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A COMPACT, RUGGED, HIGH REPETITION RATE CO_2 LASER INCORPORATING CATALYST

P M Schwarzenberger and X Matzangou
Applied Physics Division, GEC Avionics Limited
Borehamwood, Hertfordshire
United Kingdom

SUMMARY

The principal design features and operating characteristics of a high repetition rate CO_2 laser are outlined. The laser is a compact, rugged unit, completely sealed and incorporating unheated solid catalyst. Stable operation has been successfully demonstrated over a temperature range of -35°C to 65°C.

INTRODUCTION

There is currently a high level of interest in the use of CO_2 lasers for military and space applications. This has led to the development and testing of catalysts to provide long sealed pulse lifetimes without the need for gas replenishment.

At the 1986 NASA conference on Closed-Cycle, Frequency-Stable CO_2 Laser Technology, GEC Avionics reported the development of a sealed high repetition rate TEA CO_2 laser with a pulse lifetime of 20 million pulses using a solid catalyst (Reference 1). This paper provides an update on some of the work carried out by GEC Avionics since then, on high repetition rate lasers incorporating catalyst.

Having established a stable laser/catalyst system and demonstrated long-term sealed operation, the objectives of the work which followed were to produce a compact, rugged version of the laser suitable for tactical military use, and then qualify the unit against environmental requirements of which the most important are vibration and shock, and operation over a wide range of temperatures. Many of these stringent operating specifications also apply to space-based systems, such as the Laser Atmospheric Wind Sounder (LAWS).

One particular area of concern is low temperature stability, as all catalysts, depending as they do on chemical reactions, suffer a drop in activity as the ambient temperature is reduced.

LASER DESIGN

A schematic diagram of the laser is shown in Figure 1. The laser is a completely sealed unit, the gas seal being formed by a metal enclosure which also provides electromagnetic screening of the device. There is an output window incorporated to allow the laser beam to

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exit, and a military standard high voltage connector to provide connections to the discharge circuit. The laser discharge is formed between two modified Rogowski profile electrodes with a discharge volume of $11cm^3$. A tangential fan, powered by a military standard motor, circulates the gas within the enclosure at a high speed. Catalyst is mounted in the region of the fan intake. A rugged mounting scheme has been introduced for the resonator optics, and parallelism between the cavity optics is retained over a wide temperature range. The size of the laser head is 300mm x 100mm x 90mm, and the weight is 3.9kg. A photograph of the laser is shown in Figure 2.

LASER PERFORMANCE

Typical laser performance parameters are summarised below:-

Power	870kW
Pulse Width	31 nanoseconds
Energy	64mJ
Beam Divergence	3.8 mRad
Beam Wander	0.18 mRad
Mode Purity	95% TEM_{00}
Polarisation	>100:1
Pulse Repetition Rate	50Hz maximum

CATALYST CHARACTERISATION

GEC Avionics are currently evaluating a variety of catalysts from both UK and US sources. In all cases, the precious metal catalysts are solid particles mounted to the inside of the laser gas envelope by a clamp arrangement without the use of any adhesives.

The oxygen generation rate of the laser is typically 0.12 μmoles/pulse, catalyst activities had an average value of around 0.25 μmoles/second/gram, and 70g - 100g of catalyst is used.

The laser was operated at a high repetition rate and various parameters monitored, initially at room temperature. One good indicator of the catalyst activity is the laser discharge stability; in a self-sustained laser, arcing, as opposed to the correct glow discharge, can occur due to electron attachment if oxygen levels in the laser gas mix rise above approximately 0.5%. For much of the initial characterisation, the discharge stability only was monitored during some more recent testing; laser output power measurements were also recorded. Following successful operation at room temperature, the laser system was installed in a temperature chamber with a suitable aperture to allow the laser beam to exit, and diagnostic equipment was placed outside the chamber.

CATALYST A

Using catalyst A, the laser was operated in a temperature chamber at 10Hz for periods of one hour at each temperature.

The results obtained are shown in figure 3, and indicate excellent stability at room temperature, with 100% discharge stability observed throughout the 10Hz, one hour run, and very good results from 0°C to 65°C. At -15°C, however, the discharge stability drops to less than 99%, an unacceptably low level, which is thought to be due to the drop in activity of the catalyst at these low temperatures. The laser was also operated for 50Hz, one second bursts at each temperature with 100% discharge stability, even at -15°C, presumably because the run time was too short for significant oxygen build-up. While this catalyst therefore may not meet the requirements for military use, where a low operating temperature of around -30°C is normally required, it may be suitable for space applications such as LAWS, where it is anticipated that the satellite temperature can be controlled to between 0°C and 100°C.

