

## NRC Publications Archive Archives des publications du CNRC

### Some requirements of a very small gas turbine engine for canadian use Galitzine, N.

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

#### **Publisher's version / Version de l'éditeur:**

<https://doi.org/10.4224/40003960>

*Laboratory Memorandum (National Research Council Canada. Division of Mechanical Engineering. Engine Laboratory); no. NRC-ENG-22, 1960-05-26*

#### **NRC Publications Archive Record / Notice des Archives des publications du CNRC :**

<https://nrc-publications.canada.ca/eng/view/object/?id=1e6a2b1a-49fa-48a4-a1e8-2c80ea0c36d1>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=1e6a2b1a-49fa-48a4-a1e8-2c80ea0c36d1>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

**Questions?** Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

**Vous avez des questions?** Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

L.O. .... --

FILE .... --

PREPARED BY N.  
Galitzine

CHECKED BY ..--

NATIONAL RESEARCH COUNCIL  
DIVISION OF MECHANICAL ENGINEERING  
OTTAWA, CANADA  
LABORATORY MEMORANDUM

SECTION ENGINE LABORATORY

NO. NRC-ENG-22

PAGE 1 OF 8

COPY NO. 28

DATE 26 May 1960

SECURITY CLASSIFICATION OPEN

SUBJECT SOME REQUIREMENTS OF A VERY SMALL GAS  
TURBINE ENGINE FOR CANADIAN USE.

PREPARED BY N. Galitzine

ISSUED TO

THIS MEMORANDUM IS ISSUED TO FURNISH INFORMATION  
IN ADVANCE OF A REPORT. IT IS PRELIMINARY IN CHARACTER,  
HAS NOT RECEIVED THE CAREFUL EDITING OF A REPORT, AND  
IS SUBJECT TO REVIEW.

SOME REQUIREMENTS OF A VERY SMALL GAS  
TURBINE ENGINE FOR CANADIAN USE.

Table of Contents

	<u>Page</u>
Introduction	3
Present Small Gas Turbine Engines	4
Present Two-stroke Piston Engines	5
Fuel Consumption	5
Weights	6
Proposed Very Small Gas Turbine Engine	7
Conclusions	8
References	8
Figures	

SOME REQUIREMENTS OF A VERY SMALL GAS  
TURBINE ENGINE FOR CANADIAN USE

Introduction

In a renewed search for original subjects of future research in mechanical engineering, the scientific staff of the Laboratory met recently to discuss possible projects for suggestion to the Director.

The consensus of opinion, predictably enough, was that the suggested projects should have a Canadian application and be related to engines.

Out of a wide list of varied suggestions, six projects appeared to meet the above conditions. The most favoured idea was the development of a very small gas turbine engine.

In some brief preliminary inquiries it was soon established that there may indeed be a demand for such an engine in Canada, let alone outside it.

Thus the Forestry Branch of the Department of Northern Affairs and National Resources clearly indicated an interest in a lightweight 10 hp. engine for driving a water pump, which could be carried as an outfit on a man's back in fighting forest fires.

This opened up further possibilities of use in regions of remoteness or difficult access, where the particular property of gas turbine engines, their lightness, could be of great advantage. Applications to other pumping duties, electric generating sets, power chain saws, outboard motors, etc., were visualized.

It appeared, therefore, that aside from future unforeseen applications, the proposed development could fulfil a present need in Canada.

A further point to be mentioned is that the manufacture of such engines might be very suitable for a small new industry in this country, independent of the large U.S.- or British-controlled firms, who now monopolize the gas turbine field.

Various suggestions, such as worm reduction gears, positive displacement compressors, stoichiometric combustion chambers, etc., have already been made regarding original and unconventional components of the proposed engine.

NATIONAL RESEARCH COUNCIL  
DIVISION OF MECHANICAL ENGINEERING  
LABORATORY MEMORANDUM

NRC-ENG-22  
Page 4 of 8

However, the purpose of the present memorandum is not to enlarge upon these, nor to add further, but merely to start laying down some requirements, as a means of stimulating further discussion on the subject.

