Emission Characteristics of Torch Chamber S.I.E Burning Homogeneous Lean Mixture.

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EMISSION CHARACTERISTICS OF TORCH CHAMBER S.I.E
BURNING HOMOGENEOUS LEAN MIXTURE
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ABSTRACT

This work is carried out to investigate the effect of connecting passage shape and flame initiation point on emission characteristics of torch chamber spark Ignition engine burning homogeneous lean mixture. This engine has been developed to achieve lean combustion of homogeneous mixture. A torch chamber for turbulence generation is used to extend the effective lean misfire limit and to increase the flame propagation velocity. The experimental study shows that the engine emissions of NO, CO and HC, mean effective pressure and specific fuel consumption are strongly dependent on the connecting passage shape and ignition point location. In the present work, two different passage shape (cylinderical straight passage of 9 mm diameter and convergent-divergent nozzle with 9 mm throat diameter) and three Ignition point location are used. The spark gap projection examined are 3.5, 8 and 13 mm electrode lengthes. The results show good fuel consumption and lower engine emissions of NO, CO and HC over the entire range of engine operation conditions when using convergent-divergent passage shape and the extended spark gap projection.

INTRODUCTION

At the time, the conventional spark Ignition engine confronted with two severe constraints stemming from the demands for, first, pollution control due to the concern over the environmental, and, then, fuel economy due to energy crisis. So far these demands were met primarily by peripheral engine system improvement [1,2]. It is well known that fuel economy and exhaust emissions such as NO, CO

and HC can be improved when a lean mixture is adopted.
Carburetor modification for better mixture formation
improved the ignition system and adequate mixture
flow during combustion these are effective in impro-
ving lean combustion. A non-homogeneous charge
(stratified charge engine) combustion system has been
investigated for leaner combustion to improve emiss-
ions and fuel economy [3,4]. For an automobile,
however, a homogeneous lean combustion engine with
carburetor seems more desirable. Since it is simpler
in its configuration resulting lower production cost.

The torch chamber combustion system has been investigated
as a means of controlling the combustion process in spark
ignition engines [5,7]. Although, markedly differ-
ent in configuration, the object of each torch cham-
ber concept was to control the combustion process so
as to permit higher compression ratios without deto-
nation, extend the effective lean misfire limit and
the use of special fuels with a gain in power or
fuel economy. In such engine, a fresh mixture
flows into the torch chamber through an connecting
passage during the compression process resulting
strong eddies of mixture within the torch chamber.
A spark plug located in the torch chamber lgnits and
produces a flame kernel there. This flame kernel
propagates through the mixture in the torch chamber.
As a result, an optimum jet flame is thrown into
the mainchamber. This flame jet serves as an
healthy lgnition source for the mixture in the main-
chamber. The flame then propagates through the
mainchamber mixture where in the bulk of the energy
release occurs.

The torch chamber lgnition system has also been
investigated as a means of controlling exhaust emiss-
ions from spark lgnition engines [8,9]. To have an
effect on engine emissions without penalty in fuel
economy, the objective of the torch chamber system
design and optimization is the combustion of fuel –
air mixture so lean that the resulting burning gas
temperatures will not support NO_x formation while
maintaining low CO and HC emissions. The objective
of this study is to carry out the investigation of a
torth chamber spark lgnition engine burnning homoge-
neous lean mixtures. Specifically, the study is to
determine the effect of connecting passage shape and
spark gap projection on engine exhaust emissions of
NO, CO and HC's.

EXPERIMENTAL SETUP AND PROCEDURES

The experimental work is carried out at the
Center of Research of Army Forces. The experimental

setup is shown schematically in Fig. 1.   The engine
used is a modified Deutz-Disel engine.   The engine
is a four stroke, four cylinder, air cooled, overhead
valves with a swirl prechamber.   The engine specif-
ications are shown in Table 1.   The engine is mod-
ified to be a torch chamber spark Ignition engine.
The modifications have been involved are, a reduction
of compression ratio from 17:1 to 9:1 by fitting
spacers between engine crankcase and each liner. The
Intake manifold is modified to be fit with a conven-
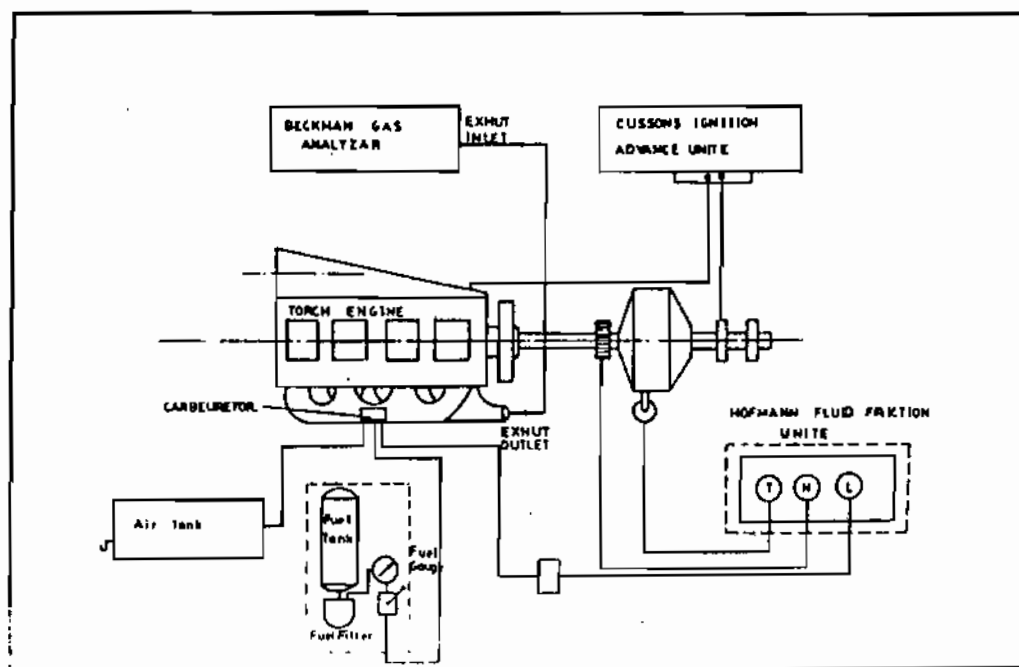tional carburetor selected according to engine air

