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May 9, 1966

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Enclosed is a draft of the technical proposal discussed in our recent telephone conversations. I would appreciate your comments on the technical content and direction of the effort.

I will submit a formal proposal after we have reviewed the draft.

Regards,

[redacted]

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WAS:nlm

Declass Review by NGA.

May 9, 1966

PROPOSAL FOR MENSURATION ERROR ANALYSIS STUDY TASKS

Measurement of extended lengths to submicron accuracy is a reasonable and attainable goal and data for cost effectiveness trade-offs is needed. Mensuration yardsticks of adequate absolute accuracy can be produced. To take advantage of them and to achieve the routine production of measurements to the final available accuracy requires progress on a broad front. Specifically, for cost effectiveness trade-offs of the measuring machine, we must consider the effect of:

the operator

the film

the environment

and obtain data necessary for these trade-off evaluations.

This proposal is concerned only with the film and the environment, but the following comments regarding operator requirements are included for completeness.

The operator has a significant impact on the cost effectiveness of the mensuration system. Since the operator is a gating function it is imperative that his effectiveness be maximized. Particular attention must be paid to:

a) Efficiency of the work station.
b) Reduction of fatigue, particularly eye fatigue in maintaining stereo registration.
c) Applying all operator faculties to achieving pointing accuracy.

In addition to the operator, both the film and the environmental inputs are potentially serious limitations to the effectiveness of a mensuration system.

The logical approach is that first their magnitudes be assessed to provide the data for cost the trade-off decisions. Determination of magnitude data is the subject of this proposal. Certain of the data will be determined by making measurements on existing equipments and it will be applicable to improving the performance of that equipment.

The film contributes to mensuration error in two ways: by physical distortion and by edge definition. In particular, we are concerned with physical distortion of the film during the mensuration process while the film is mounted on the measuring machine. (Calibrated fiducial marks are relied upon to provide correction for distortion prior to mensuration.) Film physical distortion will be principally determined by transient and steady state heat balance and humidity conditions and by the physical constraint of tension rollers and of the platen to which the film is clamped by vacuum. We propose a study task three items:

<u>Task 1. "Thermal Environment"</u>

Item 1) An analytical heat balance transient and steady state model will be prepared of film which is vacuum clamped to a glass platen.

Item 2) An analytical physical restraint model will be prepared of film clamped to a glass platen.

Item 3) A parametric study will be made of expected dimensional changes of film vacuum clamped to a glass platen due to the variations of parameters established in 1 and 2 above.

In the parametric study attention will also be devoted to the effect of film graininess on edge definition.

The environment contributes to mensuration error (other than by temperature and humidity) by vibration. The first consideration is to determine the statistical properties of the building vibration which constitutes the input disturbance to the measuring machine. The next consideration is the effect of the input disturbance on the measuring machine and the contribution to mensuration error. Finally the necessary vibration isolation must be determined. We propose a second study task with three items:

<u>Task II: Vibration Environment</u>

Item 1) Experimental requirements will be determined for statistical measurement of building vibration, the statistical experiment design will be prepared and the technique proved by making sample measurements. (We anticipate that customer technicians will continue the experimental measurements)

Item 2) Experimental requirements will be determined for measurement of resultant vibration levels at the platen of specific mensuration equipment with appropriate vibration inputs. The experiment design will be prepared and the technique proven by sample measurements.

Item 3) Vibration isolation requirements will be analyzed with due consideration to internally generated machine vibration and structural resonance.

The proposed work is delineated in detail in the accompanying task descriptions.

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MENSURATION ERROR ANALYSIS

Proposed Statement of Work by Tasks

Task I: Thermal Environment

Item 1. Heat Balance Model

Establish an analytical heat balance model, transient and steady state, for film which is vacuum clamped to a glass platen and illuminated with high intensity light.

Procedure: Make a literature search for experimental data on various film coefficients at various optical densities such as:

a) Thermal coefficient of expansion of film and variation with humidity.

b) Thermal conductivity of film.

c) Emissivity and view factor of film.

d) Convective heat transfer coefficient.

