Interim report on noise in F2C, October 2010

Rob Metkemeijer

1. Introduction.

At the 2010 CIAM plenary it was decided that in 2010 a strategy for noise control in F2C team race will be prepared, aiming for an approximate maximum noise level of 96 dB(A) @ 3 meters.
At the WC in Hungary a workshop on the subject was held by Bengt Olof Samuelsson where the two main options for noise reduction were identified:

1. Additions to the current technical specifications of engines, props, fuels or others. These could be measures that relate directly to noise emission e.g. reduced exhaust timing or addition of technically defined silencers (like now in F2D). Additional to this indirect measures are possible, that could lead to reduction of rpm and noise , like minimum size props, air intake limitation, standard fuel and tank size reduction. In this case no noise limit as such is necessary; the technical specification is supposed to lead approximately to the 96 dB(A)@3 meters goal. Model processing is done by checking the technical specifications of engine, silencers etc. No noise measurements need to be carried out
2. Simply add a noise limit to the rules, like 96 dB(A)@ 3 meters. In this case everyone is free to create its own technology to achieve this goal. A very accurate description of the method of noise measurement is necessary , because a too high noise level will lead to disqualification (from a race or from the competition) . The method of measurement should give the highest reproducibility possible.

The participants of this meeting showed no clear majority for one of the options, both have their advantages and drawbacks. Many people have a (financial) problem when a rule change would imply new engines or new cylinders.

This small report gives information of steps made to prepare a strategy to reach the goal
It contains the following steps:

- Measurement of current noise levels, so the necessary reduction figure can be determined
- Proposal for a simple way of measurement, since it turns out that ground running measurements at 3 meters distance don't give what we want.
- suggestions and possible designs for silencers that could suit team race diesels.
- a direction for additional technical specifications in case of an open exhaust approach.

2. Current noise levels

2.1 Noise measurements of flying models at the WC in Gyula

At the 2010 WC in Gyula measurements of time averaged noise levels over 10 – 30 seconds were carried out at a distance of 50 meters from the centre of circles for F2A, F2C and F2D. This was extremely well possible on this flying site because there was a lot of free space without reflecting objects available around the circles.
It turned out that all readings were quite similar for many models, so it is sufficient to give the averages of the readings.

Noise measurements at 50 meters distance from centre of circle

F2A:	82 dB(A)
F2C:	80 dB(A) 1 model flying, 85 dB(A) 3 models flying
F2D:	77 dB(A) 1 model flying, 80 dB(A) 2 models flying

All values reproduced within ± 1.5 dB(A) for the F2A models I measured and within ± 1 dB(A) for the F2C and F2D models I measured. This is of course for representative good models with optimal engine settings. Bad settings give lower speed and lower noise readings.

The variation between max and min value during one lap varies for the classes, for F2A it is I the order of ± 3 dB(A) re the average value, in F2D where 2 models fly in the order of ±2 dB(A) and for F2C in the order of

only ±1 dB(A) , probably because most current engines have the exhaust on the inside, so the effect of shorter distance when the model is at the closest position is compensated by the shielding of the exhaust in that position.
Note. The values given here could be used for approximate calculations to larger distances, by taking a noise reduction of 6 dB per doubling of distance into account, or a 20 dB reduction when the distance is 10 times larger. So a flying F2A model gives appr. 62 dB(A) at 500 meters distance, 56 dB(A) at 1000 meters a.s.o. This is a simple approach, for more accurate calculations the effects of wind and wind direction as well as sound absorption in air need to be considered, but up to 1000 metres this approach will be within ±3 dB(A)

From these measurements it is possible to calculate back to a distance of 3 meter, assuming that the effect of reflection of the ground is similar in both situations. This is more or less true in the case that one compares a 3 meter measurement over tarmac with a 50 meter measurement over a softer soil , like grass.
The noise levels calculated back to 1 model @ 3 meters are then:

F2A:	106.5 dB(A) @ 3 meter
F2C:	104.5 dB(A) @ 3 meter
F2D:	101.5 dB(A) @ 3 meter

Note that these values imply averageing over all directions of noise radiation of the models.