Fig. 1: Schematic Diagram of the Experimental
         Setup.

flow requirements at stream conditions.   The carbu-
retor used is modified to be fit with an adjustable
needle valve as shown in Fig. 2.   The engine is also
fitted with a conventional Ignition system and dist-
ributer.

     The design situation for the engine cylinder
head and the position of the spark plug is shown in
Fig. 3.   Two sets of cylinder heads equipped with
two different passage shape have been used. The first
set is originally fitted with a straight passage
having a diameter of 9mm, 20mm length and 30° incli-
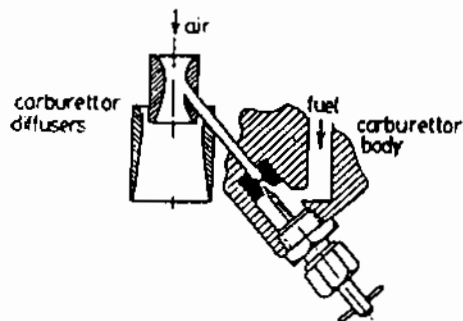nation to piston crown.   The second set of cylinder
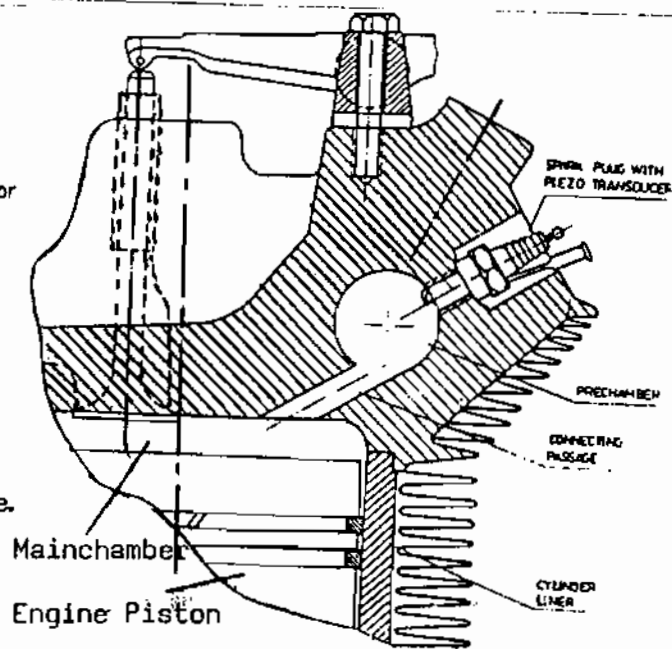
Fig.2. Mixture Strength
      Controlling Valve.

Fig. 3. The Torch Chamber Engine
         Cylinder Head.

Table 1: Engine Specifications

Engine bore (cm)			11.0
Engine stroke (cm)			14.0
Displacement volume (liter)			5.32
Connecting rod length (cm)			21.0
Compression ratio			9:1
Prechamber volume to total clearance volume ratio			17%
Connecting passage diameter (cm)			0.9
Value timing:	I.V.O	°BTDC	16
	I.V.C	°ABDC	40
	E.V.O	°BBDC	52
	E.V.C	°ATDC	16

head is fitted with a convergent-divergent nozzle
with 9mm throat diameter and 19° divergence angle.
In order to initiate the flame at different locations
in the torch chamoer, spark plugs with three differ-
ent electrode lengthes(3.5mm, 8mm and 13mm) are used.
The four torch chamber configurations to be tested
are shown in Fig. 4.

