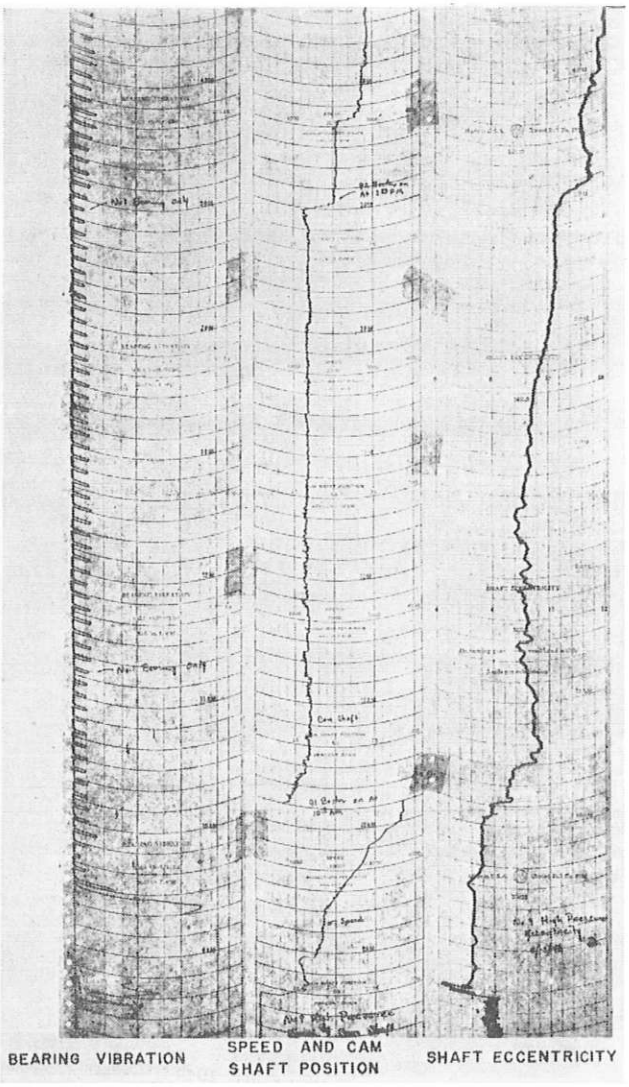

FIG. 11 ECCENTRICITY RECORD TAKEN FROM A 39,400-KW 3600-RPM HIGH-PRESSURE ELEMENT OF A CROSS-COMPOUND UNIT WITH A LOOSE THRUST SLEEVE

sequence. This equipment detects immediately disturbances which cause high vibration and also detects gradual long-time changes in vibration due to misalignment, and so forth.[3]

Shaft-eccentricity recording equipment detects and records once per revolution shaft bow, the causes for which have been covered in a previous paper.[3] However, it is extremely helpful in detecting a loose thrust sleeve or runner which would not otherwise be detected by any other means until actual failure occurred.

A complete set of turbine supervisory instruments is valuable since only a study of all records made by the recorders will give an over-all picture of the operating characteristics of the turbine generator at any particular time. Since the records for any particular machine are peculiar to that unit, normal operating records and records of unusual conditions in the machine should be used by the operators as a guide in operating, detecting unusual conditions, and in the training of operating personnel.

The interest that has been evidenced in the quick-starting of turbine generators makes the use of turbine supervisory instruments essential in order to keep track of the rapidly changing conditions.

Discussion

T. T. FRANKENBERG.[7] The authors are to be congratulated on presenting a paper of unique timeliness due to the trend for remote operation of many new turbines and the quick-starting of older units.

No turbine has been installed on the American Gas and Electric System since 1935, without two or more of the supervisory instruments. Until 1941 only bearing-vibration and shaft-eccentricity recorders were used. Starting in 1942, the speed and camshaft-position recorder was added. Shell and differential expansion recorders were not added as standard until 1949, though an earlier model of this device was given trials and is still in use on a machine started during 1941. At present, 1575 megawatts of generating capability is protected with these devices. Equal or greater coverage is planned for the 1250 megawatts now under construction.

