SEISMIC INSTRUMENTATION IN INDIA

H. N. SRIVASTAVA
Meteorological Office, Pune 411 005

ABSTRACT – *Development of seismological instrumentation in the country and its future including Seismic Telemetry System has been discussed. The performance of the indigenous seismographs vis-a-vis imported systems has been presented. A suggestion has been made about the optimum requirements and the specifications of seismographs to be recommended for river valley projects in the country.*

INTRODUCTION

Instrumental study of earthquakes in India commenced almost simultaneously with the development of seismographs during the last decades of the previous century. Since, then, the necessity of increased observational network in this country was realised after every great earthquake which occurred, such as Kangra earthquake of 1905, Bihar-Nepal earthquake of 1934 and the great Assam earthquake of 1950. More precise epicentral information about the earthquakes is now needed due to a large number of developmental projects like dams, nuclear power plants and multistoried buildings to assess earthquake risk. Thus, the demand for designs of seismographs of the imported kind has been increasing at a rapid rate. It may be mentioned that the objectives of the national network and the river valley project stations are slightly different. The national network aims at recording local events as well as teleseisms and thus the instruments have to be chosen with relatively different response characteristics than that for project stations which aim at collecting the data of local earthquakes (which contain higher frequencies) in a relatively shorter span of time. The object of this paper is to evaluate the developments of seismographs and the future projections for our country. The performance characteristics of indigenously designed seismographs vis-a-vis imported systems have been discussed.

INDIGENOUS EFFORTS IN SEISMOMETRY

A seismograph system consists of a sensor, generally of an electromagnetic type, the associated electronics like amplifiers, precision timing system and a recorder, heat sensitive, photographic or magnetic tape/solid state type. Indigenous efforts in this direction are given below.

Time Marking Systems

A simple pendulum clock was constructed at India Meteorological Department workshop at Pune in 1951 for marking time on the seismograms. Crystal clocks were designed in the department[1,2] during 1967–68, but the project was discontinued since 1970 when some commercial firms started marketing these clocks. The National Geophysical Research Institute, Hyderabad fabricated a unit for impinging time signals from radio broadcasts on seismograms automatically. Central Scientific Instruments Organisation's efforts were directed to record NPL signals on the recorders. However, since Omega Navigation Signals are transmitted round the clock, the errors in the observations to read the onset of seismic waves will be minimum if the seismographs could be automatically corrected with reference to this system.

Seismographs

These include the following:

- Wood Anderson Seismometer and Recorder designed by IMD to measure Richter magnitude and record local earthquakes[3].
- Electromagnetic Seismometer and recorders designed by IMD and imported sensitive galvanometers to record regional earthquakes. These are gradually being discontinued due to nonavailability of sensitive galvanometers.

- Portable analogue seismograph–designed by CSIO: field tested and matched to work with IMD Electromagnetic Seismometer for local earthquakes. This has given good results with IMD Seismometer at Delhi but for very quiet rocky sites the recorder may need to be used with imported seismometers to achieve very high gain.
- Accelerograph of analogue type designed by University of Roorkee without time marks to be replaced with digital systems (under development).
- A short aperture UHF digital telemetry system designed by BARC. It has the following characteristics:
- The wireless frequencies of the short aperture system installed in Bhatsa Region (Maharashtra) are in the UHF range of 461–462 MHZ.
- The transmitted RF power is less than 1 watt; mostly in the range of a few hundred milliwatts.
- The range of radio transmission at Bhatsa is 20 km, although it can easily go upto 50 km if necessary.

In Bhatsa region the sources of microearthquakes whose coda duration magnitudes are in the range $-1 < M < 2$ are located shallower than a depth of 5 km and found clustered in and around the catchment area upstream of the Bhatsa dam. (Arora, B. K. personal communication, 1990).

During the last two decades the emphasis has been shifted from analogue to digital type of instruments with telemetered links through UHF/VHF channels or through satellites. Of more recent interest is the deployment of seismographs covering a large number of frequencies connected to central recording systems linked via different types of communication channels. Also more sensitive systems for recording micro earthquakes have been brought into use.

Design of the following seismographs have been taken up through the Department of Science and Technology.

- Digital Seismograph (CSIO)[4]
- Digital Accelerograph (UOR)
- Digital telemetry system (CSIO/GCEL)[4]

It is noted that considerable efforts are needed to make indigeneous system and introduce modifications from time to time to keep pace with the development in other parts of the world.