Engine tests are designed to investigate the
effect of connecting passage shape and spark gap
projection on the emissions characteristics and
fuel economy of torch champer spark lgnition engine.
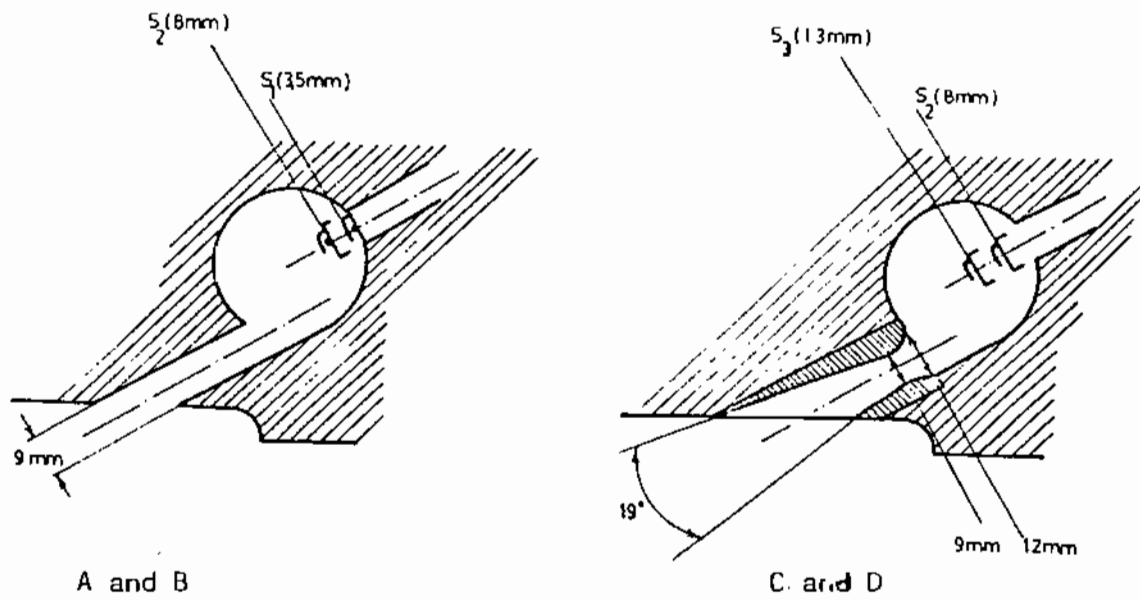
Fig(4) PRECHAMBER ARRANGEMENTS TO BE TESTED

ARRANGEMENT A _ STRAIGHT CONNECTING PASSAGE WITH SPARK GAP LOCATION S_1

ARRANGEMENT B _ S_2

ARRANGEMENT C _ CONVERGANT DIVERGENT S_2

ARRANGEMENT D _ S_3

·In order to cover the investigations, the engine has
been run at different speed, throttle opening and
different air-fuel ratios.   The engine is loaded by
an fluid friction dynamometer type Hofman-Bran-3t..
The Ignition timing is indicated using a Cusson-P
4605 Ignition advance unit.   The fuel flow is meter-
ed by a needle valve and is measured using volumetric
type flow meter.   The rate of air consumption is
determined using an air box and orifice technique.
Engine exhaust emissions of HC, CO and NO_x are meas-
ured by Beckman gas analyzers.   To measure the CO
emission a non-dispersive infrared analyzer model
864 is used.   The HC emission is indicated using
flame Ionization detector associated with sampling
heated line, Beckman model 402.   While the NO/NO_x
emission is measured using Beckman model 951A.   The
Beckman analyzer model 7003 is used to monitor the
Oxygen.

RESULTS AND DISCUSSIONS

     The results of the experiments have been collec-
ted and displayed graphically as famillies of curves.
All experiments are carried out with the torch chamber
engine, at compression ratio of 9:1.   Unless otherwise
stated, the spark timing is always set st its maximum
power value for the specific combination of torch

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chamber configuration and operating conditions being
tested. For each combination A, B, C and D in Fig.4,
engine emissions of NO, CO, and HC, b. s. f. c, b.m.
e.p and exhaust gas temperature are recorded or deter-
mined for variable loads, fuel-air ratios and engine
speeds keeping the other parameters constant.

Shown in Figs. 5 through 10, are a comparative
curves of engine emissions of CO, NO and HC, b.m.e.p.,
b.s.f.c and the exhaust gas temperature at full load
and fuel-air equivalence ratios of 1.1 and 0.8 as a
function of engine speed. It is clear from these
figures that the increase of the spark gap projection
inside the prechamber gave a lower of CO, NO and HC
engine emissions and an increase of the engine b.m.
e.p and exhaust gas temperature (Comparing Combination
A with B and C with D). It is also clear that the con-
vergent-divergent connecting passage posses the same
advantages over the straight one (Comparing Combination
B with C). Combination D satisfies lower emissions
of CO, NO and HC and higher b.m.e.p. allover engine
speeds. Regarding the fuel economy, it has been found
that the b.s.f.c decreases with increased gap projection
and using the convergent-divergent connecting passage.
Again, combination D which satifies lower CO, NO and
HC emissions, higher b.m.e.p and higher exhaust gas
temperature satifies also minimum b.s.f.c.

The relative gain obtained using combination D
instead of combination A has been noticed to increase
as the engine speed becomes higher. For example, at
engine speed of 1200 rpm, the decrease in CO is 50%,
the decrease in NO is 7.7%, the decrease in HC is 31.25%
the decrease in b.s.f.c is 13.75% and the increase in
b.m.e.p is 6.05%. This can be compared with 63.22%,
13.41%, 32.34%, 11.8% and 8.2% respectively at engine
speed of 2200 rpm.

