HIGHER ORDER MODES POWER LOSS IN THE VERTICAL SEPARATORS AT CESR

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Abstract

CESR upgrade "phase III" is designed to operate with a total current of 1.0 ampere. It was clear to us that the "old" separators, built in 1978, will not be able to handle this amount of current. Therefore, the vertical separators were re-designed and three new separators were build. Two are installed in the north side of CESR. In order to study if the new separators will be able to support the high current beams designed for phase III, an accurate calorimetric system was designed and built on one of the vertical separators, 48E. Using this system we were able to study the total higher order modes power dissipation in each component of the separator and estimate the total HOM power loss at the higher currents.

1 INTRODUCTION

At CESR the two 2.7 meter long vertical separators are used to separate the two beams at the symmetric point in the north and are also used for luminosity tuning. In each separator the gap between the two high voltage electrodes is 55 mm, which is only 10% wider than the vertical beam pipe dimension. The width of the electrodes is 203 mm. The electrodes were put 1.4 inches away from the outer vacuum tank edge on each side in order to prevent a voltage breakdown between the high voltage electrodes and the outer tank. This 1.4 inches gap is the main cause of the higher order modes power loss. Using an accurate calorimetric system, the higher order modes power dissipated in each component of the separator was measured for various CESR operation conditions. The loss parameter k of the separator was calculated from the measured dissipated power.

2 HIGHER ORDER MODES LOSSES IN THE VERTICAL SEPARATOR

The vertical separator cross section can be seen in Figure 1. The high voltage feeds-through are insulated from the outer tank via a cylindrical insulator (9 inches long and 6 inches in diameter) which is enclosed by a stainless steel tube (10.5 inches in diameter). The 7 inch flange that is mounted on top on the insulator introduces a large mismatch in impedance for the HOM power that is coupled out. The S_{11} parameter of the insulator and the enclosing stainless steel tube wasmeasured to be about -1 dB and almost all the power will be reflected back into the separator. This will increase significantly the heat load of the electrodes and lower the safe high voltage operation. To avoid this, 40 blocks of ferrite (1.5 inches by 2.0 inches) were glued inside the stainless steel tube below the top flange of the insulator. The S_{11} parameter of the insulator configuration including the ferrite blocks is about -7.5 dB. In this case only about 50% of the HOM power that is coupled outside through the feed-through is reflected back. As was mentioned above, most of the HOM power loss will occur at the gap between the electrodes ends and the end plates of the outer tank. The total HOM power loss can be calculated using the following equation.

$$P = \frac{k(\sigma_z, Pr) \cdot I_b^2 \cdot N_b}{10^{-12} \cdot Frev} Watts \tag{1}$$

Where: $k(\sigma_z, Pr)$ is the loss factor (V/pC), σ_z is the bunch length (m), Pr the horizontal beam offset at the separator due to the close orbit distortion "pretzel" that is needed for multibunch operation, I_b bunch current in (A), N_b number of bunches, $Frev$ revolution frequency (Hz). Since the gap between the electrode ends and the end plates is of the same order as the bunch length the loss factor k will depend inversely on the bunch length. Also, the high voltage electrode ends are made from 180 degrees, 6 inches in diameter elbows; therefore the gap seen by the beam is larger as the beam offset amplitude is increased and the HOM power loss will depend on the size of the closed orbit distortion as is given by the horizontal pretzel amplitude. The HOM beam power loss in the separator is dissipated in the electrodes, the outer vacuum tank and the part that is coupled outside, in the ferrite and the inductive load on the high voltage cables.

3 THE CALORIMETRIC SYSTEM

The cooling of the separator is done by two different coolant systems, one is using CESR $85°$F water and the other is using freon which is cooled via a heat exchanger by the $85°$F water. The water system is used to cool the outer tank, the ferrites in the top and bottom insulator can and the high voltage cables' inductive loads. The freon is used to cool the top and bottom high voltage electrodes. In order to be able to measure the dissipated power in each one of the seven components of the separator, the cooling is done in parallel. High resolution thermistors are imbedded, using a spacial housing, in each one of the input and output coolant pipes. These thermistors are measuring the temperature of the coolant at the input and output with resolution of $0.005°$C. The flow rate of the coolant to each one of the components was measured. By knowing the coolant flow rate and the temperature difference between input and output the dissipated power in each component of the separator can be calculated.