UPGRADATION OF NATIONAL SEISMOLOGICAL NETWORK

The four stations at Delhi, Shillong, Pune and Kodaikanal which are under operation as standardised world-wide seismograph systems have also been provided with stylus recording mechanisms thus dispensing with the galvanometer. However, the station at National Geophysical Research Institute, Hyderabad still continues to operate the standardised earlier system. Figure 1 shows the network of permanent seismological stations in the country.

The Central Seismological Station at Shillong has been upgraded to Seismic Research Observatory level under the USGS collaboration programme since June 1978. The main advantage of the SRO system is to lower the threshold of detection in the long period band. Also, because of digital recording, a large number of signal amplitudes can be accommodated. An advanced digital recording system provides at least 110 db of separation between noise levels and clipping levels in the principal bands. In addition to other equipment the Seismic Research Observatory at Shillong also operates a bore hole seismometer fitted with an advanced recording system and associated equipment for timing, power and control. This equipment produces both analogue and digital records. The seismometer system has been installed at a depth of about 100 meters through a standard 18 cm well casing. The sensors are force balance accelerometers whose output is proportional to the earth acceleration from 0 to 1 HZ. The mass position signal from each sensor is passed through a band-pass circuit with corner frequencies of 0.02 and 16 HZ and a gain of 46 db. The system has a nominal sensitivity of 1000 volts/meter/sec^2.

The seismic filters have parallel outputs. One is used for analogue recording and the other is used for digital recording. Analogue seismograms are produced on