Studying the effects of connecting passage shape
and the spark gap progections on engine emissions and
fuel economy at various loads, the same results are
confirmed as shown in Figs. 11 and 12. Shown in this
figures are the emissions of CO, NO and HC, engine b.
m.e.p and engine b.s.f.c of the engine fitted with
combination A, B, C and D at various loads and an eng-
ine speed of 2000 rpm and a fuel-air equivalence ratio
of 1.0. It can be seen from these figures that with
the engine fitted with the combination C and D, a gain
is obtained in engine emissions, b.m.e.p and b.s.f.c
allover the load range. Similar results are confirmed
at different engine speeds and various equivalence
ratios.

Shown in Figs. 13 through 18, are the dependences
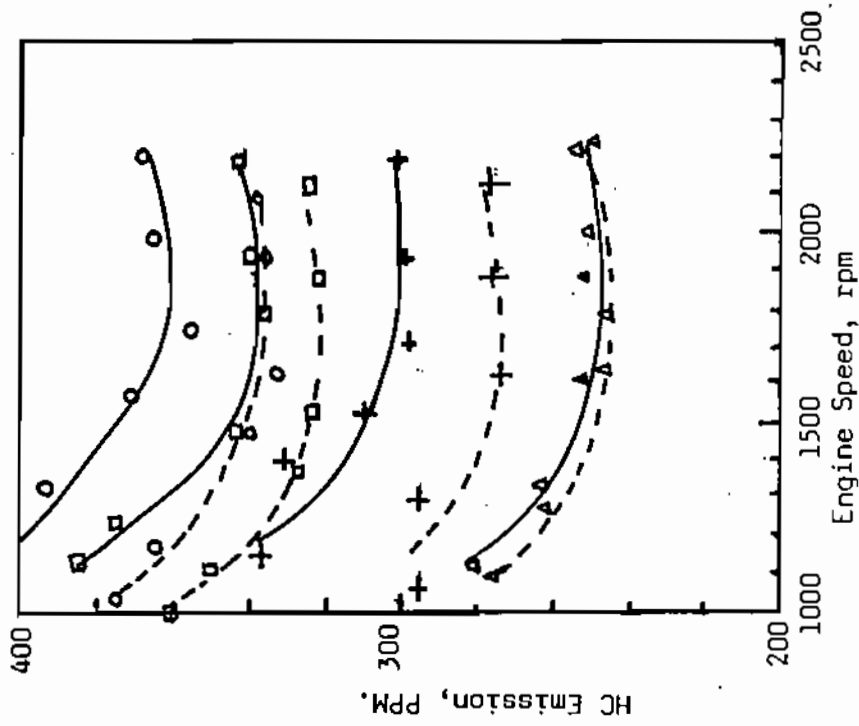of engine emissions, b.m.e.p, b.s.f.c and exhoust gas

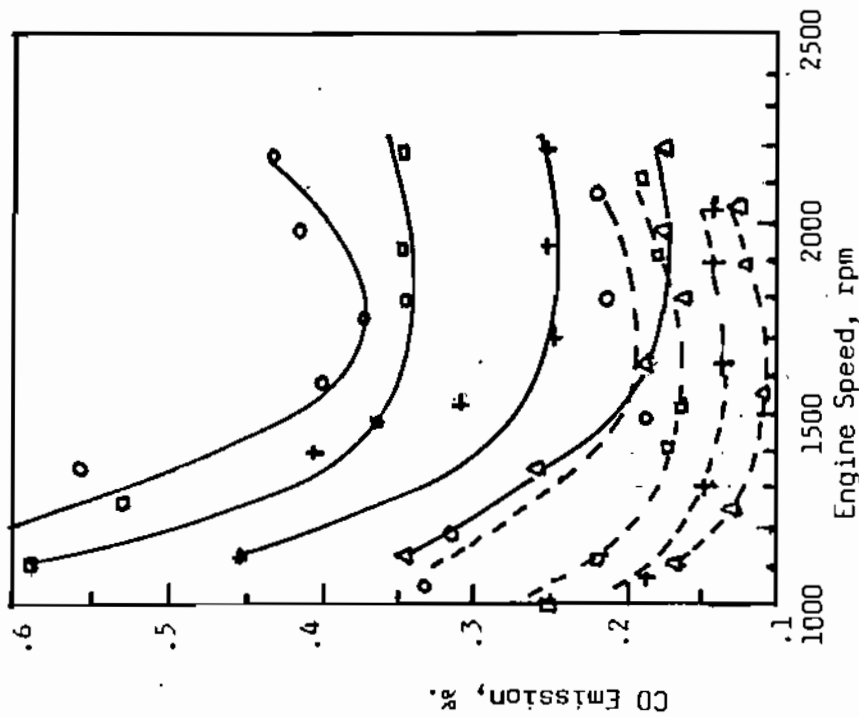Fig.6: HC Emission as a function of
Engine speed at fullload

Fig. 5: CO Emission as a function
of Engine speed at fullload.