2.2 Noise measurements @ 3meters during ground running.

This type of measurements were carried out at the flying site in Utrecht on a number of F2C models. It was clear that the type of propeller matters for this measurements, even in the case that rpm's are similar.
There is of course also a difference between exhaust side and non exhaust side.
I give the ranges for appr. 15 measurements on 6 different models during 3 sessions.
The readings given here are for the engine running at its highest possible ground rpm (which it will normally only do for a few seconds before getting hot) with a needle setting for ground running (¼ -½ turn open from flying setting). The model was hand held at a height of 1.5 m , microphone height also 1.5 m, ground surface was asphalt.

Noise measurements F2C engines @ 3 meters distance ground running

Exhaust side:	105 – 108 dB(A)
non exhaust side:	101 – 102 dB(A)

The average difference between exhaust and non exhaust side was 6 dB(A)
The average value between exhaust and non exhaust side for these F2C engines was 104 dB(A).

2.3 Measurements in the centre of the circle.

A simple way of measuring noise levels of F2C engines could be in the centre of the flying circle, at the pilot's position. The distance to the model is then 16 meters. The advantage of this position is obvious: the distance to the model is constant (which gives a constant reading of the noise level) and the model is in a representative flying condition. It will be proposed to use this method of measurement for F2C models. Noise checks can be done easily and quickly on solo flying models.
We have done these measurements on 6 models in 2 sessions at the Utrecht site, all on models with the engine exhaust on the in side. model flying height 2-3 meters, microphone height 1.5 meters.

Measurements F2C engines @ 16 meters distance during flight

Exhaust side: 92.5 – 94.5 dB(A)

Taking the distance ratio into account this would mean a noise level (exhaust side) of 107 – 109 dB(A) @ 3 meters. If the same ratio between exhaust side and non exhaust side applies, the noise level on the non exhaust side would be 102 – 104 dB(A) and the average over the two directions 105.5 dB(A) , all calculated back to a distance of 3 meters.

2.4 Summary and discussion.

3 types of measurements on F2C models were carried out. The results reproduce quite well and the differences in noise levels between the models (with proper engine settings) are small, in the order of 2 dB.
Averaged over all directions the noise level of an F2C model <u>in flight</u> calculated back to 3 meters distance is 105 dB(A), the noise level at the exhaust side is 108 dB(A).

The measurement of the noise level in the centre of circle is preferred and may be chosen for , because this represents true flying conditions and a constant distance to the model, giving almost constant, reproducing readings of noise levels. These are appr. 14 dB lower than the levels at 3 meter distance . This measurement method could be developed for use in the F2C Sporting Code.
Almost all current engines have the exhaust on the inside.
If the noise level maximum of 96 dB(A) @ 3 meters would be applied for the average noise levels over all directions, and, since the level at the exhaust side is 3 dB(A) higher than that, 99 dB(A) at the exhaust side would be the limit.
This leads to a criterion of 85 dB(A) measured in the centre of the circle for engines with an open exhaust on the inside, 80 dB(A) for engines with the exhaust on the outside and 82 dB(A) for engines with a front- or rear exhaust.
In the case of application of silencers the difference between exhaust side and non exhaust side will diminish, as can be read further in this note. In that case the 96 dB(A)@ 3 meter criterion can be applied directly without giving too much consideration to the directionality of the noise source, so for engines with silencers the criterion would be 82 dB(A) in the centre of the circle (measured near the pilot's head position).

3. Experiments with silencers on an F2C engine.

3.1 Concept and design.

Until now I have always been pessimistic about the feasibility of silencers in F2C, because the back pressure of a silencing system would give unpredictable feedback to the effective compression ratio of the engine which would make the engine unstable in its operation.