CATALYST B

With catalyst B installed to the unit, a number of measurements were taken. Power readings were taken with the laser at a variety of temperatures. These results are shown in figure 4, and indicate a high output power level over the tested range of 0°C to 60°C.

As before, discharge stability measurements were also recorded for a 10Hz, one hour run at each temperature and the results are shown in figure 5. These results are very encouraging as they demonstrate a good discharge stability at the low end of the military temperature range, for an extended period of laser operation.

The laser was then subjected to 10 minutes random vibration in each of three axes, at a level of 6g RMS from 5Hz to 2000Hz, with no cracking or dusting of the catalyst particles.

CATALYST C

With catalyst C installed to the laser, discharge stability results were obtained over the range -35°C to 65°C and are shown in figures 6, 7, and 8, for 10Hz, 30Hz and 50Hz operation respectively. Again these results are very promising, in that they demonstrate good discharge stability over the entire temperature range required for military applications for various laser repetition rates and operating times.

They were followed by peak power and pulse width measurements taken at a range of temperatures. Figure 9 shows the output power and pulse width, at 30Hz, and figure 10 shows similar results at 50Hz. In both cases the output power remains high, even at the lowest extreme tested, -35°C, and the pulse width remains essentially constant indicating a consistent gas mix at all temperatures.

Figure 11 shows measurements at the start and end of a 10Hz, one hour run, at different temperatures. They show a drop in laser output of typically 15% over the one hour run, and a slight rise in the pulse width. The parameters even at the end of the run are well above the laser output requirements, and a short rest period is found to restore the power to its original level.

Taken together, these results demonstrate good stability and a high laser output power over a wide temperature range. It should also be noted that, throughout the series of tests, the transverse mode quality of the laser output remained constant, with no evidence of detuning at temperature extremes. This is a particularly notable engineering achievement, as it implies the resonator optics remained parallel to within approximately five arc-seconds, over the entire temperature range tested.

In initial proving tests, the catalyst was tested for a total of 90 minutes random vibration and six 30g, 11ms shock pulses, with no adverse effects.

A laser incorporating Catalyst C was exposed to 10 minutes 6g RMS random vibration in each of three axes. The laser output was consistent before and after the test, there was no evidence of damage to any laser components, and no cracking or dusting of the catalyst.

CONCLUSION

Over the past three years, GEC Avionics' pioneering work in long life, high repetition rate CO_2 lasers has continued with the development of a compact, rugged version of the laser.

The unit has been shown to survive severe levels of environmental testing, and stable operation with high output powers has been demonstrated over a temperature range suitable for both military and space applications. This is indicative not only of the recent advances in laser catalyst technology, but also of the high engineering standards of laser design and construction.