——— Ø=1.1,.... Ø=0.8,○ Combination A, □ Combination B,+ Combination C, △ Combination D.

Fig. 8:   NO Emission as a function of engine
          speed at fullload.

Fig. 7:   Exhaust gas temperature as a function
          of engine speed at fullload.

———— Ø=1.1,···· Ø=0.8,0 Combination A,◻ Combination B, + Combination C,△ Combination D.

Fig. 10: Brake specific fuel consumption as a function of engine speed at fullload.

Fig. 9: Brake Mean effective pressure as a function of engine speed at fullload

──── Ø=1.1,.... Ø=0.8,O Combination A, ▫ Combination B, + Combination C, ▲ Combination D.
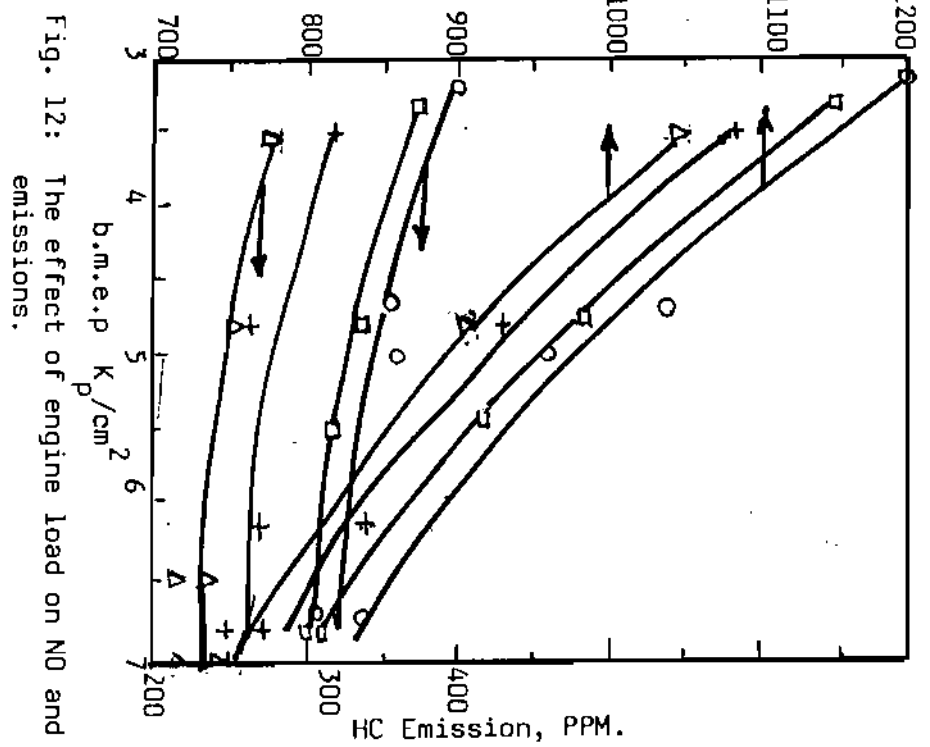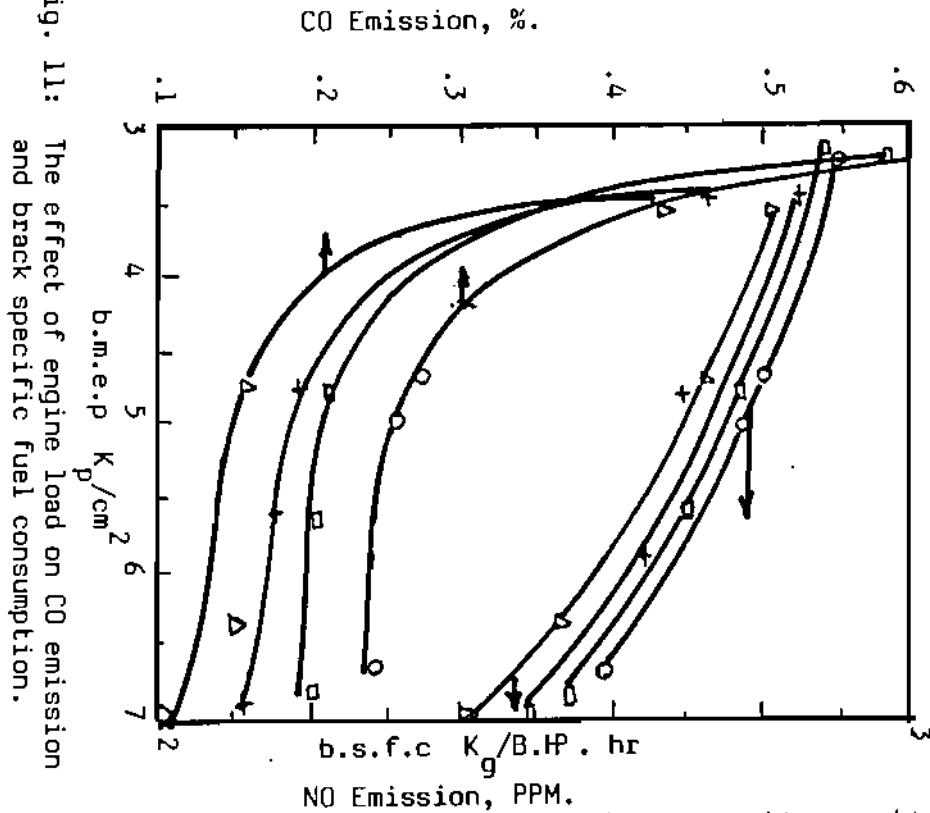
Fig. 11: The effect of engine load on CO emission and brack specific fuel consumption.