I concluded that the only way to solve this could be to separate the gas flow and back pressure from the acoustic performance.
For this purpose a “neutral” mini pipe was designed for suitable gas flow, with resp. 2 and 3 resonant side chambers. “Neutral” would mean here that the sucking effect of the mini pipe is compensated by flow resistance by dimensioning the mini pipe quite long with a relatively small cross section, using the resonant side chambers to “smooth out” the reflected (negative) wave.
The mini pipe is based on a constant exhaust cross section of 60 mm2, which is already in the rules for the exhaust opening area , equivalent to a diameter of 8.7 mm.(in fact I used an internal diameter of 8.5 mm) and a total effective length, incl. manifold of 125 mm. The length is critical here, because we have to stay in between a too strong mini pipe effect (a too short pipe that sucks the gases strongly out of the exhaust) and tuned length effects, that may occur with a longer pipe.
For this 125 mm length the negative pulse (smoothed by the side-resonant chambers and the relatively small diameter of the inner pipe) comes back to the engine between 70 and 100 degrees of crankshaft rotation (for exhaust gas temperatures between 200 and 300°C and rpm’s between 25000 and 30000) after the pulse is released, where it acts to compensate for the flow resistance of the pipe, to attain effectively an approximate zero back pressure to the exhaust in the optimal case

Two silencers were designed and made of the multi chamber side resonant type, a two and a three chamber type. From earlier acoustic analysis it appeared that the frequency bands that need most reduction are between 1500 and 5000 Hz.
The first silencer had two chambers of resp. 1800 and 3800 Hz, resonance frequencies, the second one had three chambers tuned at resp. 1900, 3000 and 4100 Hz, see photo’s and sketches.

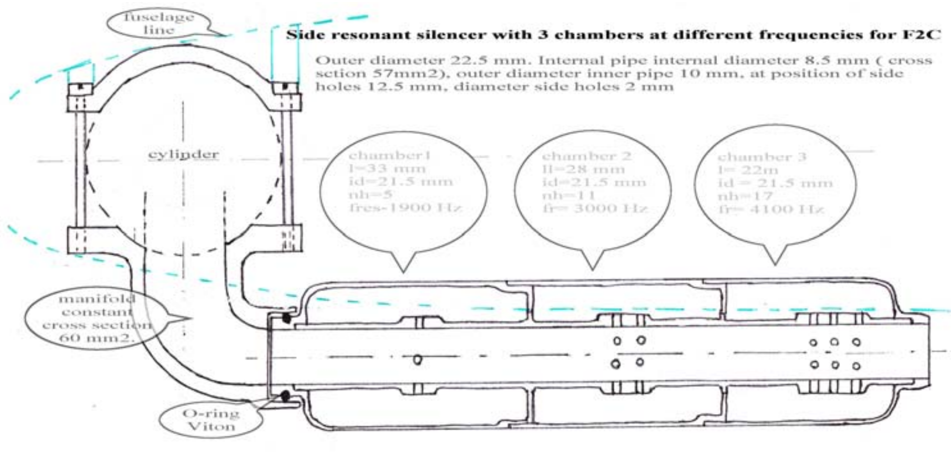

fig.1 Sketch of the 3 chamber side resonant silencer.
l is length chamber, **id** is internal diameter chamber, **nh** is number of holes, **fr** is resonance frequency assuming a gas temperature in the chambers of 150° C.

A two chamber silencer was also built. It had identical dimensions for the inner and outer pipe and total length.
The characteristics of the chambers are :
chamber 1: l = 50 mm, nh = 8, fr = 1900 Hz
chamber 2 : l = 35 mm, nh = 20, fr = 3800 Hz

2 chamber silencer in parts

3 chamber silencer in parts

Manifold to Profi TR engine, effective length 23 mm, exhaust section area 60 mm2 constant.

Engine with silencer

<u>3.2 Tests in the model.</u>

3.2.1.Noise measurements

The tests were carried out on a Profi TR engine and model, propeller 156 mm diameter. A manifold was made to direct the exhaust gases to the rear side and the silencer was attached to the manifold by an O-ring, see photo's. Noise measurement results for this specific engine were the following:

	centre of circle, 16 meters distance	ground running, 3 meters distance, exhaust side	ground running , 3 meters distance, non exhaust side
open exhaust	94 dB(A)	107 dB(A)	101 dB(A)
2 chamber silencer	82 dB(A)	100 dB(A)	99 dB(A)
3 chamber silencer	80 dB(A)	99 dB(A)	98 dB(A)

Model with manifold/ silencer.

