

13. FUTURE DEVELOPMENT PROGRAMS

Les Waters

Teledyne Continental Motors
Mobile, Alabama

The programs conducted to date by TCM have provided useful information on aircraft engine emissions characteristics and on the potential for reductions obtainable by leaning of current fuel systems. The work completed to date allows us to draw important conclusions at this time, the most significant being that none of the engines tested in the program, which covers a significant group of our basic engine types, could meet Part 87 of EPA regulations on a production basis and within safety of flight limits. As stated in an earlier TCM presentation, some reductions are possible but they are small compared to baseline emissions of current engines.

In considering our present knowledge of exhaust emissions at TCM and the work that lies ahead of us to achieve the substantial emission reductions needed to meet Part 87, we have planned a company program which has a main drive to develop those emission reduction concepts that have the promise of earliest success. These programs will, in general, attempt to enhance existing engine systems, exploiting their potential for emission reduction as far as is compatible with retaining the well established features in them that are well understood and in current production. This approach will minimize development times and retain much of existing know-how that is always vital in ensuring technical performance in production engines.

This program of direct development of emission reduction requires complementing by an additional very substantial effort to provide a wide spectrum of information to fully circumscribe the problems of ultimately producing aircraft engines that meet Part 87.

The intended programs identified to date in the area of new concepts are

(1) Upgrading the TCM fuel system. Temperature and altitude compensation capability will be developed for the system. The potential benefit of better fuel-air ratio control over a temperature range would be, for instance, in reducing idle/taxi mode fuel-air ratio which presently is set for operation at the coldest day and is richer than necessary for engine operation at higher temperatures.

(2) Evaluation of accelerator pump. We have seen that a limitation in leaning the idle and taxi modes is the inability to accelerate from those conditions. Temporary augmentation of fuel flow by acceleration pumps may have the potential to provide safe operation in the transient condition between steady-state leaned conditions.

(3) Reduced cooling requirement. Cylinder head overheating also imposes limitations on leaning. We are therefore investigating the potential for improved cooling using two approaches. These are means for reducing thermal loading of the cylinder assembly and secondly improved heat dissipation. Hardware evaluation will follow if present studies show promise.

(4) Variable spark timing. The lean misfire limits can be extended by varying the ignition timing. Although misfiring has not yet imposed a limitation on leaning, we believe it is possible that this limit will be met as we attempt further leaning. An automatically controlled variable spark timing could be beneficial, probably in transient conditions. No such systems are presently available for aircraft, and a considerable development program would be involved in attaining production status of this idea.

The following programs are intended to provide the information we believe is needed for a full definition of the emission reduction task in TCM engines.

(1) Survey of baseline emissions of TCM engine range. The baseline must be determined; case 1 and case 2 emission levels for the basic engine models have not been tested to date.

(2) Determine effect of production tolerances. We have seen in the difference between baseline and case 1 emissions that the effect of fuel flow tolerance is very significant. It is probable that other effects are significant also, one possibility being varying hydrocarbon emissions having as a source the lubricating oil which passes into the combustion chamber. The consistent control of lubricating oil in the first few hours of engine life is notoriously difficult especially in air cooled engines. An investigation of the effect and understanding of tolerances is clearly vital.

(3) Effects of cumulative operational time. Several areas of deterioration may be expected to affect emissions as an engine wears or loses initial calibration. Fuel calibration, piston sealing, and lubricating oil consumption are obvious possibilities that could affect emission characteristics.

(4) Flight testing. The flight testing conducted to date has been effective in demonstrating operational limits on leaning. Further testing in cooperation with airframe manufacturers is needed to provide in-

formation on the performance penalties incurred by improved cooling. Also, further data are required to enable us to project uninstalled engine results for the actual aircraft installation. Flight service testing will also be required to assess the effect on engine TBO and reliability.