Fig. 12: The effect of engine load on NO and HC emissions.

Engine speed = 2000 rpm, Ø = 1.0 e Combination A, □ Combination B, + Combination C, △ Combination D.

temperture on spark gap projection, connecting pass-
age shape and fuel-air equivalence retio at an engine
speed of 2000 rpm for different engine loads namely
0.7 and full loads.   It is clear from these figures
that the engine emissions of CO, NO and HC, b.m.e.p
and b.s.f.c are strongly enfluenced by the equivale-
nce ratio.   As the later goes to be leaner, the
formers are decreased.   During the engine tests, it
has been found that the effective lean misfire limit
(LML) goes to less leaner mixtures as the load decr-
eased.   It is also found that LML has been extended
by extending the spark . gop progection and a further
extension has been gained using the convergent-dive-
ergent passage.   It must bear in mind that this
further extension led to decreased engine emissions
and b.s.f.c as shown in Figs. 13 through 18.   The
leanest LML, $\emptyset=0.7$ ($\simeq 20:1$) air to fuel ratio) is
obtained with the engine fitted with combinations C
and D.

The results of the experiments described in this
paper show that changes in the geometry of the conn-
ecting passage and location of the spark gap inside
the prechamber can greatly affect the emissions and
fuel economy of the torch chamber spark lgnition
engine.   The engine emissions and fuel economy are
improved when using the convergent-divergent passage
coupled with the extended spark gap projection.   The
emissions and fuel economy exhibited by the combina-
tion C and D can be contributed to the better perfo-
rmance and combustion characteristics and thecontrols
of the fast pressure rise in the mainchamber when
using the extended spark gap projection coupled with
the convergent divergent passage (7).   The better
lgnition and combustion conditions in the torch cha-
mber spark lgnition engine are proved by the delayed
optimum lgnition point.   As in the conventional
spark lgnition engine, the exhaust gas emission of
the torch chamber engine can be influenced by modif-
ying the lgnition point.   This applies to the quan-.
tity of CO, NO and HC.   As long as the lgnition and
combustion conditions are not essentially deterlora-
ted retarded lgnition points tend to reduce the HC
and CO emission as an increase of the expansion
temperatures favour the post-combustion.   The results
also indicated that a very siqnificant reduction in
NO formation is obtained due to the shortened expos-
ure time at high temperature.

CONCLUSIONS

Studying of the experimental engine emissions
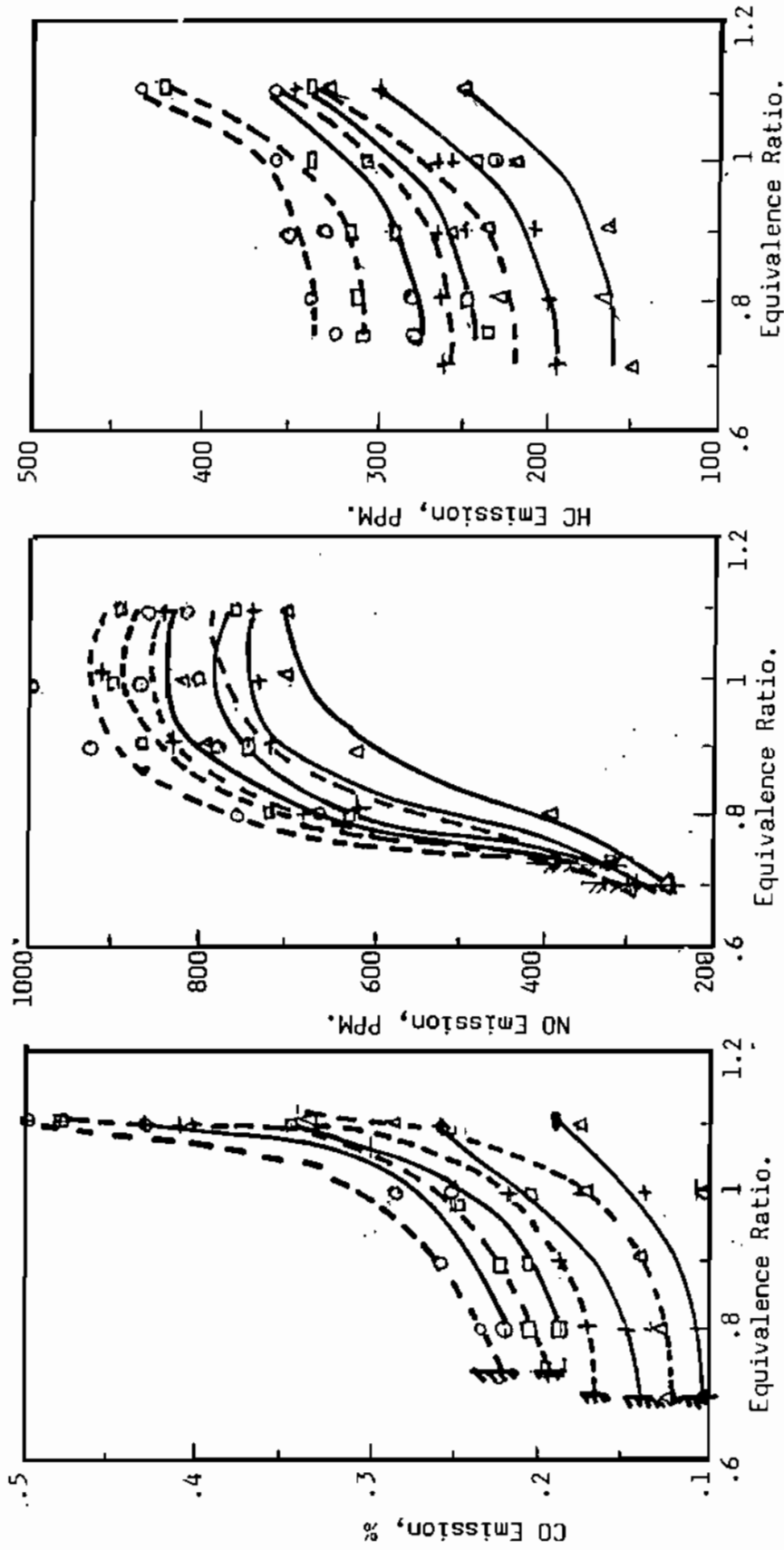and fuel economy curves reveals the following concl-
usions,