The conclusions of the acoustic measurements are the following:

- In flying condition (measured in the centre of circle) the noise reduction was 12 dB(A) for the 2 chamber silencer and 14 dB(A) for the 3 chamber silencer. The criterion given above (82 dB(A) in centre of circle, equivalent to 96 dB(A) @ 3 meter) is met. The 3 chamber silencer is even 2 dB better than that. Propeller noise can clearly be distinguished with the silencer fitted. A next step in noise reduction would affect the propeller blade loading and/or rpm.
- In ground running the noise reduction by the silencer is limited to 7 - 8 dB(A) on the exhaust side. It is quite clear that propeller noise in this case (with the propeller running in very inefficiently and therefore noisy) limits the noise levels. Exhaust side and non exhaust side give the same readings which suggests that in this case the exhaust noise has only a small contribution to the total noise. In flight the propeller noise turns out to be substantially less than in ground running. 96 dB(A) @ 3 meter during ground

running is therefore not achievable with current props and rpm's; but it is achievable in flight. This is another argument that noise measurements during ground running are not effective for our goal.

3.2.2 Power, airspeed, handling.

For both silencers (which are almost identical for gas flow) there was a reduction of airspeed of 1 – 1,5 second/10 laps. A rough calculation of the extra aerodynamic drag due to extra frontal area of the fuselage (from 39 to 45 cm2) and a less good aerodynamic shape, shows that the addition of this outboard silencer would give a speed reduction of appr. 0.8 seconds/10 laps. So the net effect due to reduced engine power can be estimated in the order of 0.5 seconds/10 laps. This compares well with the measured reduction of rpm of appr. 2 %. The number of laps was appr. 3 more. Both effects suggest that effectively there is a small positive back pressure to the exhaust. The total effect on the running of the engine is very similar to a certain venturi size reduction.
The most positive observation of the exercise was however that the handling of the engine was very good, actually it was easier to handle with the silencer than without it. The effects of needle and compression adjustments were very predictable and regular. Compression setting hardly changed after adding the silencer and starting was normal. It was clear that the operating temperature of the engine was not significantly affected by the silencer.

4 . Solutions with open exhaust.

From acoustic measurements appr. 30 years ago it turns out that an approximate noise level of 96 dB(A)@3 meters (exhaust side) with an open exhaust may be achieved by limiting exhaust timing to appr. 120 degrees and a minimum size propeller e.g. 175 mm diameter, 8 mm blade width at 85 mm diameter, 3.5 mm venturi diameter.
Since it is not possible to do such an experiment with the nowadays engines due to the way they are built, the data are derived from some acoustic work done in the early 80's with Nelson and FMV engines.
For experiments with current technology engines new cylinders need to be developed with low exhaust timings. Who will do it?

5 Conclusions and recommendations:

1. Rewrite the 96 dB(A)@ 3meters to 82 dB(A) in the center of the circle , e.g. 20cm from the right side of the pilots head. Measurements can be taken during solo practice flying.
2. Silencers on F2C engines turn out to be feasible on existing engines. Use 2011 to develop an optimal standard silencer, possibly based on the findings reported here. The advantage of a standard homologated device is that probably one or more of the engine manufacturers will make them in sufficient numbers to make them available for everyone.
3. A second way is testing (during processing) home made silencers on the electro acoustic tester from F3D, the requirement of a silencer on this system of measurement will be a 16 dB(A) reduction figure relative to the open outlet of the acoustic driver. See CIAM F3D site.
4. For open exhaust solutions work from the engine manufacturers is urgently necessary, new cylinders with lower exhausts have to be made. Testing with new, bigger props and possibly smaller air intakes will be necessary to be able to make a formulation of a new noise rule.

I expect that in the case a silencer rule is accepted, there will be some development in engines, firstly to add simple lugs to easily mount the silencers, secondly on a change of direction of the exhaust (45 or 90 degrees backwards) to make better aerodynamics for the model with silencer possible.

Rob Metkemeijer
October 15th 2010