0.80 (0.50)	30.2 (18.8)	3.06 (1.90)	17.2 miles/gal. (13.7 liters/100km)
CSAD-avg. of 2 tests	0.93 (0.58)	39.1 (24.3)	2.63 (1.63)	18.2 miles/gal. (12.9 liters/100km)
% change from baseline	+16%	+29%	-14%	+6% (-6%)

A detailed breakdown of '75 FTP, HFET and steady state test data can be found in Tables I-VII.

Discussion

The effect of the Morse CSAD on fuel economy ranged from no change with no accessory load, to a 6% improvement with accessory load. The effect on exhaust emissions (during the '75 FTP) was variable, increasing HC and CO emissions without accessory load, and reducing HC, CO and NOx with accessory loads. The changes in exhaust emissions (CSAD installation vs. baseline) could be due to more than one effect of the CSAD. Reduced engine loading with the CSAD installed would tend to increase HC and CO emissions, and lower NOx emissions. Changes in engine cooling as a result of the CSAD installation might also affect emissions (see the following paragraph).

During the Highway Test, it was noted that the engine temperature gauge was reading higher with the Morse CSAD installed (compared to the production configuration). This is probably due to the slower waterpump speed and resultant decrease in coolant circulation, although the cooling fan used during the dynamometer test does not provide air flow equivalent to actual on-the-road driving. Table VIII shows waterpump speed and crankshaft speed measured during the steady state tests. The waterpump speed is reduced 22-31% in the speed range most prevalent during the Highway Test, so the change in engine temperature is not suprising. Inadequate cooling could be a possible problem area for a car equipped with the Morse CSAD. The loads encountered in the EPA tests do not impose much strain on the engine. Higher engine temperatures would be expected when driving in mountainous terrain or when heavily loaded (such as in trailer pulling).

*Ambient temperature between 86-91°F.

For all test conditions, the exhaust emission penalty due to air conditioner operation was greater for the production accessory drive than for the Morse CSAD. The fuel economy penalty due to increased accessory loads was 9-10% with the Morse CSAD installed and 14% with the production accessory drive installed.

It should be noted that normal test procedures for new vehicle certification do not call for operation of the air conditioner at maximum output during the emissions test. For new vehicle certification, air conditioning load is simulated by increasing the normal road load horsepower absorbed by the dynamometer by 10%. Average road load for each inertia weight class is given as part of the '75 FTP in the Federal Register (Federal Register, June 30, 1975, Vol. 40 No. 126, Part III).

Conclusions

1. The Morse Controlled Speed Accessory Drive does have a beneficial effect on fuel economy when the test procedure is modified to provide conditions of high accessory load. For the vehicle used in the EPA test program, the improvement in fuel economy was approximately 6%.

2. The current design of the CSAD might not drive the waterpump at a sufficient speed to provide adequate engine cooling under high load conditions. This point was not investigated during the test program, but engine temperature was unusually high in some portions of the test program.

3. The Morse CSAD reduced the fuel economy penalty caused by operation of the air conditioning and headlights at maximum setting from about 14% to 9-10%. Savings could be greater under more severe air conditioner requirements but this was not quantified in the EPA tests.

Table I

'75 FTP
Mass emissions in
grams per mile
(grams per kilometer)
No accessory load

Test #	HC	CO	CO2	NOx	mpg (ℓ/100km)
Baseline					
77-1279	0.51 (0.32)	5.1 (3.2)	594. (369.)	2.27 (1.41)	14.7 (16.0)
77-1416	0.68 (0.42)	7.4 (4.6)	593. (369.)	2.13 (1.32)	14.6 (16.1)
Average	0.60 (0.37)	6.3 (3.9)	594. (369.)	2.20 (1.37)	14.7 (16.0)
Morse CSAD					
77-1265	0.76 (0.47)	7.6 (4.7)	590. (367.)	2.12 (1.32)	14.7 (16.0)
77-1420	0.62 (0.39)	8.4 (5.2)	595. (370.)	2.28 (1.42)	14.5 (16.2)
Average	0.69 (0.43)	8.0 (5.0)	593. (369.)	2.20 (1.37)	14.6 (16.1)