Any proposed gas turbine engine would naturally have to compete with existing prime movers. Its closest rival would no doubt be the two-stroke piston engine.

Now the specific fuel consumption of simple gas turbine engines is not particularly good, but if it could match or better the level of two-stroke engines, with an engine weight of say at least half, then a distinct advantage could be claimed. That is the theme of what follows.

Present Small Gas Turbine Engines

The table below shows the presently developing or manufactured gas turbine engines of 100 hp. or less:

Manufacturer	Curtiss Wright	Aire-search	Budworth	Solar	Solar	Rover
Model designation	Turbo-Mite	GTP30-1	--	Mars	Mercury	--
Year	1959	1958	1959	1958	1959	1954
Purpose	Elec.	All	Indus-trial	Indus-trial	Heli-copter	Indus-trial
Rated power hp.	5 or 10	30	45	50	55	60
Turbine speed rpm.	92,000	53,000	45,000	40,000	60,000	46,000
Output speed rpm.	24,000	6-8000	3,500	4-6000	--	4,500
Mass flow lb/sec.	--	--	--	2.7	1.2	1.4
Pressure ratio	--	--	--	2.5	--	2.9
Turb. Inlet Temp. °K	--	1065	--	920	1060	1063
S.F.C. lb/hr/hp.	--	1.4	--	2.1	--	1.5
Weight without gears	30	--	--	--	--	116
Weight with gears	--	40	--	100	50	--

NATIONAL RESEARCH COUNCIL  
DIVISION OF MECHANICAL ENGINEERING  
LABORATORY MEMORANDUM

NRC-ENG-22

Page 5 of 8

Assuming that about 10 hp. might be the desired rating of a Canadian engine, the nearest presently being made is the Curtiss-Wright Turbo-Mite, shown in Figure 1.

Available in 5 and 10 hp. models, the Turbo-Mite is claimed to be the smallest gas turbine engine ever developed. It is a twin-spool coaxial machine, apparently specifically intended for electric generation at 400 cycles, although other applications, such as pumping and pneumatic power, are also suggested.

There is no reduction gearing, and hence the output speed is a high 24,000 rpm. in contrast to the range of about 4000-8000 rpm. of the other units.

It is obvious that the fuel consumption of present engines, 1.4-2.1 lb/hr/hp., is rather high, probably mostly due to the low turbine inlet temperatures and pressure ratios used.

Present Two-stroke Piston Engines

Fuel Consumption

The table below shows some of the available, rather scanty, information on the fuel consumption of two-stroke engines under 100 hp.

Manufacturer	Vincent	Villiers	A.R.L.	Maritimes	Scott	Nelson & McCulloch
Purpose	Industrial	Industrial	Model Aircraft	Marine	Aircraft	Aircraft
Year	1955	1938	1950	1952	1936	1959
Rated Power hp.	1.3	2.5	3.5	3-8	34	40-60
No. of cylinders	1	1	2	1	2	4
Cooling	Air	Water	Air	Water	Air	Air
Speed rpm.	2,500	1,400	4,000	600	5,200	4,000
S.F.C. lb/hr/hp.	0.9	0.7	0.95	1.0 - 1.1	0.6	0.8-0.9

No reliable information has so far been found on the fuel consumption of marine outboard and motorcycle engines, which is unfortunate, because the power range would have covered the rating of the proposed gas turbine engine. Some German motorcycle machines are said to have sfc's between 0.7 and 0.8 lb/hr/hp.

Perhaps the most reliable figures in the above table are those of the Australian Aeronautical Research Laboratories model aircraft engine (Reference 1) and of the marine engines, manufactured

in the Canadian Maritime Provinces, which were tested, with improvements, by the N.R.C. (Reference 2).

In any case, the range of specific fuel consumption of two-stroke engines appears to be 0.6 - 1.1 lb/hr/hp., with 0.9 probably about the true median for the smaller engines, a figure which the proposed gas turbine engine would have to attain in order to be competitive.