REFERENCES

1. H T Price, S R Shaw: NASA Conference Publication 2456, pages 77-84, 1986.

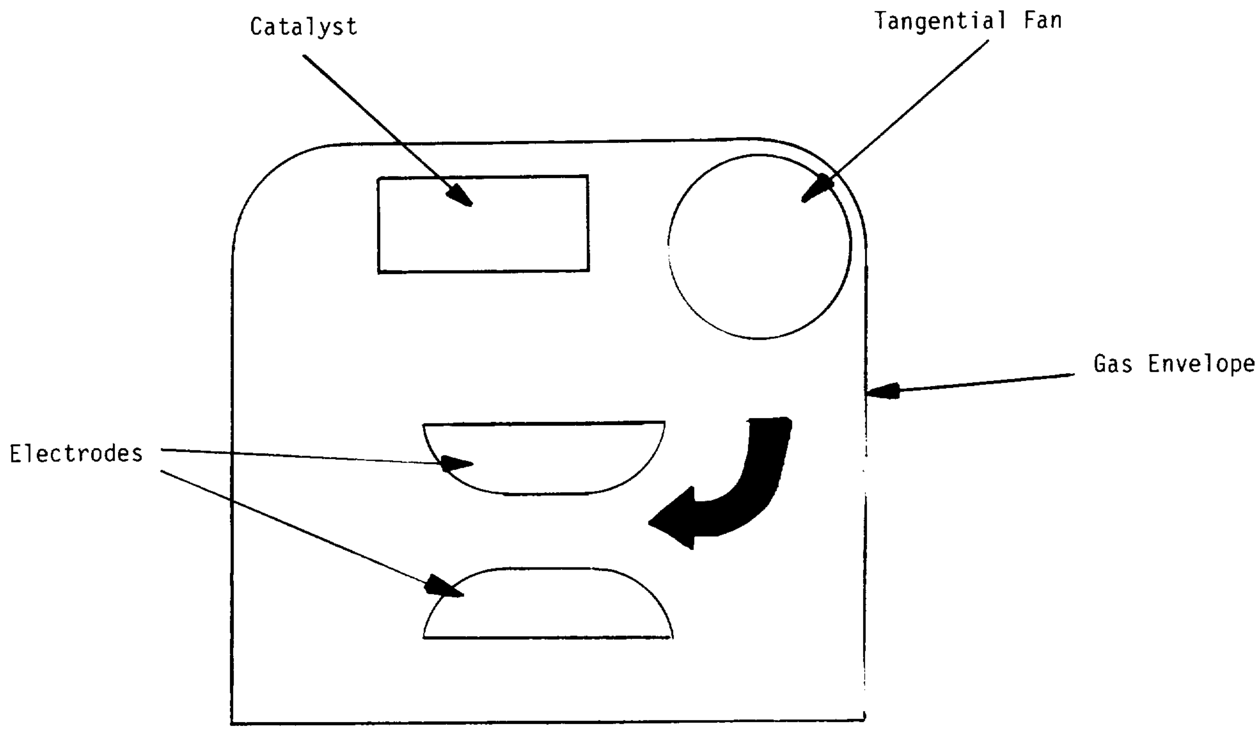