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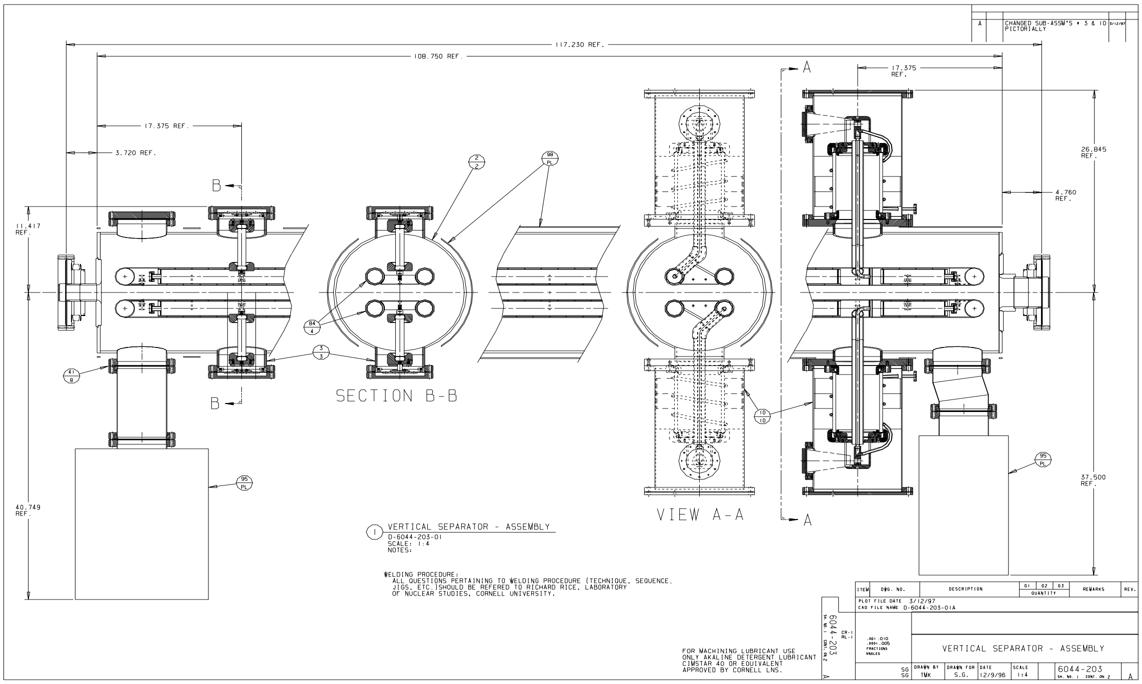

Figure 1: The vertical separator cross section

4 H.O.M POWER LOSS MEASUREMENTS

Using the calorimetric system we have measured the HOM power loss in the vertical separator for different CESR operation parameters :

A. The dependence of the HOM power loss on horizontal beam offset as is determined by the horizontal closed orbit distortion and is given by the pretzel amplitude ,can be seen in the upper part of Figure 2. The HOM losses increase as the horizontal pretzel amplitude is increased since the gap seen by the beam is larger. For example, when going from zero pretzel, beam on axis, to HEP pretzel which shifts the beam horizontally at the separator by about 1 inch, the gap seen by the beam changes from 1.4 inches to 1.53 inches and the HOM power loss increases by 10%.

B. The measurements described above were repeated with the two wigglers closed, as can be seen in the lower part of Figure 2. The power loss for the case when the wigglers were closed was lower by about 8% compared to whe n the wigglers were open. The reason for this is that the bunch length is elongated by the wigglers by 8% as was also seen with a streak camera[1]. In HEP condition, wigglers closed and full pretzel, the increase in the HOM power loss due to the horizontal beam offset is partly cancelled by the elongation of the bunches by the wigglers, since both effects are of the order of 8%.

C. The HOM power loss as function of the number of bunches in a train, can be seen in Figure 3. It was found that the loss factor k increases by about 17% when the number of bunches in each train was increased from 1 to 3. The increase in power loss is probably caused by the interaction of the trailing bunches with the HOM power induced by the leading bunches in the train. (The spacing between the bunches was 14 and 28 nsec while the spacing between the trains is about 280 nsec.)

D. The change in the HOM power loss as function of the bunch length, can be seen in Figure 4. The bunch length was changed by changing the RF Accelerating voltage[1]. The HOM power loss is proportional inversely to the bunch length.

The distribution of the HOM power loss in the different components of the separator as function of current per bunch can be seen in Figure 5. The percentage of the total

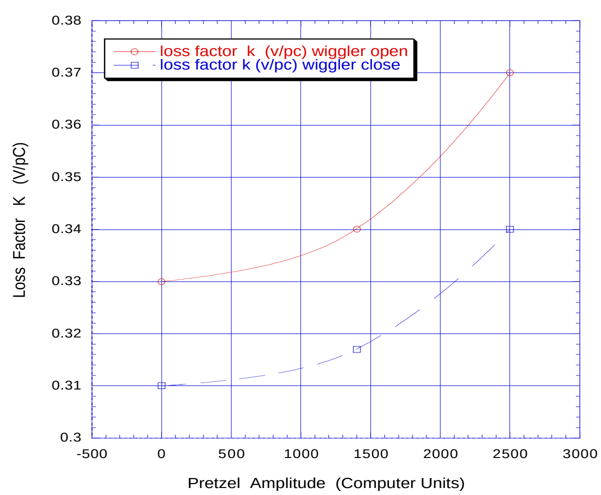

Figure 2: HOM power loss as function of the horizontal beam offset determined by the pretzel amplitude for open and closed wigglers. 2500 computer units correspond to about 25 mm off center beam shift.