### Weights

A great deal of weight information on two-stroke engines is not appropriate to the present study. Inboard marine engines for example are usually desired to be on the heavy side, whereas aircraft and motorcycle engine weights do not include provision for cooling outside the special environment.

Perhaps the most relevant weights are those of marine outboard engines, where minima are of course very desirable. However, in these weights are included the propeller and sometimes the fuel tank, but complete water-cooling systems are also properly covered.

A representative series of powers and weights (Johnson Outboards 1951) is given in the table below:

	<u>Rated Speed 4000 rpm.</u>			
Power b.h.p.	2 1/2	5	10	25
Weight lb.	31	44	56	85

Latest (1959) figures seem to be if anything slightly heavier, possibly due to the introduction of fancy gadgets, etc.

As can be seen, a complete 10 hp. two-stroke outboard weighs 56 lb.\*, of which the engine and cooling system alone is guessed at 45 to 50 lb.

Thus, a gas turbine engine of the same power would have to weigh, say, 20-25 lb., including reduction gearing, to claim a distinct 2 to 1 advantage.

---

\* Incidentally, the four-stroke lightweight piston engine of the nearest power to 10, a Briggs & Stratton 9 hp., weighs 98 lb., and is included in a Ward LaFrance portable fire pump outfit weighing 130 lb.

Proposed Very Small Gas Turbine Engine

Figure 2 shows the calculated specific fuel consumption of simple cycle gas turbine engines, using various turbine inlet temperatures, pressure ratios, and component efficiencies.

The curves are based on a combustion efficiency of 95%, pressure loss 5%, with compression  $C_p = 0.24$ ,  $n = 1.4$ , turbine  $C_p = 0.27$ ,  $n = 1.34$ , and fuel calorific value = 10,000 CHU/lb.

Three groups of curves are shown, with (compressor and turbine) component efficiencies of 75, 80 and 85%.

A report of tests on an early (1951) model of the previously tabulated Solar Mars engine has been published (Reference 3), and the results are also shown in Figure 2. At a pressure ratio of 2.44, turbine inlet temperature 889°K, the specific fuel consumption was 2.22 lb/hr/hp., and the compressor and turbine component efficiencies 74.5% and 78% respectively.

Modern large aircraft gas turbine engines may be represented by a pressure ratio of 9, turbine inlet temperature 1300°K, and component efficiencies 85%, giving a specific fuel consumption of about 0.5 lb/hr/hp.

According to Figure 2 then, in order for the proposed very small gas turbine engine to reach an sfc of about 0.9 lb/hr/hp., the following alternatives would have to apply:

Component efficiencies = 80%

Turbine inlet temperature °K	1000	1100	1200
Pressure ratio	6	5	4

A turbine inlet temperature of 1200°K, pressure ratio 4, component efficiency 80%, is suggested as a starting aim. The corresponding specific power is 83 hp/lb/sec., so that a 10 hp. engine would require an air mass flow of about 0.12 lb/sec.

These are conditions rather removed from present small gas turbine engine specifications, and would no doubt require a considerable development, particularly if weight were to be kept low.

The same regard to weight would of course be necessary if other means to improve sfc's., such as the addition of heat exchangers, etc., were considered.