(5) Effect of inlet manifold tuning. Aircraft engines extensively utilize tuning of inlet manifolds to improve volumetric efficiency. This arrangement can, however, produce inconsistency of fuel-air ratio between cylinders during low speed operation. This effect needs studying for its impact on emissions.

(6) Facilities. We intend to upgrade our emission test facility by the addition of equipment to control the temperature and humidity of engine induction air. This control will improve repeatability of emission determinations and allow us to study effects of temperature and humidity.

We have shown that small improvements in emissions in two TCM engine types are possible by leaning in two modes. Those two engines cover only a fraction of our total production, and further work would be involved to production release even these gains. Development of production hardware, service tests, and engine and airframe certification work would be necessary.

We believe that implementing these small improvements would be a Pyrrhic achievement. The effort could be better expended in the programs mentioned previously, which have the promise of more worthwhile gains.

It is abundantly clear that several years of work and large expenditures are required before the emission levels prescribed in Part 87 can be achieved. Although it is not possible to plan the detailed program required to achieve regulated emission levels, we have attempted a conservative estimate of the cost impact of doing so.

If we apply presently known technology and project progress typical of our industry, we would anticipate a cost increase per engine of 15 to 20 percent based on amortization of engineering development, production facilities, and the unit cost increase. This increase arises only from engine changes. It can reasonably be expected that engineering development and certification costs arising from airframe changes to accommodate the emission conforming engine will be similar to the increase in engine price. Since the cost of engine(s) in an aircraft is approximately 20 percent of the selling price, the increase in cost of the airplane will be approximately 6 to 8 percent.

After the time that engine development to EPA requirements would be achieved, we estimate that an additional 3 years would be needed to re-identify all engine models in their emission reduced versions.

Test facilities would require extending to achieve this, and we estimate that one-time expenditures of \$800,000 would need to be made. These facilities would be surplus to our needs at the completion of work.

This discussion of costs is based on TCM projections.

Sales of piston powered general aviation aircraft is soon expected to be 1 billion dollars; thus, we are facing an annual expenditure of 60 to 80 million dollars to meet prescribed emission levels. It is a large sum for our industry and we seriously question the cost benefit to the community. We recognize that we have an obligation to the country to act responsibly toward upgrading and preserving the quality of life in all that this implies. But we believe that this end would better be served by expenditure of our technical effort in the direction of improving the fuel economy and reliability of aircraft.

DISCUSSION

Q - C. Rembleske: You mentioned something to the effect that it would take approximately 3 years to recertify the engines you now have in production. Is that all 60 models or 30 models?

A - L. Waters: It's 30 OEM models.

Q - C. Rembleske: One of the problems that concerns us in the airframe industry is the fact that you today still build engines for aircraft which have long been out of production. The way we interpret the rules today, and I feel they're rather clear, is that all newly manufactured engines are going to have to meet these specifications. How are we going to handle the engines for the aircraft which are no longer being produced but which are covered by the rules? There are a significant number of engines models, as you said 30 of your own, which fall into this classification. That means there are probably double that number of airplanes in the field, models of airplanes, that will have to be considered. We do not expect these people to junk these airplanes, and I'm sure that will not be done.

A - L. Waters: That is a very important point. There are another 30 models. Moreover, the technology we would develop during the work to be done for our OEM models wouldn't apply to the older ones. Many of the older engines are quite different. It would be a messy problem. I would hope that there would be relief from certifying the older engines made for airplanes no longer in production. This obviously would be a massive, unrewarding task.

COMMENT - C. Rembleske: That was the purpose of my bringing it out. It needs to be concerned when the EPA and FAA consider this matter. Also, we need to seriously think about what we are going to do about those aircraft which are still flying and must be re-engined periodically with new engines.

