~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

MASTER

WANL-TME-677
FEBRUARY 4, 1964

(14)

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

SUBMITTED BY:

Westinghouse Electric Corporation
Astronuclear Laboratory
Pittsburgh 36, Pennsylvania

SPECIAL REVIEW
FINAL
DETERMINATION
Class: U
Reviewers: KAW
Date: 5-3-82

INFORMATION CATEGORY CRD	
<u>LDW/1</u>	<u>2/14/64</u>
Authorized Classifier	Date

Classification cancelled (or changed to _____)
by authority of _____
by H.F.C. TIC, date SEP 12 1973

PREPARED BY:

D. B. Mattson

T.B. Mattson

APPROVED BY:

D.W. Drawbaugh
D.W. Drawbaugh

FURTHER RESULTS
OF A THEORETICAL
FLOW-VIBRATION MODEL

(Title Unclassified)

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

GROUP 1 EXCLUDED FROM AUTOMATIC DOWNGRADING AND DECLASSIFICATION
--

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy 1954~~

Introduction

This report discusses the results of a number of runs that were made using the "Flow Vibration Program" as was discussed in Part II of WANL-TME-447 (1). The computer program determines the one-dimensional motions of a set of rods hinged at one end (the inlet, or cold end); each pair of rods is separated by a prescribed gap thickness when in equilibrium. The motions of the rods are the result of a fluid flow between them. The input parameters for the runs made using this program were primarily chosen to study the effect of seals located on the left and right ends of the set of rods, either at the top (inlet, or cold end) or the bottom (outlet, or hot end). A spectrum analysis was done on the results of the computer runs, similar to the analyses of actual experiments in Part I of WANL-TME-447 (1).

The most significant results of the analyses of the runs were the following: (1) the bottom seals significantly reduced the relative amplitudes of those vibrations present during the runs; (2) the insertion of bottom seals on the left and right ends resulted in a bundling of the rods; (3) the insertion of top seals on the left and right ends had varying effects, none of which were favorable.

A detailed discussion of the runs made, and the quantitative and qualitative results of their analyses is contained in the following sections.

Description of Runs Made

The series of runs discussed in this report was concerned with the variation of relatively few of the parameters involved. In Table I a

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy~~

list of those parameters whose values were varied together with their values for each of the runs is to be found. The starting time for recording the results to be analyzed was set equal to 0.125 seconds so that a steady-state condition might be reached during the run. Only runs 5, 6, and 9 used recorded values from the beginning. The final time was chosen so that 50 points were available for the spectrum analyses (100 points in runs 5, 6 and 9). The size of the equilibrium gap between rods was either 0.005 inches or 0.04 inches.

In Part II of WANL-TME-447 (1) the differential equations describing the motions of the rods were developed; the form of those equations is given by

$$\ddot{y}_i + \frac{k}{M} (y_i - b_i) = (1/M)(U_{n,i} - U_{m,i+1}), \quad i = 1, 2, \dots, k$$

where the forcing functions (the U's) are complicated expressions as given in that report. The Flow Vibration Program has the option of altering the forcing functions on the left and right ends according to the equations

$$U_{n,1} \leftarrow a \cdot U_{n,1} + b_{\text{left}}, \quad U_{m,k+1} \leftarrow a \cdot U_{m,k+1} + b_{\text{right}}$$

where a , b_{left} , and b_{right} are input constants. By assigning proper values to these constants, bottom or top seals can be simulated. Thus, a bottom seal is effected by setting all three constants equal to zero, while a top seal is given by $a = 0$, and $b_{\text{left}} = b_{\text{right}} \neq 0$. For this series of runs, a pressure difference of 10 pounds between the inlet and the outlet was used, resulting in a value for

$$\frac{b_{\text{left}}}{M} = \frac{b_{\text{right}}}{M} = 63,685.4 \text{ in.}^{-2}\text{-sec.}^{-2}$$

for a top seal.