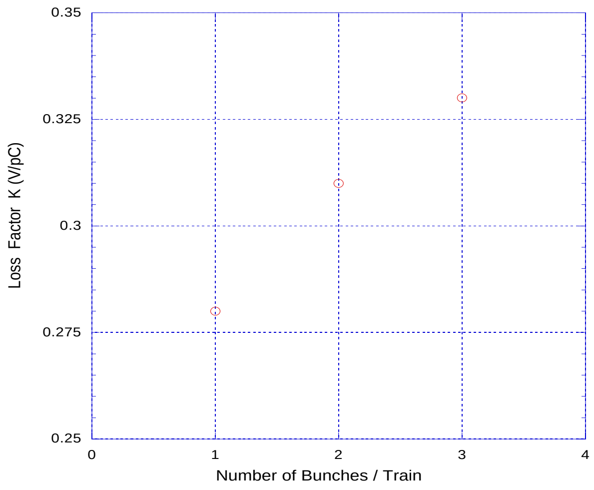

Figure 3: HOM Power Loss as Function of the Number of Bunches in a Train, Beam on Center Wigglers Open

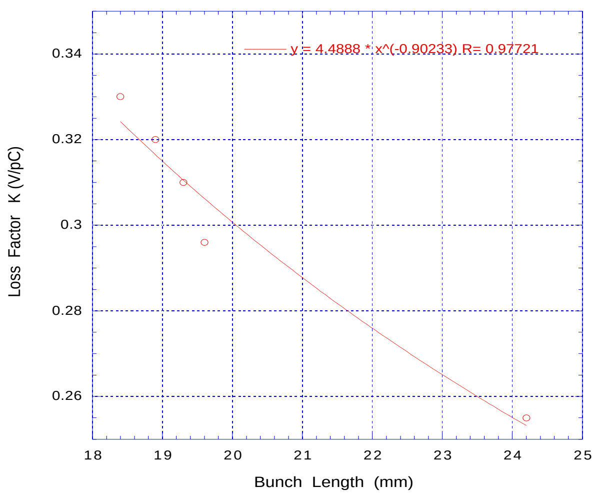

Figure 4: HOM power loss as function of the bunch length, beam on center, wigglers open

power dissipated in each component is independent of the current. Fifty seven percent of the total HOM loss power is coupled out through the feed-through of which fifty percent is dissipated by the ferrite blocks and eight percent in the inductive load of the high voltage cables, thirty percents is dissipated in the electrodes and about thirteen percent is dissipated in the outer tank.

5 CONCLUSION

Only thirty percent of the total HOM power loss is cooled by the freon system and the remaining seventy percent by the water system. This reduces significantly the heat load on the freon system which is much less efficient than the water system. Ninety percent of the HOM power that is coupled outside through the feed-through is absorbed by the ferrite blocks and the rest by the inductive load. Thus

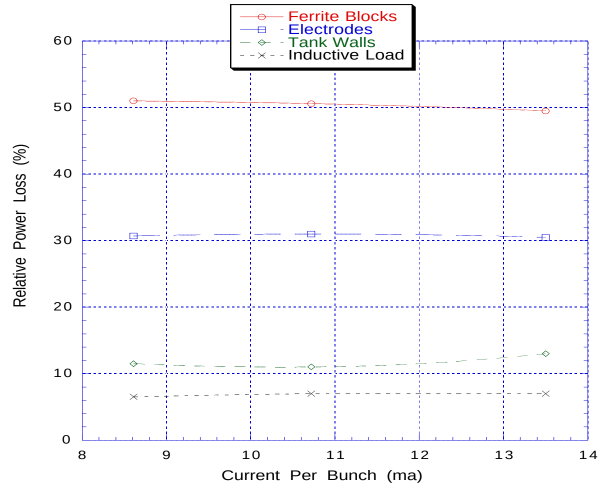

Figure 5: The distribution of the HOM power loss in the different components of the separator as function of current/bunch

there is hardly any power dissipated on the high voltage cables and connectors. This increases the reliability of the high voltage cables and connectors. The loss factor k for the separator in colliding condition with two bunches per train is 0.32 ± 0.01 V/pC, while for three bunches per train it is 0.34 ± 0.01 V/pC. The expected HOM power loss in future upgrades of CESR with three bunches per train with total of 600 ma will be $5.6KW$, while for five bunches per train with total current of 1.0 ampere it will be $9.5KW$. The vertical separators will be able to handle this power with any problems.

6 ACKNOWLEDGMENT

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7 REFERENCES

[1] R.Holtzapple and D. Hartill Streak Camera Measurenents at CESR to be published.