Figure 1:   High Repetition Rate Laser Schematic

Figure 2

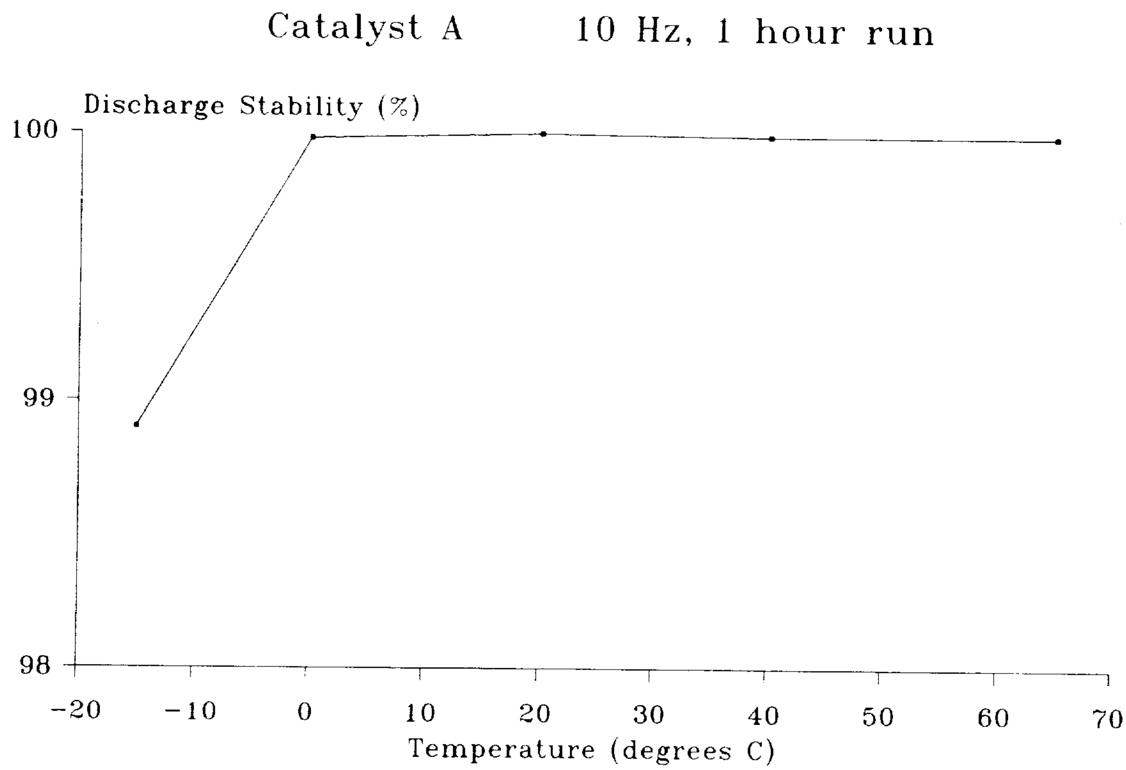


Figure 3

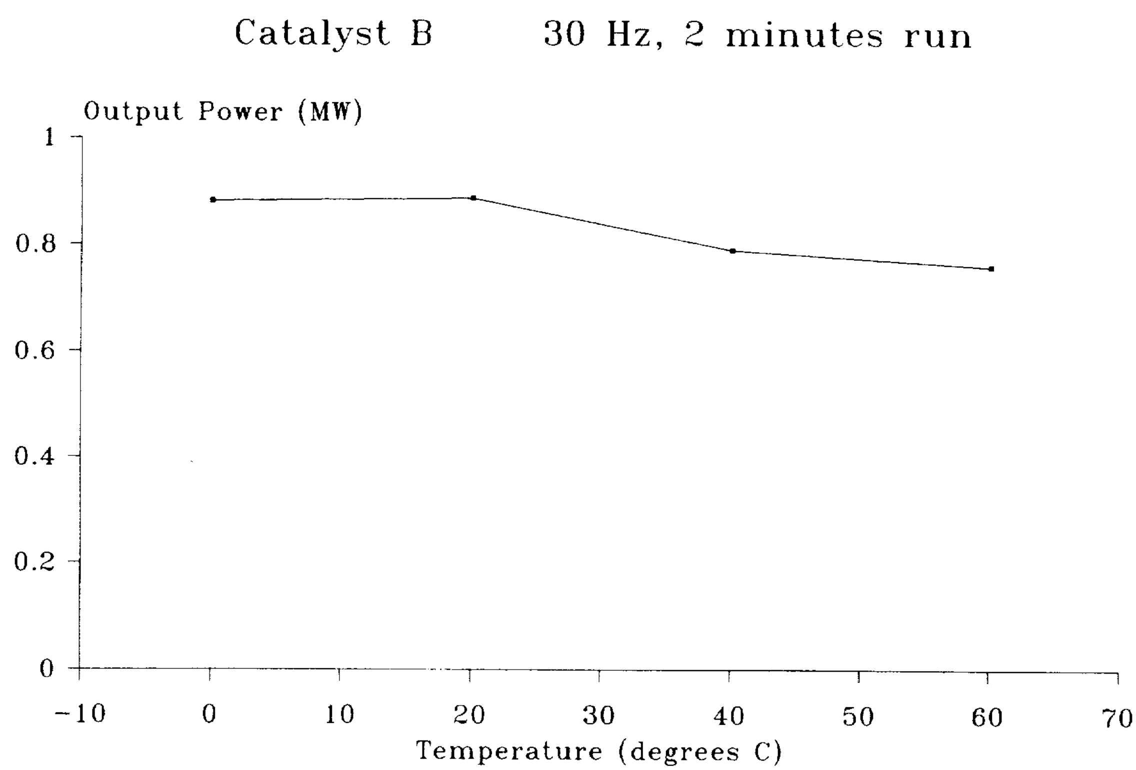


Figure 4