Two different sets of initial conditions for displacements and velocities were used. The first set, referred to as "equilibrium position-moving ends", is such that all the rod displacements are their equilibrium positions, and all the velocities are $\pm 2.5 \text{ in.}^{-1}\text{sec.}^{-1}$ (minus to the left of center, plus to the right) except the center rod, which is stationary. The other set of initial conditions differs from this in the conditions for the rods on the left and right ends. These rods are splayed out, touching the left and right sides, and have zero velocities. This second set of initial conditions is referred to as "splayed position-stationary ends."

Discussion of Results

For all thirteen runs, plots of the auto spectrums were made for each of the seventeen rods. For example, Figure 1 shows a plot of the auto spectrum for the eighth rod of run 10. This run, with a top seal and a 0.005 inch gap size, approximates the KIWI B4-A Cold Flow Test conditions. It is of interest to note that the first harmonic peak occurs at $6/54$ cycles per data point (22.2 cycles per second), which is the same frequency as was obtained in the analysis of the cold flow test results. The second harmonic peak is approximately at $12/54$ cycles per point, and while there is no peak at $18/54$ cycles per point, a peak does occur at $25/54$ cycles per point. Eight of the rods in this run exhibited similar

spectrums. In contrast to this run the auto spectrum plots for run 11 exhibit no definite pattern, appearing to be noise. The relative amplitudes are in the range 10^{-12} to 10^{-16} . This run duplicated the conditions of run 10 except for one important difference - the seal was a bottom seal in this run.

Figures 2 and 3 are plots of maximum amplitude versus rod number for runs 8 and 10, respectively. The plot for run 8, which has a top seal and a gap size of 0.04 inches, is similar to the plots of intensity as a function of position which were obtained from the analysis of KIWI B4-A data (cf. (1)). However, the plot for run 10, which also approximates the KIWI B4-A conditions, does not exhibit quite the same relationship. Similar plots made for the other runs with a top seal show roughly similar relationships, while the plots for the runs with a bottom seal exhibit a more random character.

The positions of the rods at the end of the runs give rather interesting results. The runs which resulted in a bundling of rods in the center were runs 1, 7, and 13, all of which had a bottom seal. Runs 3, 5, and 11 ended with a bundling of rods at the left end; these runs also had a bottom seal, the difference being in the initial displacements and velocities. This bundling effect with a bottom seal was also reported on in WANL-TME-645 (2).

With a top seal (or no seals, as in run 9) the final positions of the rods were either randomly distributed from the left to the right side, or distributed in several bundles. This would indicate that vibrations were still occurring when the runs were stopped.

Table II lists the maximum intensities at the first harmonic peak of all the auto spectrums of those runs with a top or bottom seal. Note that the bottom seal runs have maximum intensities significantly lower than those runs with a top seal. The average maximum intensity for bottom seal runs is several orders of magnitude smaller than the average for top seal runs. Thus the vibration that is present in the bottom seal runs seems to be of little significance.

The gap size between rods in the flow vibration model was found to have an effect on the results. Table III lists the maximum intensities at the first harmonic peak in pairs, where each pair of runs have the same parameters except for gap size. In every pair of runs, the maximum intensity is significantly larger for larger gap size. The effect of bottom seals as discussed above remains, however, when the effect of gap size is removed.

It was also noted that, depending on the seal conditions, gap size had an effect on the final displacements of the rods when the run was terminated. With a bottom seal, gap size had no effect on these displacements; with a top seal, positions at the end of the run were different for different gap size.

Runs 12 and 13 are identical, respectively, with runs 8 and 7, except 12 and 13 have initial velocities for the rods which are double those for 8 and 7. The only effect that this change had on the results was a significant lowering of the average frequency for the harmonic peaks. The average frequency for the first harmonic peak for run 8 was 20 cycles

per second, whereas run 12 had an average frequency of 13 cycles per second. Similarly, run 7 had an average frequency of 17 cycles per second, while run 13 had an average of 15 cycles per second.

Conclusions

The analyses of these runs have yielded several significant results. The most important of these is the fact that a bottom seal, as opposed to a seal at the top, reduced the relative amplitudes of any vibrations at least by a factor of several orders of magnitude. Moreover, the bottom seal had a definite bundling effect on the rods. The analyses of the runs with a top seal showed both higher relative amplitudes of vibration and unstable rod positions at the end of the runs. All of these effects are in keeping with analytical and test results as reported in WANL-TME-645 (2).