Q - G. Kittredge: I don't think I'm in a position to give you a really satisfying response to this point. Certainly, as the rules are laid out now, newly produced engines for installation in any sort of aircraft would be required to comply. Although we have talked about this problem within the government, we have not resolved it yet. I think that what we need to dig into is the reason why is it not possible to install an emission control equipped engine in such older aircraft. It would be quite useful to the EPA if TCM could break the 15 to 20 percent estimated cost increase into the various components that went into it - that is, the specific new emission control system devices, whatever they are, the projected market for the engines, etc.

A - L. Waters: I can't break the numbers down in that detail, but I certainly can tell you the elements that we took into account and I can tell you why I use the word conservative. The elements that we had used in this study are the engineering development cost, people, materials, and facilities covering the programs I have mentioned. Bernie Rezy said we may have to go to a more sophisticated

timed injected fuel system. Our own fuel system is not timed. So we are covering the programs I have mentioned plus the possibility of an element of a new timed FIE system and the development of new cooling cylinder heads. Remember we have six different basic engines. In production facilities more test cells will be needed and these cells will have to be more fully equipped for emission regulation. On the unit cost side, the cost of the new fuel injection system, the cost of the improved new cylinder heads, and the extra "break in time" of the engines were included. Presently, we run engines for about 3 to 3 1/2 hours. It's common over the next 10 hours or even more for the lubricating oil consumption to fall further. For all the emission testing that we have done on our engines, we have run at least 10 hours to stabilize the lubricating oil consumption because of its effect on hydrocarbons. If the control of hydrocarbons stays in the EPA standard, there's little doubt that the engines will have to be run longer during the break-in period. The conservatism is that we did not include inflation over these years for the cost of the engineering or materials, and, secondly, we did not include any unknowns. Inevitably other programs will arise that we will have to look into. We did not include any of these in our estimate.

- Q - C. Rembleske: I think one of the big things we have to recognize is that even though the engine manufacturer comes up with an engine that might meet certain emission requirements, that is by far a long way from getting the FAA to approve that installation in a specific airplane. They may have a perfectly good and suitable engine. However, to demonstrate the capability of meeting the right federal regulations with that engine installed in an aircraft is going to mean going out into the field, getting one of these old airplanes, some of which may be 15 years old, and trying to get that airplane recertified. Could the FAA comment on whether they have another way?
- A - N. Krull: We happen to be in the office of policy development rather than flight standards. They're much more involved with the individual certification. We're very much aware of the problems that are going to come up with these emission standards and the problems in certifying not only new engines but overhauled engines as well as engines with various modifications. We will be continuing to work with the EPA on developing these requirements to a point where they can be applied within the industry. Earlier there was a discussion concerning the time lapse for certification. In our role of promoting aviation, we will certainly be working to minimize the requirements in terms of certification of additional engine models and to cut that time span as much as we possibly can within the limitations of safety. Would somebody from Flight Standards like to comment on the recertification of old aircraft?
- A - C. Price: As the rules presently require, if there is a model change, or any substantial change at all, it would require a recertification of the aircraft as well as the engine. The current rules are Part 33

for the engine and probably Part 23 for the aircraft. When you change the fuel schedule you change power, and you change cooling requirements - all of this has to be recertified on the aircraft. The ridiculous example I used for an illustration was an A-65 engine and a J-3 Cub. It is conceivable that we would have to recertify a J-3 Cub under the present situation.

COMMENT - L. Waters: I would like to make one point. There seems to be no doubt to us at TCM that our final developed engine, our final emission new old model engine, will most certainly need full recertification. The design changes will be profound.

COMMENT - L. Helms: I can't help but pick up the example he used and pose the question to the group - who do we expect to pick up the costs of engineering to recertify the J-3 Cub? The J-3 Cub, incidentally, has been out of production for about 25 years.

Q - C. Price: An A-65 engine could conceivably come off in 1980 from his remanufactured or rebuilt engine line. And we would now have to do something with that engine?

A - L. Waters: Under present rules, that's right.

COMMENT - L. Helms: Even if there were changes and even if FAA eliminated the STC, there would have to be engineering to install that engine. And who wants to do engineering on an airplane that's 25 years old?