Table II

'75 FTP
Mass emissions in
grams per mile
(grams per kilometer)
AC-lights on

Test #	HC	CO	CO_2	NOx	mpg (ℓ/100km)
Baseline					
77-1386	1.02 (0.63)	23.4 (14.5)	687. (427.)	3.43 (2.13)	12.2 (19.3)
77-1418	1.08 (0.67)	20.4 (12.7)	645. (401.)	2.82 (1.75)	13.0 (18.1)
Average	1.05 (0.65)	21.9 (13.6)	666. (414.)	3.13 (1.95)	12.6 (18.7)
Morse CSAD					
77-1272	0.95 (0.59)	17.2 (10.7)	643. (400.)	2.76 (1.72)	13.2 (17.8)
77-1773	0.80 (0.50)	13.9 (8.7)	638. (397.)	3.00 (1.87)	13.4 (17.5)
Average	0.88 (0.55)	15.6 (9.7)	641. (399.)	2.88 (1.79)	13.3 (17.7)

Table III

HFET
Mass emissions in
grams per mile
(grams per kilometer)
No accessory load

Test #	HC	CO	CO_2	NOx	mpg (ℓ/100km)
Baseline					
77-1280	0.09 (0.06)	3.2 (2.0)	435. (270.)	1.96 (1.22)	20.1 (11.7)
77-1417	0.19 (0.12)	7.9 (4.9)	430. (267.)	1.79 (1.11)	20.0 (11.8)
Average	0.14 (0.09)	5.6 (3.5)	433. (269.)	1.88 (1.17)	20.1 (11.7)
Morse CSAD					
77-1266	0.37 (0.23)	15.2 (9.4)	409. (254.)	1.64 (1.02)	20.4 (11.5)
77-1421	0.48 (0.30)	20.3 (12.6)	409. (254.)	1.79 (1.11)	20.1 (11.7)
Average	0.43 (0.27)	17.8 (11.1)	409. (254.)	1.72 (1.07)	20.3 (11.6)

Table IV

HFET
Mass emissions in
grams per mile
(grams per kilometer)
AC-lights on

Test #	HC	CO	CO_2	NOx	mpg (ℓ/100km)
Baseline					
77-1287	0.51 (0.32)	21.4 (13.3)	477. (296.)	2.97 (1.85)	17.3 (13.6)
77-1419	1.09 (0.68)	38.9 (24.2)	457. (284.)	3.14 (1.95)	17.0 (13.8)
Avera	0.80 (0.50)	30.2 (18.8)	467. (290.)	3.06 (1.90)	17.2 (13.7)
Morse CSAD					
77-1273	0.91 (0.57)	36.2 (22.5)	429. (267.)	2.67 (1.66)	18.2 (12.9)
77-1774	0.95 (0.59)	41.9 (26.0)	422. (262.)	2.58 (1.60)	18.1 (13.0)
Average	0.93 (0.58)	39.1 (24.3)	426. (265.)	2.63 (1.63)	18.2 (12.9)

Table V

Steady State
Mass emissions in
grams per mile
(grams per kilometer)
No accessory load

	HC	CO	CO_2	NOx	MPG (ℓ/100km)
Baseline					
idle (300 sec.)	0	0	498.gms	0.87gms	
15 mph (24 kph)	0.01	0	472. (293.)	0.45 (0.28)	18.8 (12.5)
30 mph (48 kph)	0.04 (0.02)	0	348. (216.)	0.86 (0.53)	25.5 (9.2)
45 mph (72 kph)	0.04 (0.02)	0.01	392. (244.)	1.05 (0.65)	22.6 (10.4)
60 mph (97 kph)	0.20 (0.12)	13.4 (8.3)	430. (267.)	0.81 (0.50)	19.6 (12.0)
Morse CSAD					
idle (300 sec.)	0	0.1gms	516.gms	1.13gms	
15 mph (24 kph)	0.09 (0.06)	0	486. (302.)	0.51 (0.32)	18.2 (12.9)
30 mph (48 kph)	0.06 (0.04)	0	360. (224.)	0.99 (0.62)	24.6 (9.6)
45 mph (72 kph)	0.11 (0.07)	1.42 (0.88)	391. (243.)	0.99 (0.62)	22.5 (10.5)
60 mph (97 kph)	0.43 (0.27)	18.5 (11.5)	403. (250.)	2.2 (1.37)	20.5 (11.5)