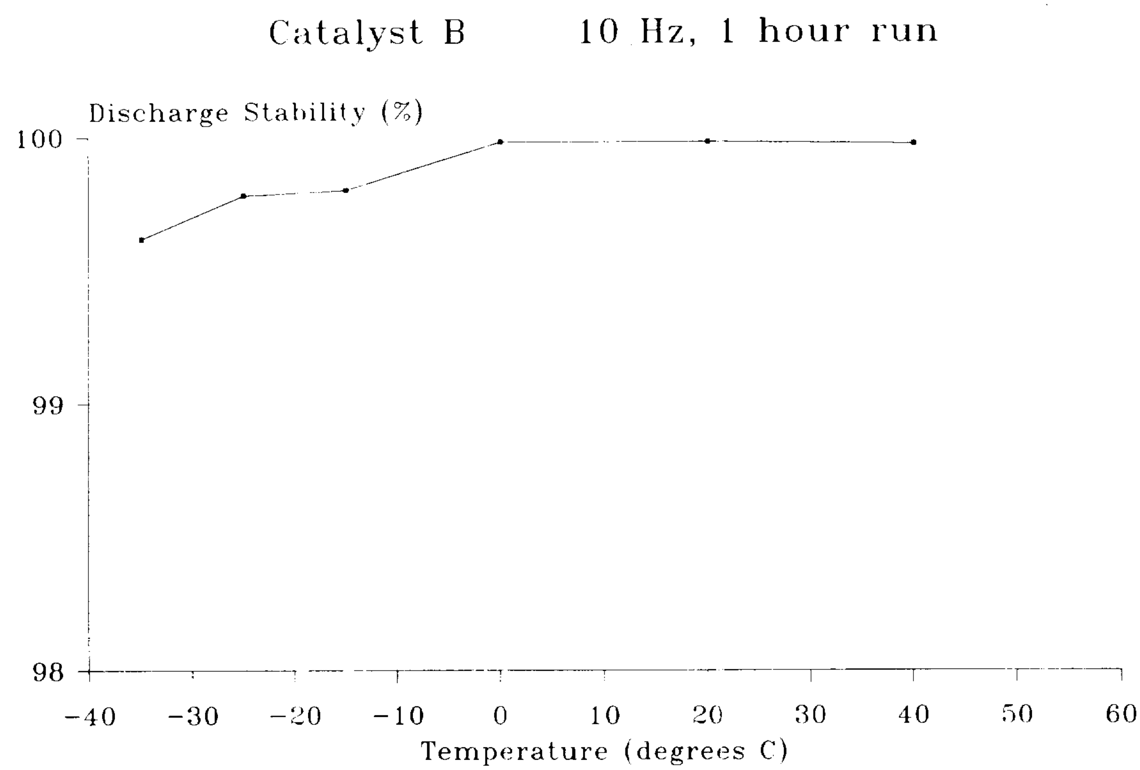


Figure 5

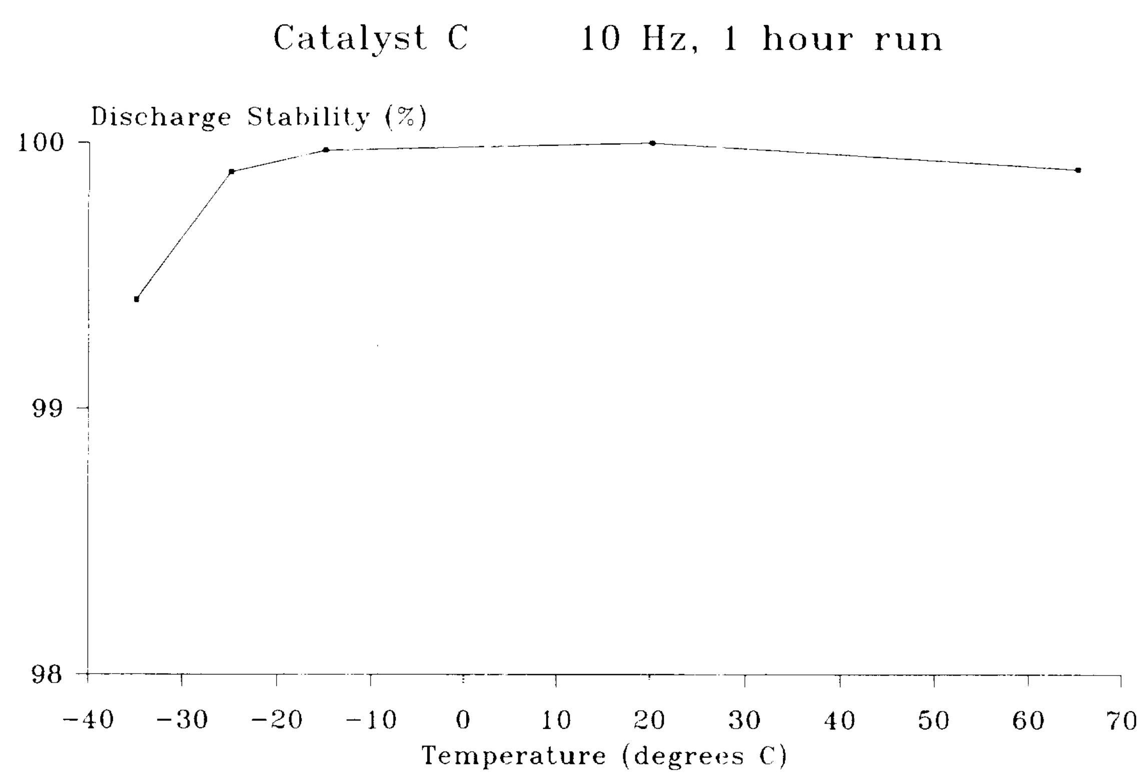


Figure 6

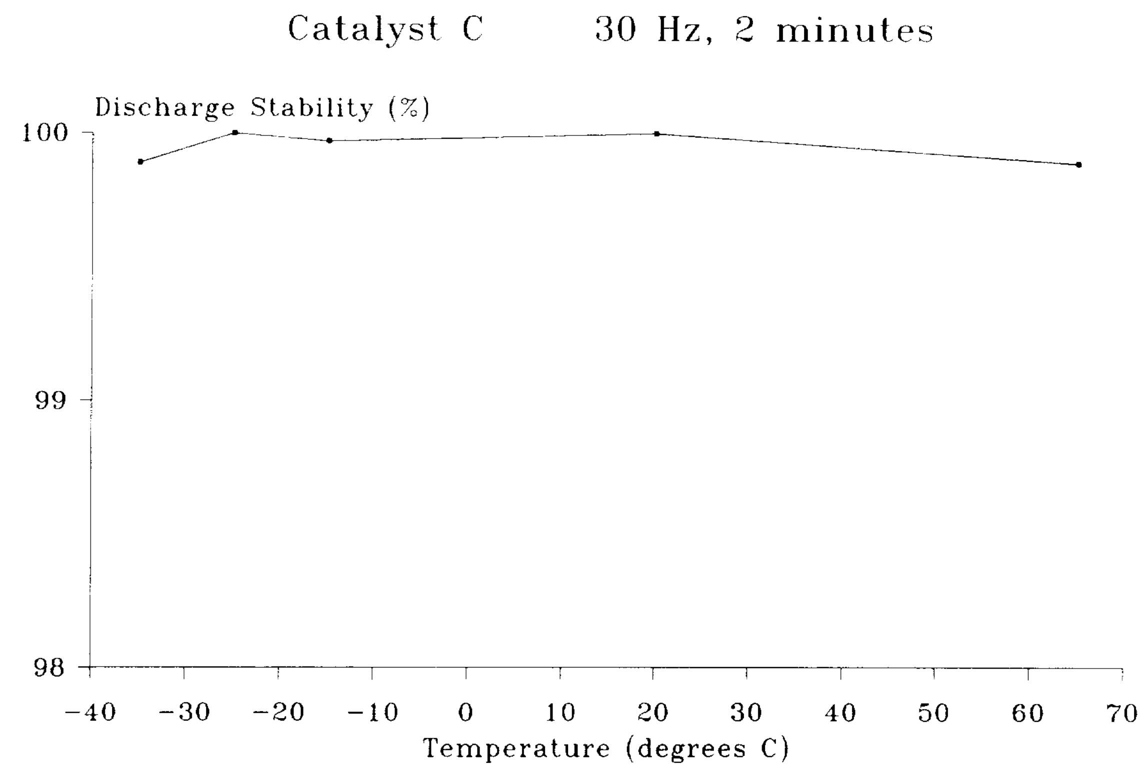


Figure 7