In spite of this widespread use, there has been a considerable reluctance on the part of operators to give full regard to the indication of these instruments. Several of the authors' examples bear out this point, showing that immediate recognition of the trouble (and appropriate action) would have minimized the damage or at least the period during which the turbine was placed in jeopardy by continued operation. The reason for such reluctance and the resultant hesitation is to be found at least in part in some of the early difficulties with this equipment. For example:

1 Certain cam-operated selector switches created open circuits when the wires became disarranged.

2 During the war it was necessary to make a circuit change in all of the eccentricity units to lessen their sensitivity to defects in the vacuum tubes then available.

3 The field installation of the primary elements was not always carefully performed so that wear and bearing heat lessened or eliminated their useful life.

4 Finally, a number of minor mechanical failures in electrical components added to the time this equipment was out of service.

An equal handicap to the operator's confidence was the inability fully to interpret those readings which he did have.

A great deal of educational work remains to be done before the turbine supervisory instruments will be providing the operator with all of the information of which they are capable. This paper should help considerably in the education of the top level of operating plant personnel. The magnitude of the remaining job, however, is indicated by the following comparison: In order to interpret the indications of these instruments to a highly intelligent group which should be skilled in making engineering deductions, it was necessary to line up carefully the time co-ordinates of the charts and then use an average of 250 words of explanation to point out the trouble. Now consider the typical operator in the midst of some fast developing difficulty (who has many other responsibilities), and expect him to make a correct decision affecting four or five million dollars' worth of turbine-generator equipment. The case for more education and clearer presentation of the story is complete.

The necessity to correlate the readings of three and in some cases four charts has led to inquiry into the possibility of combining these various records on a single chart. To date the lack of unanimity on the part of users as to which records should be provided has encouraged the manufacturer to treat them as entirely separate units. It is our experience that all records are needed to interpret troubles adequately, and that presentation on a single chart would eliminate faulty time settings between charts,

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conserve panel space, and, most important, save time for the operator when making comparisons during unusual operating conditions. Since the average size of turbine purchased by utilities has increased rapidly since World War II (see Table 1, herewith), the cost of one additional record may be as little as 0.25 per cent or even 0.10 per cent of the total cost. This should encourage users to accept the full complement of instruments for the protection of their equipment.

TABLE 1 AVERAGE SIZE OF UTILITY TURBINES ON SHIPPING SCHEDULE OF ONE MANUFACTURER

Year	Average size, kw
1946	29800
1947	35000
1948	42200
1949	51600
1950	54800
1951	57600
1952	71300
1953	77300

H. Weisberg.[8] The justification for the supervisory instruments described by the authors is self-evident when we consider that the total installed cost is less than $20,000, and that these instruments are used to safeguard the operation of a machine which may cost as much as $4,000,000, and be part of a $30,000,000 installation. The outage of these large units results in a daily loss up to $10,000. Detection of abnormal operating conditions which would avoid 2 days' outage in the life of a machine would pay for the total cost of the instruments.

It is suggested that development of additional instruments which will indicate the operating condition of the machine would be well justified. In particular, more information on the operation of the thrust bearing, indicating perhaps the direction and amount of the thrust load, would be of considerable value for a continuous check of the condition of the blade path.

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Authors' Closure

The authors would like to thank the discussers for their interest in the paper and for the various points that were brought out. These discussions have emphasized the authors' contention that turbine supervisory instruments are a valuable adjunct in turbine-generator operation. Several points have been brought up, however, that require further explanation.

Some difficulty was experienced with the instruments early in their history as indicated in T. T. Frankenberg's discussion. These difficulties have since been rectified by design changes. Drawing upon our long field experience with the instruments, a complete redesign has been made within the last year of all four instruments that make up the turbine supervisory group. Our objective in the redesign was to make them more reliable and rugged and easier to service.

The authors agree that educating the turbine operators in the interpretation of the records made by the instruments is a real problem. Recognizing a need for educational work, the authors' company held a supervisory-instrument symposium early in 1950, which was attended by results engineers from interested power companies and our own district service men. Not only was the operation and maintenance discussed but those attending actually tested and calibrated the instruments. During this period, a lecture with illustrations was given devoted entirely to record analysis.

Recording simultaneously all four instrument readings on one piece of paper is a desirable objective, yet no practical solution has been found.

H. Weisberg's suggestion of an instrument to measure the direction and thrust load is a good one. The differential-expansion recorder can be used to indicate and record thrust direction, provided the detectors are located forward of the thrust bearing. Such an application was used some years ago. At the present time a study is being made of the possibility of developing an instrument to measure thrust load.