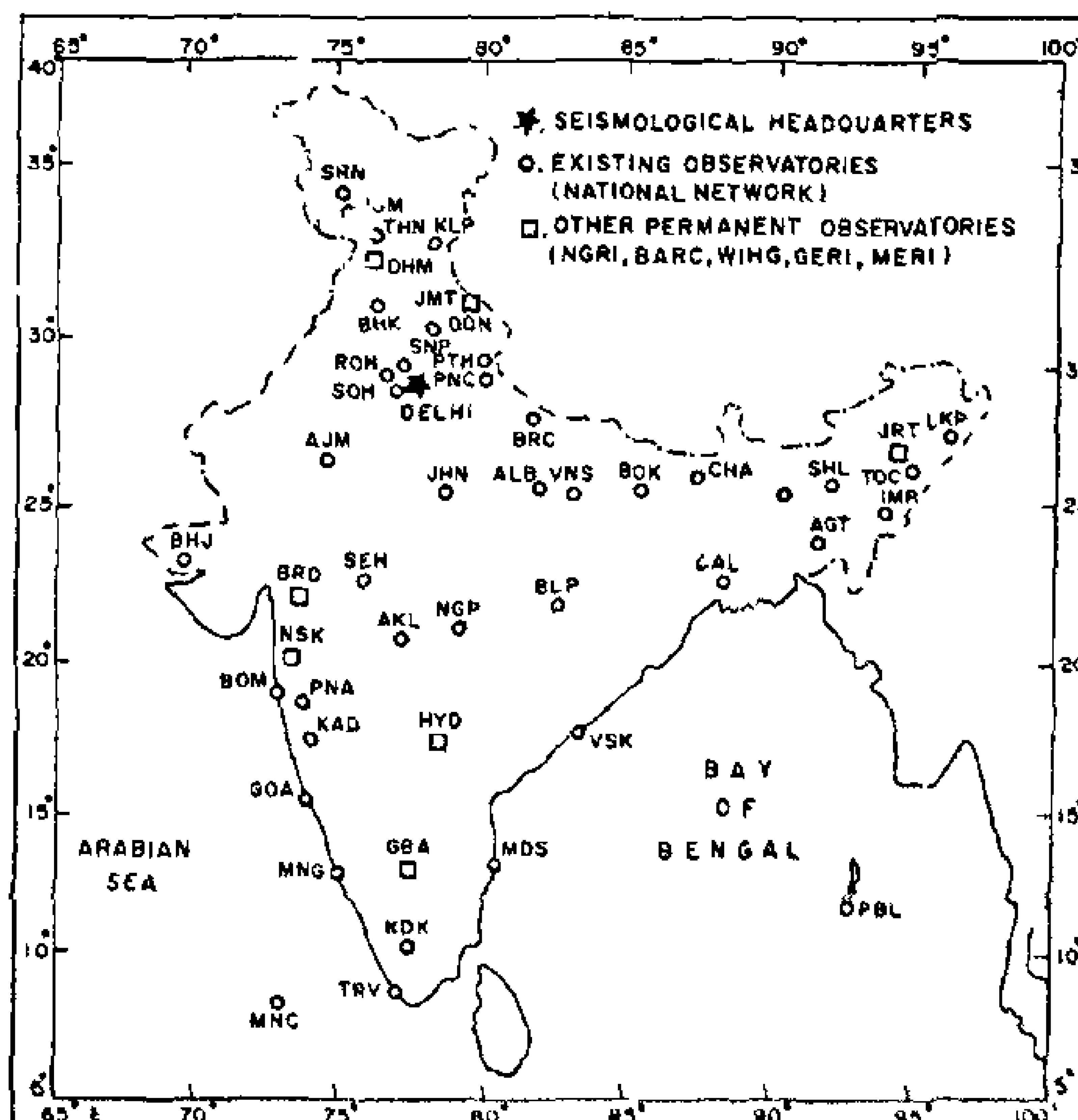

FIGURE 1. Seismological observatories in India.

helicorders using heat sensitive paper. The digital recording system consists of a gain ranged analogue to digital converter, a station processor with 16 K bytes of memory and magnetic tape recorders. The analogue to digital converter samples the long period signals once each second and the short period signal 20 times each second. Long period data are recorded continuously on tape. Only those events which are detected by the station processor in the short period signal are recorded in order to conserve tape and reduce the volume of data generated by the network. Two tape drives are furnished with each system to maintain uninterrupted recording. These tapes are usually changed at intervals of two weeks.

The station operator communicates with the station processor and controls the SRO system using a teletype writer. The operating software permits him to select the recording models, adjust gain levels, set events detection parameters, calibrate the sensors and perform other functions. These instruments have served a limited purpose due to the limitations of frequency response and the problem of stabilised power supply.

The national network has been further modernised with the addition of digital short period seismometers at Pune, New Delhi and Shillong. A single channel VHF digital telemetry system is being installed at New Delhi. Suitable PC based software has been developed for retrieval of seismic data. Additional digital instruments have enabled us to determine the dynamic source characteristics. About 6 stations out of 40 in India Meteorological Department are also equipped with accelerographs.

Instrumentation at other Geophysical Institutions in India

Roorkee University

A short aperture sample digital telemetered seismic array procured from Earth Data, U.K. has been installed in Ganga-Yamuna valley by the Department of Earthquake Engineering, University of Roorkee under the 'All India Coordinated Project on Seismicity and Seismotectonics of the Himalayan Region' of Department of Science and Technology. The array consists of two 3-component and six single-component seismometer stations. The signals in the form of digital time history of ground motion from individual remote seismometer stations are transmitted via radio link to the central recording station. The single component (vertical) seismometer stations are established at Chakrata, Dhargaon, Pauri, Shakumbhari Devi Hill, Surkanda Devi Hill and Roorkee and three-component seismometer stations at Narendranagar and Uttarkashi. The central recording station is located at Surkanda Devi Hill and the operating frequencies are in the range of 160 MHZ[5].

The central recording station continuously receives data from all the seismometer stations. The time intervals for calculation of Long Term Average (LTA) seismometers are selectable. When the ratio of STA/LTA of signals from three or more stations exceeds preset values, then each channel comes to a triggered state for the system to record the ground motion. Thus comparison of observed ratios with the preset values is performed every tenth of a second by addition in the latest 36 data samples and subtracting the oldest 36 data samples. The triggered system continues to record the ground motion sensed by the seismometers till the signals are reduced in magnitude which do not meet preset criteria and the system reverts to updating the LTA value. Whenever an event occurs, data from trigger point of the event plus a predetermined amount of data before and after this time is recorded on to the magnetic tape. Data is written on the magnetic tape until either the event is over, or until a predetermined time interval has elapsed. The event data is recorded on a 9 track 1/2 inch magnetic tape and log of the events is printed on the printer. The analog output of any four selectable channels can be taken on the chart recorder. The system has faced the problem of maintenance due to power problems and snowfall.

The wide band instruments at Roorkee University (Earth Science Department) presently with analogue recording is also in the process of conversion to the digital form.

The strong motion array in Himachal Pradesh and northeast India (of about 45 accelerographs each) has generated acceleration data for moderate earthquakes at several stations which served two purposes. Since these instruments have timing system, the data along with the local network improved the focal parameters of earthquakes. The working paper based on global data enabled International Seismological Centre UK to include strong motion data for epicentral determination in their monthly seismological Bulletins[6]. Also, the attenuation characteristics could be worked out for earthquake risk assessment[7] Another array of 45 analogues and 5 digital instruments sanctioned to Roorkee University by the Department of Science and Technology is being installed in west Uttar Pradesh Hills.