Conclusions

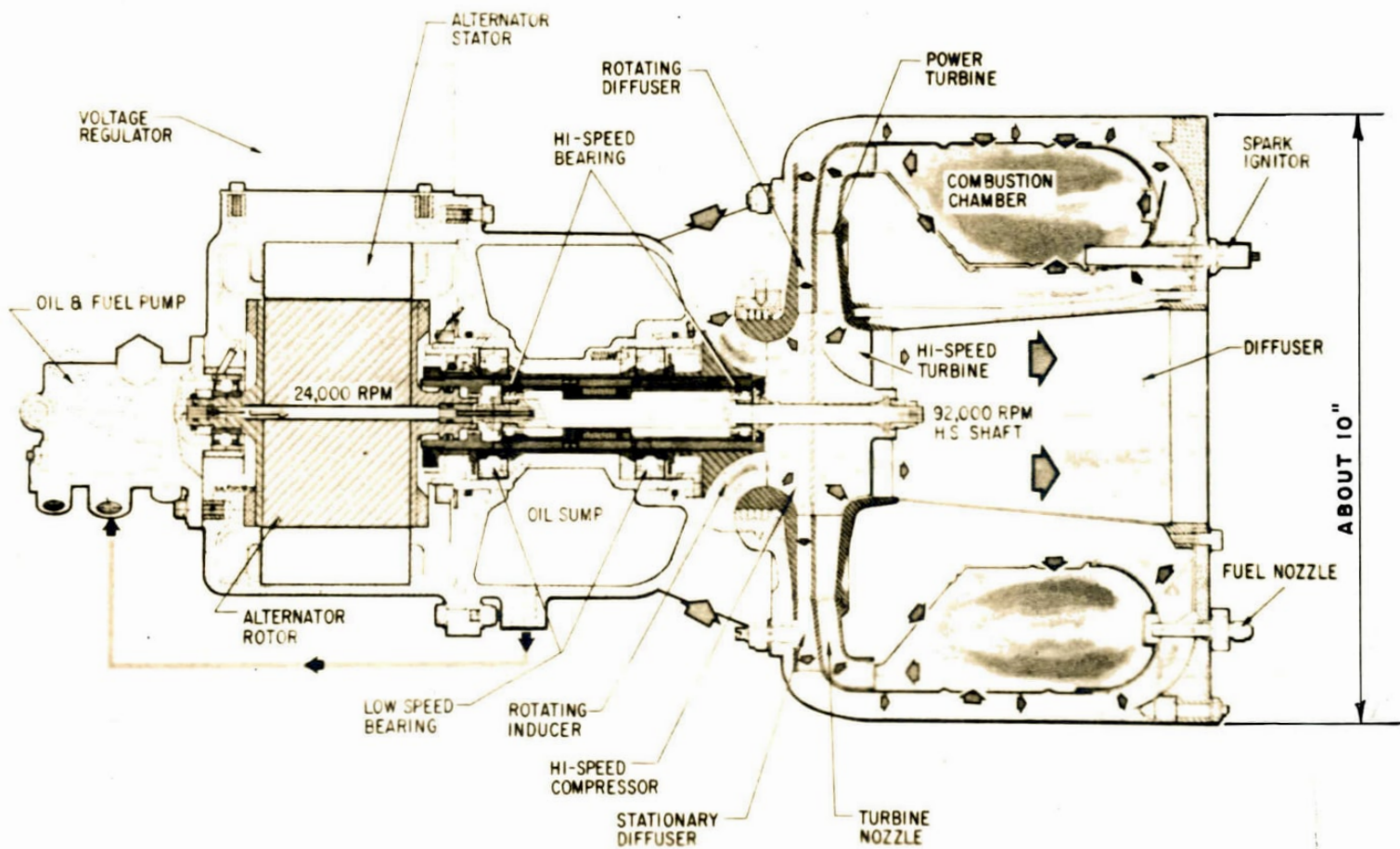
There may be applications in Canada for a very small gas turbine engine of light weight.

The following requirements are suggested for further discussion:

Power	10 hp.
Output speed	4000 rpm.
Weight	20-25 lb.
Air mass flow	0.12 lb/sec.
Specific fuel consumption	0.9 lb/hr/hp.
Pressure ratio	4
Turbine inlet temperature	1200°K
Component efficiencies	80%