Fig.13: The effect of fuel-air equivalence ratio on CO emissions.

Fig.14: The effect of fuel-air equivalence rqtio on NO emissions.

Fig.15: The effect of fuel-air equivalence rqtio on HC emission.

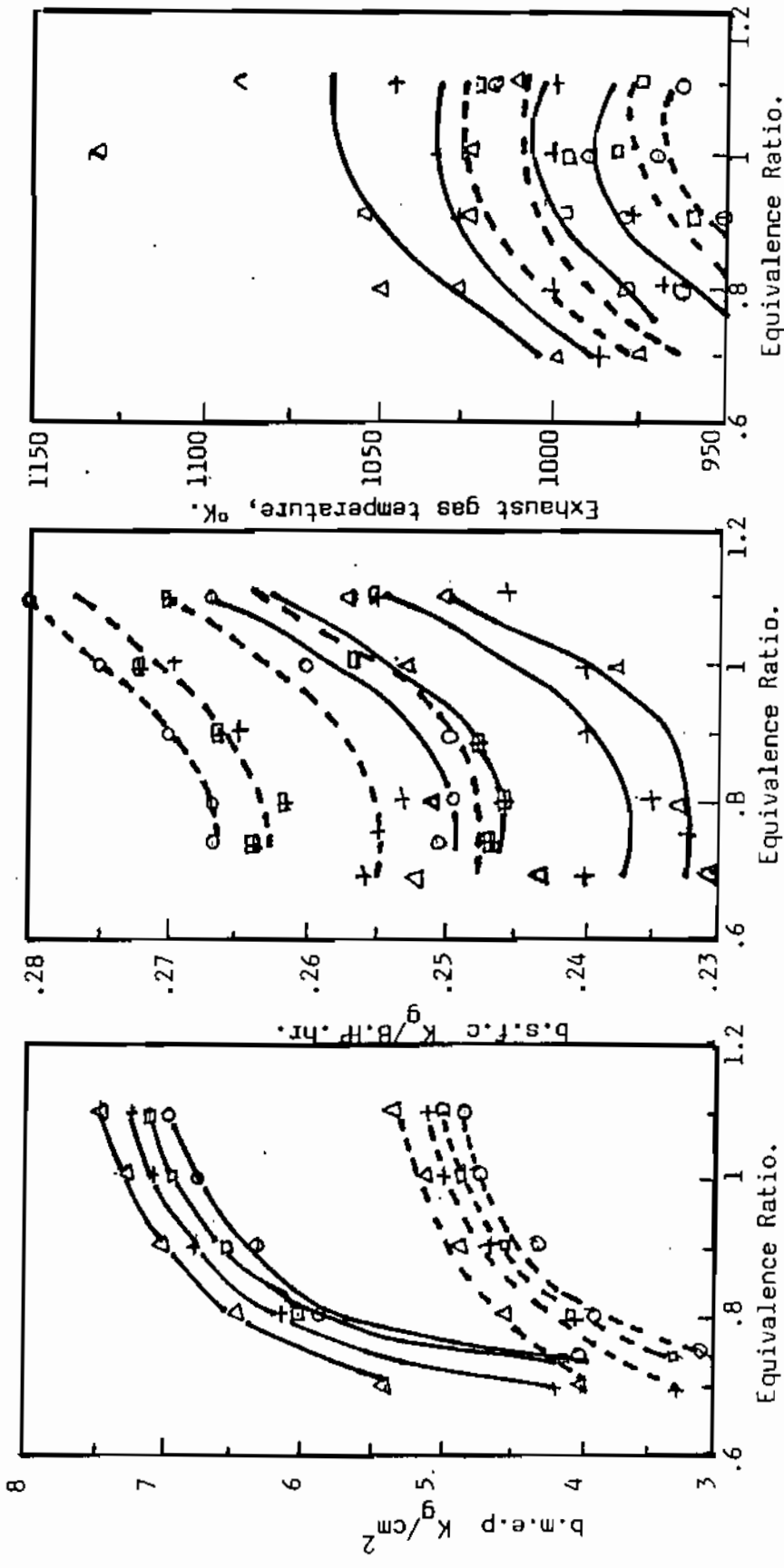N=2000 rpm,.... .7 throttle opening,___full-load. ◇ Combination A,◻Combination B, + Combination C, △ Combination D.