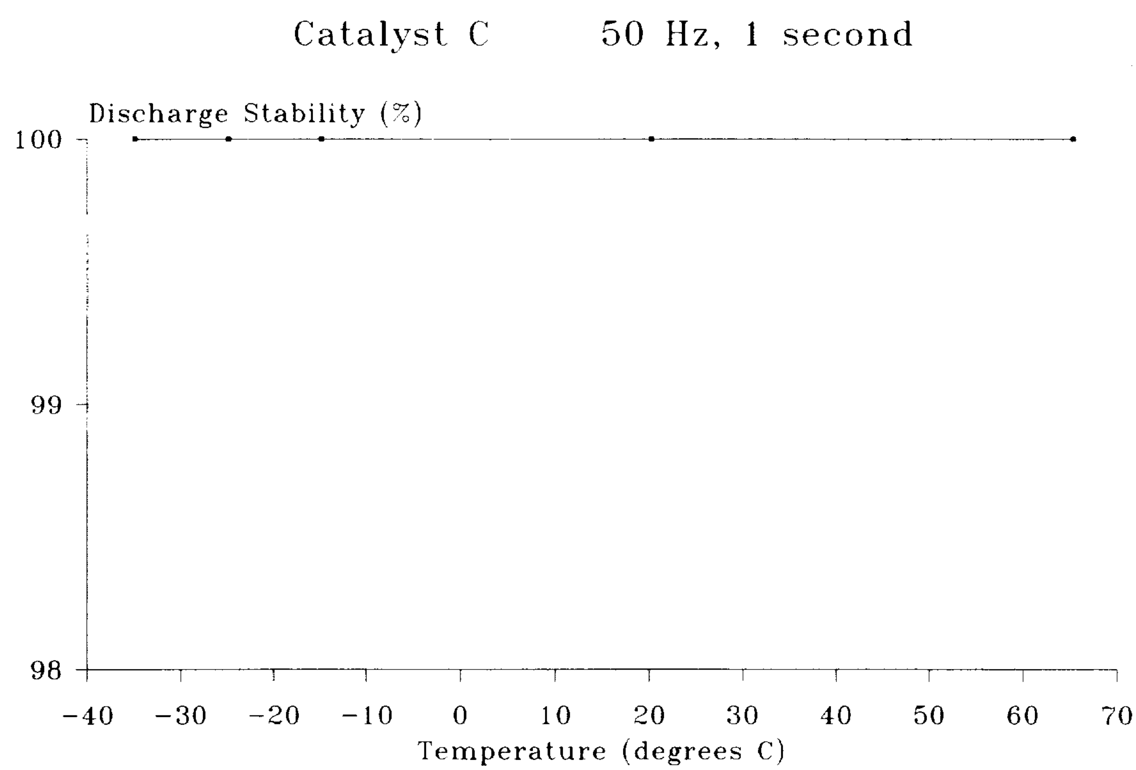


Figure 8

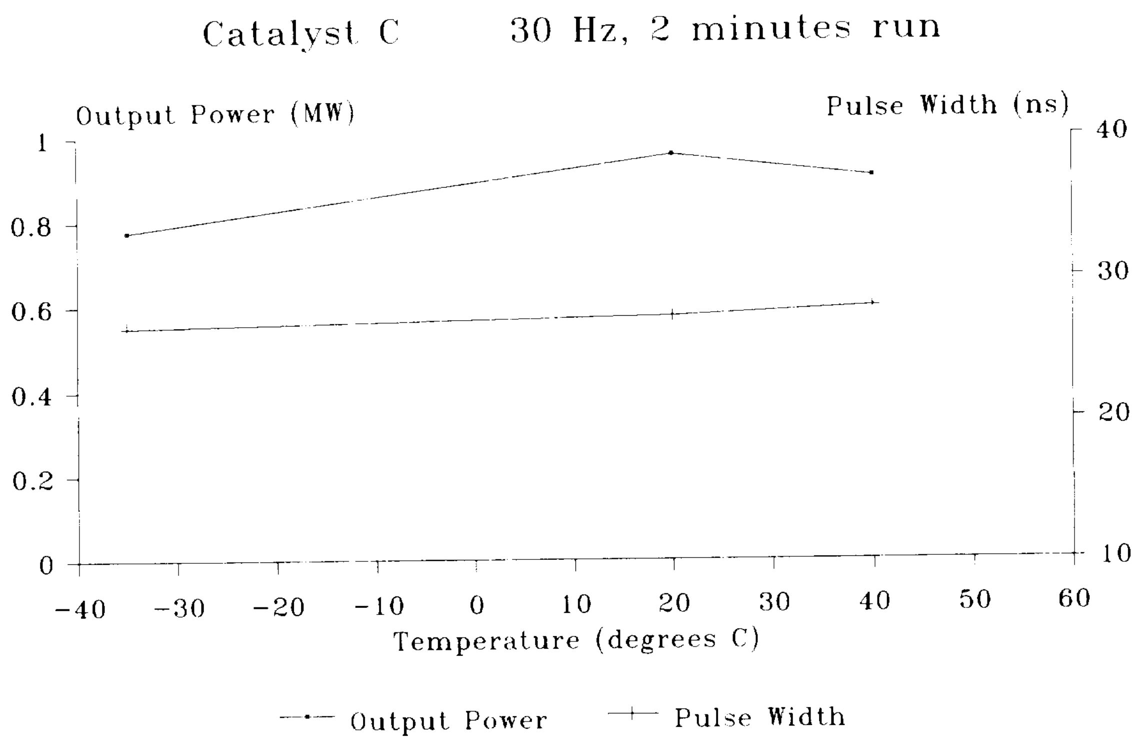


Figure 9

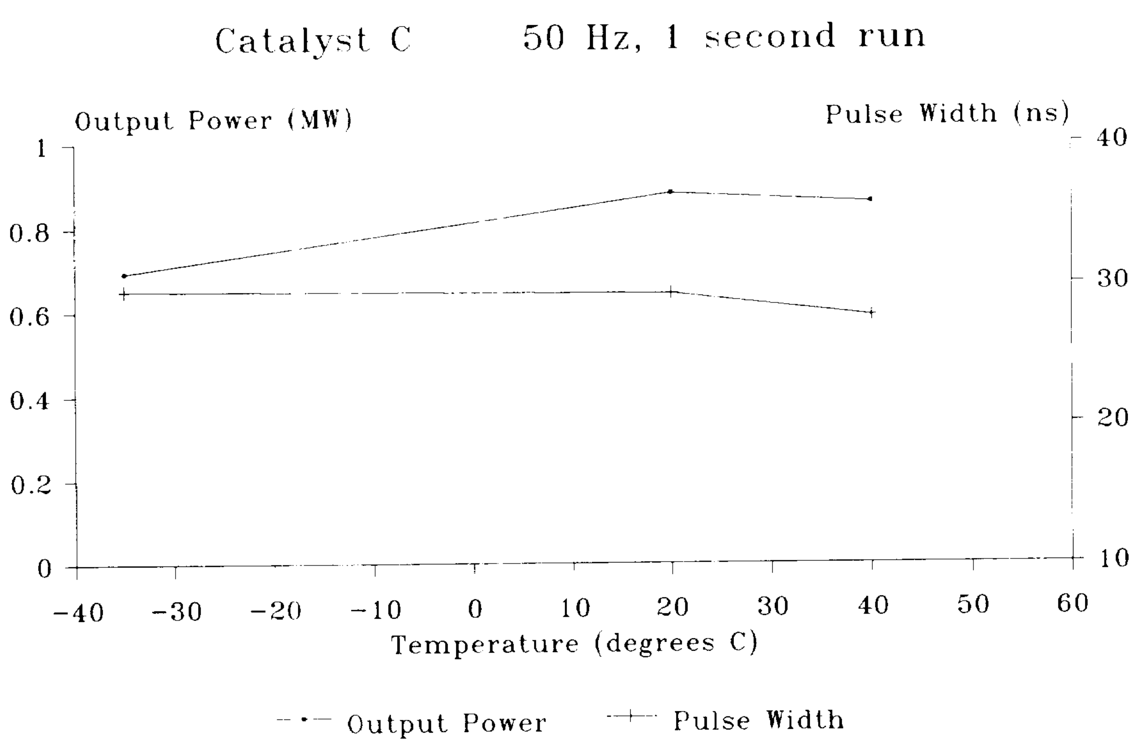