Table VI

Steady State
Mass emissions in
grams per mile
(grams per kilometer)
AC-lights on

	HC	CO	CO_2	NOx	mpg (ℓ/100km)
Baseline					
idle (300 sec.)	0	0.9gms	495gms	2.53gms	
15 mph (24 kph)	1.19 (0.74	13.2 (8.2)	548. (341.)	1.26 (0.78)	15.5 (15.2)
30 mph (48 kph)	0.87 (0.54)	21.0 (13.1)	441. (274.)	0.68 (0.42)	18.6 (12.6)
45 mph (72 kph)	0.05 (0.03)	2.0 (1.2)	465. (289.)	1.75 (1.09)	18.9 (12.4)
60 mph (97 kph)	0.82 (0.51)	35.0 (21.8)	436. (271.)	4.27 (2.65)	18.0 (13.1)
Morse CSAD					
idle (300 sec.)	0	1.8gms	511.gms	2.74gms	
15 mph (24 kph)	1.07 (0.67)	11.2 (7.0)	584. (363.)	1.15 (0.71)	14.7 (16.0)
30 mph (48 kph)	1.07 (0.67)	25.1 (15.6)	406. (252.)	0.64 (0.40)	19.8 (11.9)
45 mph (72 kph)	0.44 (0.27)	28.7 (17.8)	404. (251.)	1.30 (0.81)	19.7 (11.9)
60 mph (97 kph)	1.18 (0.73)	49.4 (30.7)	426. (265.)	3.26 (2.03)	17.5 (13.4)

Table VII

Individual Bag Emissions in Grams per Mile

Test #	Bag 1: Cold Transient					Bag 2: Stabilized					Bag 3: Hot Transient				
	HC	CO	CO2	NOx	MPG	HC	CO	CO2	NOx	MPG	HC	CO	CO2	NOx	MPG
Baseline: No accessory load															
77-1279	1.32	10.0	608.	3.39	14.1	0.09	2.6	616.	1.62	14.3	0.70	6.4	540.	2.65	16.1
77-1416	1.25	9.4	610.	3.58	14.1	0.31	5.0	618.	1.39	14.2	0.94	10.6	534.	2.44	16.0
Morse CSAD: No accessory load															
77-1265	1.98	14.7	587.	3.12	14.4	0.30	5.2	620.	1.48	14.1	0.69	6.9	535.	2.60	16.2
77-1420	1.33	9.9	603.	3.47	14.3	0.25	6.8	627.	1.63	13.9	0.81	10.5	530.	2.61	16.2
Baseline: AC - lights on															
77-1386	1.53	20.6	702.	4.93	12.0	0.74	21.7	717.	2.77	11.8	1.17	28.6	618.	3.58	13.3
77-1418	1.40	13.8	666.	4.48	12.8	0.75	19.5	676.	2.05	12.5	1.46	27.2	570.	3.06	14.4
Morse CSAD: AC - lights on															
77-1272	1.38	13.9	656.	4.00	13.0	0.61	16.5	680.	2.05	12.5	1.28	21.1	563.	3.17	14.8
77-1773	1.24	10.2	651.	4.43	13.2	0.61	13.7	668.	2.32	12.8	0.82	17.2	571.	3.23	14.8

Table VIII

Morse CSAD
Crankshaft rpm vs. Waterpump rpm

Vehicle Speed	Crankshaft rpm	Waterpump rpm
Idle (neutral)	600	750
Idle (drive)	550	600
15 mph (24 kph)	800	900
30 mph (48 kph)	1100	1100
45 mph (72 kph)	1600	1250
60 mph (97 kph)	2250	1550

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1975 Chevrolet Nova
Emission control system - 1976 Engine, OC/EGR/EFE

Engine

type	4 stroke, Otto Cycle, V-8 ohv
bore x stroke	3.74 x 3.48 in./95 x 88.4mm
displacement	305 cu. in./4999cc
compression ratio	8.5:1
maximum power @ rpm	140 hp/104kW at 3800 rpm
fuel metering	2 barrel carburetor
fuel requirement	91 RON, unleaded

Drive Train

transmission type	3 speed automatic

Chassis

type	Front engine, rear wheel drive
tire size	FR 78 x 14
curb weight	3797 lbs/1722 kg
inertia weight	4000 lbs.
passenger capacity	5

Emission Control System

basic type	OC/EGR/EFE
oxidation catalyst location	Underfloor
substrate.	Pellet
volume	260 cu. in./4261cc
loading.	.05 troy oz./1.56gm
EGR type	Ported
durability accumulated on system .	33000 mi/5300km