National Geophysical Research Institute

The digital telemetry system was procured from Geotech, USA. The frequencies used for communication are in VHF range namely around 318 MHZ. The system has a dynamic range of about 120 dB without any gain ranging technique. It has a resolution of 24 bits throughout the dynamic range. The system first installed at Pune faced power supply problems and only analog records could be obtained. Also the problems of high temperature and dust at the top of hills did not enable the operation of computer system for recording the digital data. The system is now being installed in northeast India around Jorhat where better maintenance facilities are available due to Regional Research Laboratory (RRL). (R. K. Rao, 1991, Personal communication) About a dozen analog seismographs are being maintained in northeast India under a joint programme of NE council and NGRI. The first digital wide band system, called GEOSCOPE has been also installed at NGRI. It is linked as a part of the world wide programme of seismic monitoring.

Bhabha Atomic Research Centre

The Seismic Array continued to operate at Gauribidnaur. Attempts were made to link this station with International Seismological Centres using Gateway Packet Switched system of Videsh Sanchar Nigam, Bombay[8].

Wadia Institute of Himalayan Geology

Under the DST project on 'Himalayan Seismicity' three stations as a part of National Network have been opened with analogue instruments (Kinemetrics, USA)

SEISMIC INSTRUMENTATION AROUND SPECIAL PROJECTS

The instrumentation around river valley projects was not only modernised but also expanded around river valley projects. New network of stations was commissioned around Salal Hydro Electric project in addition to that around the Pong and Pondoh Dams being maintained by India Meteorological Department. Digital and Analogue Seismographs were procured for ten new stations around the Sardar Sarovar Project. The facility of detailed analysis of the digital data was procured using DAC 300 (Sprengnether, USA) by Govt. of Gujarat.

Keeping in view the monitoring of microearthquakes for local seismicity studies, the Department of Science and Technology funded procurement of microearthquake seismographs at Delhi University and Wadia Institute of Himalayan Geology. Several other organisations in the country like IMD, Geological Survey of India, Central Water and Power Research Station and State Governments in Maharashtra, Gujarat, Karnataka, Kerala, Andhra Pradesh, Uttar Pradesh, Assam and a few Universities have been operating microearthquake seismographs for specific projects. It is however, noticed that the problems of operation, maintenance and data retrieval from the imported digital micro earthquake records have not been commensurate as compared to the analogue seismographs. However, the updating of the technology and indigenous development of PC based software has opened the possibility of their better utilisation.

PERFORMANCE CHARACTERISTICS OF INDIGENOUSLY DESIGNED AND IMPORTED SEISMOGRAPHS

The performance characteristics of indigenously and imported analogue type of seismographs have been studied.[9] It was found that different types of imported seismographs installed at the national seismological stations recorded fewer teleseismic events than did the IMD electromagnetic seismograph with optical recording. Also, because of the difficulty of identification of S-phases beyond $\Delta = 15–20°$, only the P-wave onset time could be read. At some stations, such as Calcutta and Madras, where the IMD optical electromagnetic seismograph was functioning at low gain, the helicorder system could not work because it picked up traffic and other cultural noise even with different combinations of filter settings. The operation of these systems, however, improved with the high cut-off filter at 2.5 Hz instead of 10.0 Hz at some of the IMD stations, because of the reduction of higher frequency traffic noise. As the sites of indigenous and imported seismographs remained the same after the change over, the helicorder could not be set at a higher gain. Thus, even the advantage of better response to nearby earthquakes could not be obtained at the permanent stations.

Considerable operational problems were experienced with the recent long-period systems. The Geotech model with seismometer SL-210 remained stable at only about 12-s period, which limited its utility.

For retrieval of digital data, software was developed for demultiplexing from the magnetic tapes in the SRO system at Shillong through the IBM 360/44 computer at IMD. It was noticed that the SRO System was frequently triggered by traffic noise around Shillong station, due to which the digital output of the system runs into hundreds of pages from a 15 day tape which is mostly full of noise.

The analogue accelerographs (without timing system) designed by the Roorkee University whose performance was evaluated using a shaking table[10] continued to function with the support of the Department of Science and Technology. A few accelerographs were triggered during the earthquakes of August 1988 near India-

Nepal and Manipur-Burma borders and enabled us to get acceleration data. (Report, *University of Roorkee*, 1989) However, a critical evaluation of data recorded by *Indian Strong Motion Network* (INSMIN) vis-a-vis imported system in the field is yet to be made.