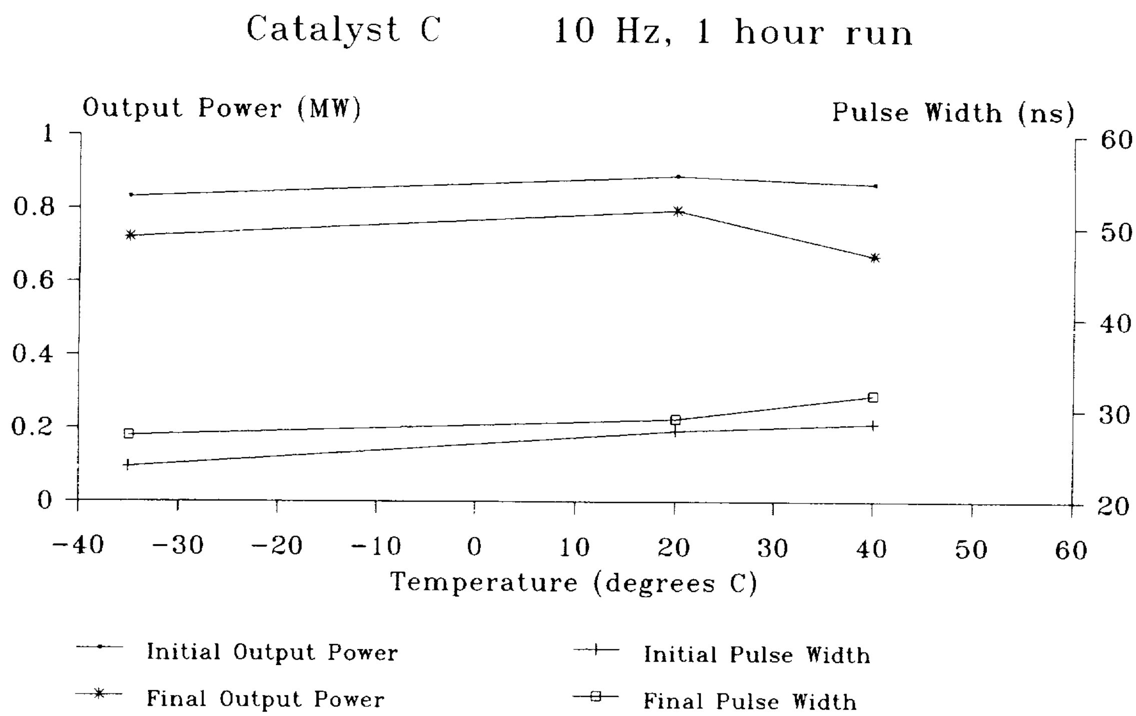


Figure 10



Catalyst C 10 Hz, 1 hour run
Output Power (MW)
Pulse Width (ns)
1
0.8
0.6
0.4
0.2
0
60
50
40
30
20
-40
-30
-20
-10
0
10
20
30
40
50
60
Temperature (degrees C)
Initial Output Power
Final Output Power
Initial Pulse Width
Final Pulse Width

Figure 11