If this problem warrants any further study, then a more thorough analysis of the effects of various parameters is in order. For example, the question of how well steady-state conditions were approached remains unanswered.

If anyone is interested in other runs, the "Flow Vibration Program," with documented instructions, is available. All the plotted data for the computer runs described in this report are also available.

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act of 1954~~

References

1. D. W. Drawbaugh, et al., "Analysis of KIWI B4-A Cold Flow Test Cinema and Results of a Theoretical Flow-Vibration Model," WANL-TME-447, (September, 1963).
2. B. L. Pierce, "Comparison of Analytical and Experimental Flow Induced Core Vibrations," WANL-TME-645, (January, 1964).

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act of 1954~~

CONFIDENTIAL
RESTRICTED DATA
 Atomic Energy Act, 1954

- 8 -

Run No.	Seal	Starting Time (sec.)	Final Time (sec.)	Gap Size (in.)	$(b_{\text{left}}/M)=(b_{\text{right}}/M)$ (in.-sec. ⁻²)	a	Initial Displ. & Velocities (in. & in.-sec. ⁻¹)
1	Bottom	0.125	0.375	0.005	0	0	Equil. Pos. - Moving Ends
2	Top	0.125	0.375	0.005	-63,685.4	0	Equil. Pos. - Moving Ends
3	Bottom	0.125	0.375	0.04	0	0	Splayed Pos. - Stat. Ends
4	Top	0.125	0.375	0.04	-63,685.4	0	Splayed Pos. - Stat. Ends
5	Bottom	0.005	0.510	0.04	0	0	Splayed Pos. - Stat. Ends
6	Top	0.005	0.510	0.04	-63,685.4	0	Splayed Pos. - Stat. Ends
7	Bottom	0.125	0.375	0.04	0	0	Equil. Pos. - Moving Ends
8	Top	0.125	0.375	0.04	-63,685.4	0	Equil. Pos. - Moving Ends
9	Open	0.005	0.510	0.04	0	1.0	Splayed Pos. - Stat. Ends
10	Top	0.125	0.375	0.005	-63,685.4	0	Splayed Pos. - Stat. Ends
11	Bottom	0.125	0.375	0.005	0	0	Splayed Pos. - Stat. Ends
12	Top	0.125	0.375	0.04	-63,685.4	0	Equil. Pos. - Moving Ends
13	Bottom	0.125	0.375	0.04	0	0	Equil. Pos. - Moving Ends

Table I - Input Parameters for Runs

CONFIDENTIAL
RESTRICTED DATA
 Atomic Energy Act, 1954

Astronuclear

<u>Run No.</u>	<u>Seal</u>	<u>Maximum Intensity at First Harmonic Peak</u>	
2	Top	3.5×10^{-9}	
4	Top	1.8×10^{-2}	
8	Top	1.6×10^{-2}	Average = 1.6×10^{-2}
10	Top	5.4×10^{-3}	
12	Top	4.1×10^{-2}	
1	Bottom	2.2×10^{-8}	
3	Bottom	5.0×10^{-4}	
7	Bottom	1.1×10^{-4}	Average = 1.2×10^{-4}
11	Bottom	2.5×10^{-12}	
13	Bottom	3.0×10^{-8}	

Tabel II - Maximum Intensities at First Harmonic Peak

<u>Run No.</u>	<u>Gap Size</u>	<u>Seal</u>	<u>Maximum Intensity at First Harmonic Peak</u>
1	0.005	Bottom	2.2×10^{-8}
7	0.04	Bottom	1.1×10^{-14}
2	0.005	Top	3.5×10^{-9}
8	0.04	Top	1.6×10^{-2}
11	0.005	Bottom	2.5×10^{-12}
3	0.04	Bottom	5.0×10^{-4}
10	0.005	Top	5.4×10^{-3}
4	0.04	Top	1.8×10^{-2}

Table III - Effect of Gap Size on Maximum Intensity

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954