Seismometric network for river valley projects

Indian Standards Institution Code IS: 4967–1968 for river valley projects is under revision due to recent advancements of seismological instruments. According to International recommendations, the network of stations around large dams of a height greater than 100 m should consist of 8 to 10 seismographs well distributed in azimuth. A question arises as to what type of instrumentation should be adopted for this purpose. Digital recording instruments which provide a wide dynamic range are considered ideal for such projects. The large amount of data thus collected can be easily processed through modern computers. However, their maintenance is often difficult at remote places. It is suggested that for projects having 8 to 10 local network of stations, the operation of 5 digital seismographs and 3 analog instruments may be adequate. For smaller projects only 5 stations may be needed, namely one digital and 4 analogue seismographs may be sufficient. The timing system should be tuned to Omega signal to reduce errors. Telerecording seismographs which provide location of seismic events with greater precision due to common time base than conventional seismic observatories, may be deployed in difficult terrains with Solar Panels or around more important projects like nuclear power plants or dams of height greater than 100 m. Such instruments may also be used during the planning phase of other projects when short term microearthquake surveys for 2 to 3 months may yield more reliable epicentral information in relation to the local tectonics. Also five accelerographs and one set of Wood Anderson Seismograph may be deployed to study source parameters and standardisation of magnitude respectively.

Future projections

While efforts have been made in the recent past to develop recording systems, sensitive seismometers have yet to be designed in the country. Keeping in view the recent developments in USA and other advanced countries, we need to concentrate on broad band seismometers which would eventually form a part of the National network of seismological stations. Such a network has been planned for U.S. Geological Survey. The heart of this instrument is a leaf spring (instead of a pendulum), a set of metal strip bracketed together to form a complete spring. A weight is attached to the end of the spring and an electronic force sensor detects the motion of the magnet. It is equally sensitive to events at higher frequencies–10 HZ range and low frequencies with periods as long as one hour. An analogue to digital converter is able to read the signals over the entire frequency range. Using Satellite links, the data can be transmitted. Each seismometer will produce about one gigabyte of data each day. Also, we may need to participate in the global network of standardised modern instruments in the plan of Incorporated Research Institute for Seismology to collect high quality data to get an accurate picture of seismic events. Preliminary attempts to link short period seismographs with INSAT have been made through an experiment called SEQUEX under a joint programme of NGRI, IMD and Department of Space for which the commercial channels of the satellite could now be utilised on an experimental basis. This is all the more important because earthquake prediction research requires to study the space time changes in seismicity patterns for which such dedicated systems can be useful.

The Eastern margin of the Indian plate passes close to the Andaman and Nicobar Islands where moderate to great earthquakes occur. In addition to studying the role of diffuse seismicity observed in different parts of the Bay of Bengal, the new fault identified close to Madras coast also needs to be studied in detail. The deployment of ocean bottom seismograph (of moored and pop up type) will throw light on the microearthquake activity and the geodynamic processes occurring in this region. It is therefore, envisaged to undertake the design of ocean bottom seismographs on a priority basis.

Conclusion

The above study brings out the following facts:

- More efforts need to be made to commercialise the indigenous seismographs as early as possible.
- Broad band and ocean bottom seismometers need to be developed with associated electronics particularly for telemetry linked systems.

References

1. Srivastava, H. N. and Lamba, B. K., *IMD Scientific Report*, No 79, 1968.
2. Srivastava, H. N. and Lamba, B. K., *J. Inst. Telecom. Eng.*, 1969, **15**, 609–676.

3. Tandon, A. N., *Indian J. Meteorol. Geophys*, 1951, **2**, 203.
4. Shamshi, N. A., Sharma, B K. and Sharma, V. P., *National Symposium on Recent Advances in Seismology and their Applications, Gauribidanur, 1990 (Abstract)*, ss6–1.
5. Wason, H. R., Sharma, M. L., Pal, K. and Srivastava, L. S., *8th Symp on Earthquake Eng. Roorkee*, 1986, **1**, 80.
6 Srivastava, H. N., *Bull Indian Soc. Earthq Technol.* 1989, **26**, 221.
7. Das, J. and Chandrasekaran, A. R., *National Symposium on Recent Advances in Seismology and their Applications, Gauribidanur, 1990 (Abstract)*, ss4–10.
8. Kumar, V. *et al., National Symposium on Recent Advances in Seismology and their Applications, Gauribidanur, 1990 (Abstract)*, ss6–9.
9. Srivastava, H. N., *J. Phys. Earth Planet. Inter.*, 1989, **58**, 19.
10. Srivastava, H. N. and Kumar, A., *Report*, Deptt. of Earthquake Engg., Roorkee University, 1979.

ACKNOWLEDGEMENT: The author is grateful to the Director General of Meteorology for permission to publish the paper.