Where coefficients are not reported, derive an estimated value from known related technology. Establish the two-dimensional transient temperature distribution in the film as affected by the above coefficients and:

a) Ambient temperature and humidity changes.

b) Absorption of radiation from the light source.

c) Cooling jets of air.

Establish an analytical model for the resulting two dimensional distribution of film distortion and the transient time constants. Determine test requirements for experimental verification of the analytical model.

Item 2. Physical Restraint Model

Establish an analytical model of the physical restraint of film clamped to a glass platen by vacuum and under tension by tension rollers.

Procedure: Make a literature search for experimental data on various physical constants of film such as:

a) Frictional coefficient between film and plate.

b) Young's modulus.

c) Poissons ratio.

d) Tensile strength and ductility.

e) Flexural rigidity.

Where coefficients are not reported, derive an estimated value from known related technology. Develop an analytical model for the two-dimensional film distortion under the appropriate restraints as related to the free state dimensional change. Determine the test requirements for experimental verification of the analytic model.

Item 3. Parametric Study

Make a parametric study of the expected dimensional changes of film clamped to a glass platen due to variations in parameter of 1 and 2 above.

Procedure: Results of the analytical models will be combined in graphical, tabular, and or analytic equation form to permit ready determination of the resultant film dimensional changes due to variation of inputs and coefficients.

Task II: Vibration Environment

Item 1: Statistical Properties of Building Vibration

Determine the experimental requirements for statistical measurement of building vibration. Design the statistical experiments and make sample measurements. (We anticipate that continued gathering of statistical data can be accomplished by customer technicians on a routine periodic sampling basis.) The building vibration statistical data to be determined is essential to cost effectiveness trade offs for measuring equipment design and for vibration isolator determination.

Procedure: The power spectrum; the average amplitude; rms amplitude; average 1/3 highest, 1/10 highest and 1/100 highest amplitudes are the statistical properties desired. The usual vibration measuring or seismic equipment does not produce this information.

It is necessary to convert the time dependent output of standard seismic equipment to the above statistical data. One approach is to record the output on magnetic tape, then play the tape through a power spectrum analyzer. Another method is to make an analogue to digital conversion of the recorded data and compute the power spectral density by digital computer program. We will determine availability of seismic measuring and analysis equipment with suitable response and amplitude sensitivity. The equipment interface compatability, filter and buffer requirements, auxilliary monitoring requirements and digitizing requirements will be determined. The experimental set up will be established and sample measurements taken. The statistical averages will be computed from the analyzed data.

Item 2: Statistical Properties of Platen Vibration

Determine the experimental requirements for statistical measurement of platen vibration of specific equipments. Design the statistical experiments and make sample measurements.

Procedure: The unit vibration response versus frequency of specific equipments is the most powerful and effective engineering tool for design and specification purposes. Unfortunately, for completed and installed equipment it is extraordinarily difficult to make meaningful measurements of unit vibration response. Instead, we propose two other measurements which will produce reliable data. The first is to measure film platen vibration of specific equipments subjected to actual building vibration.

The experimental techniques will be similar to those discussed in the previous section. The second is to make a resonance survey of specific equipments when subjected to artifical controlled vibration inputs. The usual technique is to place a small exciter on the floor or on the machine near the floor, sweep through the desired frequency range and monitor platen vibration to detect peaks. The testing should probably be done during building quiet times and the exciter input must be larger than building input. At the resonant frequencies the instrument structure will be probed to find the offending resonating members.

In addition to the above experimental activity, we will investigate possible techniques of measuring unit response of equipments which are completed and in place.

Item 3: Vibration Isolation Requirements

From the analytical and experimental vibration data obtained above, the vibration isolation requirements will be determined. From the vibration resonance survey of equipments, we will determine what corrective measures are necessary to reduce resonances and internally generated vibrations.

For certain specific mensuration equipment in design, we will prepare an analysis of vibration resonance and amplitude using building vibration power spectrum as a forcing function.