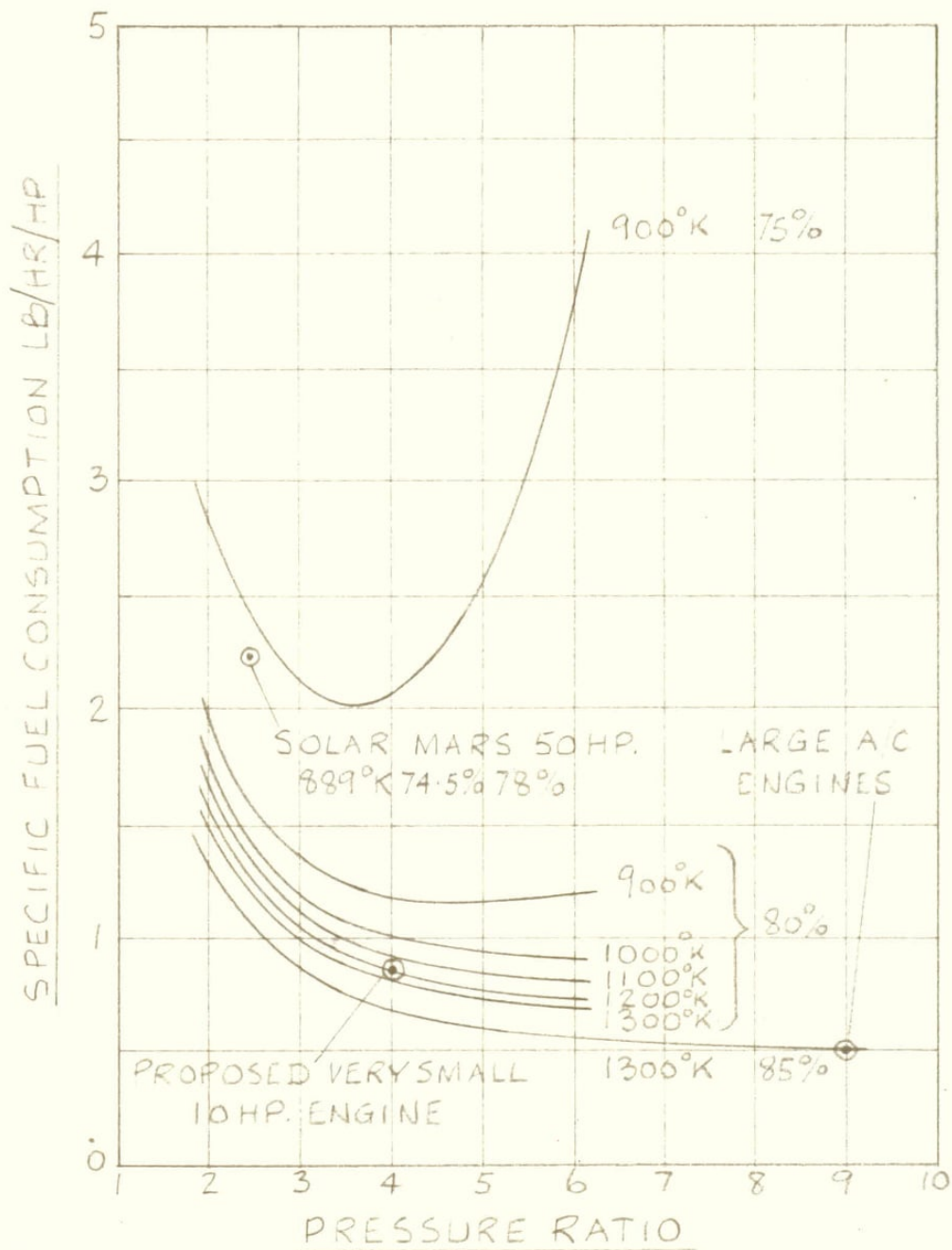
References

1. Aeronautical Research Laboratories of Australia Report E67.
2. National Research Council Reports ME-199, 200, 201, 202, 203, 206.
3. The "Oil Engine and Gas Turbine", October 1951.



**CURTISS-WRIGHT TURBO-MITE ENGINE  
( WITH ALTERNATOR )**

GAS TURBINE ENGINE  
SPECIFIC FUEL CONSUMPTIONS  
(SIMPLE CYCLE)



THE FIGURES ON THE CURVES ARE TURBINE INLET TEMPERATURES °K AND COMPONENT EFFICIENCIES %