Fig.16: The effect of fuel-air equival- Fig.17: The effect of fuel-air Fig.18: The effect of fuel-air Equivale-
ence ratio on engine b.m.e.p.   equivalence ratio on engine   nce ratio on engine exhaust gas
                                     b.s.f.c.   temperature.

N=2000 rpm,.... .7 throttle opening,—full-load. ○ Combination A, □ Combination B, + Combination C, ◁ Combination D.

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1- The torch chamber spark lgnition engine improves
   the combustion of the lean mixture.
2- Allover the range of fuel-air equivalence ratio
   examined, engine spead and engine load the engine
   emissions and fuel economy are improved when the
   convergent-divergent passage coupled together
   with the extended spark gap projection inside the
   prechamber.
3- At part load, the advantages are still gained
   with the convergent-divergent passage and the
   expanded spark gap projection.
4- The leanest misfire limit at $\emptyset=0.7$ (Air-fuel
   ratio $\simeq$ 20:1) is achieved when using the conver-
   gent-divergent passage and extended spark gap
   projection.

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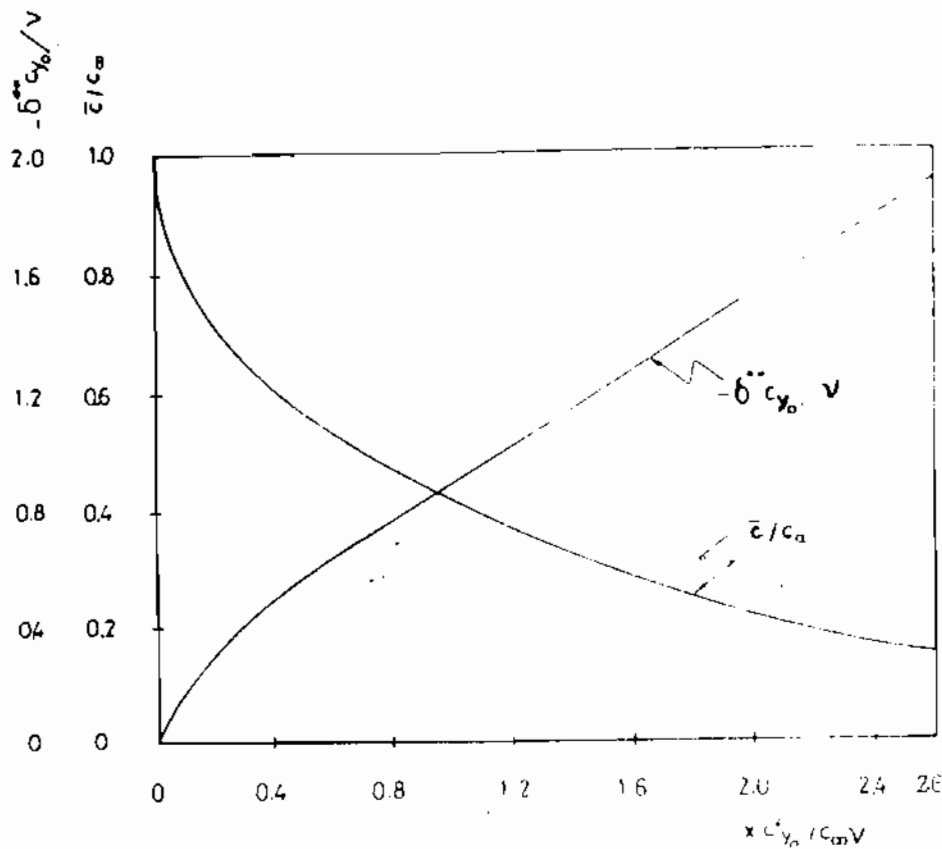| $\bar{c}/c_\infty$	$-\delta^{\mathbf{xx}}\,cy_0/\nu$	$x\,cy_0^2/c_\infty\nu$
1.0	0	0
0.9	0.105	0.024
0.8	0.223	0.098
0.7	0.357	0.228
0.6	0.511	0.424
0.5	0.693	0.696
0.4	0.916	1.059
0.35	1.050	1.281
0.3	1.204	1.514
0.25	1.386	1.829
0.2	1.609	2.172
0.15	1.895	2.564

Table (1) Results

Fig.(1) Flow with varying velocity gradient and constant suction