COMMENT - D. Page: The owner pays for everything that does into any product. If he has a J-3 Cub, it is on the market new as a \$4000 to \$5000 airplane. If he had to pay a \$25,000 certification for it, he'd have a \$30,000 airplane. He could put it in the barn, give it to a museum, or pay the money.

COMMENT - C. Price: Under the current rule, a Supplemental Type Certification (STC) would have to be issued to any model engine change and to the aircraft change for each individual aircraft that comes under this sort of thing. Now, of course, you could get blanket STC's, which could cover a number of aircraft under a specific model change. People are modifying aircraft engines constantly. They have a perfect right, under the rules, to do so provided they stay within the flight standard rules,

COMMENT - L. Waters: Quite clearly, the work involved in reducing emission for the 30 engines in our case that belong to the after market and the re-engineering of these engines into the airplane recertification is an astronomical task. Hopefully, this will be removed.

Q - H. Nay: Les, a point of clarification on your cost estimates. You refer to them as conservative. Does that mean these are upper limits or not?

A - L. Waters: There are lower limits. The element of conservatism was that we did not put in inflation for the years of escalation. We used 1976 dollars and we did not include any new programs with unknown problems that we might run into. The figures are low.

COMMENT - L. Helms: I might comment on that because it might help the other people in the audience. What we did was to ask Continental and Lycoming to select, on their own, two different approaches and come up with their own ideas. Obviously, in the GAMA technical policy committee, we considered this for some time. The industry people said, "Well, we don't know how to do that. It's not defined. We don't know what the requirements are going to be." But we did press on, on the basis of if we can't do it, certainly we can't expect the government to do it. So now that you've heard Les outline what Teledyne did, you might be interested in knowing the Lycoming side. Lycoming made their estimates and came up with a cost of approximately \$1000 per engine. Since some were as low as \$700 to \$800 and others were as high as \$1400 or \$1500, they averaged it out at \$1000 an engine. After you take that \$1000 an engine to the airframe manufacturer, we then get into other things. The Truth in Pricing Act requires us to price certain things which can be explainable to the Treasury Department. The Treasury Department requires us to break this down for tax purposes, and we have to segregate the costs for tax purposes on every part when it comes in, so that we can meet the SEC regulations in truth and disclosure. We take that \$1000 and we must allocate some to that, a portion of what we call material handling or material burden. It could be as low as 6 percent or as high as 12 percent. Each of the aircraft manufacturers must then install the engine, they must build it up, and/or put accessories on it. They must put their own baffles on it and that adds labor. Then to meet the SEC requirement of complete disclosure, you have to allocate the factory burden to it; the burden of the individual plant can be anywhere from 80 to 200 percent to that \$1000. Then to meet the further requirements of the accounting profession of our respective auditors, we have to add G&A. What I'm saying is that the \$1000 engine becomes somewhere around a \$2000 engine when it goes out of the airframe manufacturer's plant and to the consumer. It could be as low as \$1500 or could be as high as \$3000. Let's say it's a \$2000 engine. This year we'll built a little more than 15,000 airplanes. Next year we're forecasting an increase, of which approximately one-third would be twin engine airplanes. If we take 5000 of those, we've added 5000 more engines and we're up to 20 000 engines. If we export 3000 to 4000 engines a year, we're up to 23 000 or 24 000. Now we've got 2000 to 3000 or 4000 of after market engines or spares. I'm going to round this off to about 25 000 engines a year that go out. If you take that 25 000 engines a year and multiply them by the added cost, you come up to about \$50 million or \$60 million. So he went on the basis of 20 percent. We looked at it and said it is about 6 to 8 percent of the final sales price and came up with about 60 to 80 million. Lycoming came up with about \$50 or \$60 million. We can't make it any closer than that, but it does tend to give you an idea of the approach we took to get our arms around the subject some way. We're looking at somewhere between \$50 and \$100 million a year of added costs.