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DEVELOPMENT OF SLURRY PIPELINE DESIGN CAPACITY

DP/IND/78/054

INDIA

Technical report: Slurry Pipeline technology

Prepared for the Government of India by the United Nations Industrial Development Organization, acting as executing agency for the United Nations Development Programme

Based on the work of Clifton A. Shook, expert
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Vienna

[redacted]

This report has not been cleared with the United Nations Industrial Development Organization which does not, therefore, necessarily share the views presented.

ABSTRACT

This Report summarizes the findings of Project DP/IND/78/054/11-04/32.1.F concerned with upgrading the design capability of Engineers India Ltd. in the area of slurry transport systems. This phase of the Project was of one month duration, a continuation of work begun in 1982. The specific objective was to assess progress and to suggest modifications to procedures. It is concluded that the capability of EIL in this field is well established and the project can be regarded as completed.

Explanatory Notes

EIL	:	Engineers India Ltd.
RRL	:	Council for Scientific and Industrial Research Regional Research Laboratory, Bhubaneswar, Orissa.
R/D	:	Research and Development Division, Engineers India Ltd.

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INTRODUCTION

As part of a project to upgrade the consulting and design capacity of Engineers India Ltd. in a variety of areas, a particular effort has been made by EIL in the field of slurry pipeline technology. Three staff members have been sent abroad for experience and an expert visit of two and one-half months was made in 1982. At that time, it was ascertained that good progress had been made by EIL but that further development was limited by data availability for particular slurries. Test facilities had been designed for installation at the Regional Research Laboratory of the CSIR in Bhubaneswar, Orissa but little substantive data had been generated there.

In the intervening two years, the laboratory facilities were constructed and further equipment was obtained. Since the laboratory staff had no previous experience in slurry technology, an assessment of progress was considered desirable. It was realized that modifications to operating procedures would be more easily made in the early, learning stages rather than later after habits became established. Furthermore, it would not be practical to send large numbers of laboratory staff abroad for training before they began serious work in the field. A second expert visit would provide some assistance of this type and this was the principal goal of the mission.

A second goal was to discuss particular projects with which the EIL R/D group are currently involved. Here, the consultant would not be serving in the capacity of an instructor because the level of EIL competence had been determined in the previous mission. Rather, the role would be to offer suggestions of directions for future effort.

PROJECT RECOMMENDATIONS

Since the host agency, EIL, has passed through the stage of background preparation, has procured the necessary resources to achieve its goal and is poised to act as a fully-fledged consultant and designer in the field, it is now only necessary to maintain the momentum which has been generated. Maintaining this momentum will require a conscious effort to stay abreast of this developing technology. Specifically, it is recommended:

PR 1: EIL R/D personnel be encouraged to transfer their experience within the company in some regular, organised manner. This transfer can be formal, in seminars, or informal through R/D group participation in project efforts. This participation should be more than perfunctory or as a source of data; rather they should act as internal consul tants vetting designs and calculations.

PR 2: The role of R/D personnel as guides and co-investigators with the RRL group will have to be maintained for the next few years at least. This will ensure good communication between those operating the test facility and those using the results.

PR 3: EIL R/D personnel should be encouraged to maintain foreign contact through participation in technical conferences in this field as contributors to the international body of knowledge.

PR 4: It appears that as far as slurry pipeline technology is concerned, this project can be reasonably regarded as completed.

I. ACTIVITY AND OUTPUT

A. Activities Undertaken

Upon arrival in India, preliminary briefing sessions with the host agency were held on Friday and Saturday, April 20-21. The journey to the RRL in Bhubaneswar was made on April 22 and working sessions were held from Monday April 23 to Saturday April 28 inclusive. Following the return to New Delhi on April 29, the expert was situated in the R/L Division of EIL in New Delhi. The following days were used for

- contact with UNDP, New Delhi.
- Report preparation
- discussion of details thereof with EIL personnel
- reviewing internal reports concerned with projects undertaken in the slurry field since 1982.

At the time of writing a visit to a recently-commissioned EIL-designed pipeline in Udaipur was planned. The return to Vienna is scheduled for 13 May.

B. Laboratory Visit

Following a preliminary visit to the test pipelines, the first two days were used for a review of procedures, progress to date and plans for each of the five operational subgroups concerned with slurry transport. This review began with a presentation by each subgroup leader in the presence of the whole group. Discussions involved all members of the group, the RRL group coordinator, the EIL representative and the expert.

The remaining time was spent visiting each subgroup in its physical facilities and in further detailed discussion there (no facilities were seen in the case of dewatering). Procedures and data interpretation and equipment performance were discussed thoroughly.

A final meeting with the laboratory director was held and an overview of the assessment was given verbally at that time.

C. Detailed Recommendations

For convenience in assessing a particular activity, recommendations have been classified by operational subgroups, test pipeline operation, rheology, etc. For convenience of implementation, a consecutive numbering system has been used so that a particular recommendation can be identified quickly by those discussing it. This consecutive numbering naturally prevents recommendations from being arranged in a heirarchy of relative importance : recommendation 23 is not by definition less important than, sav, recommendation 19. Such a heirarchy is impractical in any event, after the first few, most pressing items have been identified. Because of the hazard to human life which was noted, the order of presentation of the subgroup activities has in fact permitted the most important to be given the precedence it deserves. Thus recommendation number 1 is in fact the most important.

Test Pipeline Operation:

DR 1: The method of loading solids into the pipeline must be altered completely to remove the risk to human life or limb.

DR 2: Although various methods of complying with DR 1 are possible, bag discharge into the top of the tank should be replaced by slurry feeding from a mixing sump at ground level. The feed pipeline from the mixing sump to the test system should be short and easily disconnected for cleaning.

DR 3: Trash screens must be placed on top of the tank before any further work is done. These screens should be capable of bearing a human weight.

DR 4: When fine coal slurries are prepared the risk of explosions of dust, initiated by the non-explosion-proof electrical devices, must be borne in mind. Administrative procedures which ensure this must be developed in consultation with all working personnel, including casual labor.

DR 5: The magnetic flowmeters must not be left energised when the pipeline section containing them is empty.

DR 6: Flushing lines (clear water) must be connected to the manometer system and points liable to blockage in the test pipelines and feed tanks.

DR 7: The 50 mm pipeline suction system is much too long and must be drastically shortened.

DR 8: The volume of all test loops should be substantially reduced to reduce the quantity of solid material required for testing. In the case of the 50 mm pipeline it may be possible to arrange a form of closed loop operation and simultaneously implement DR 7. For the 100 and 150 mm pipelines, the tank will probably have to be retained within the circuit for some time at least. However, the operating level should be lowered and this will probably require substantial changes to the sunction piping. Although a large diameter valve would be desirable, as an interim measure the flush system of DR 6 should be tried as a method of removing potential blockages.

DR 9: The piping system should have sufficient flanged, Victaulic coupling or other quickly disconnected sections to allow easy removal for cleaning and inspection.

DR 10: The 25 mm pipeline should be disconnected from the 50 mm one. The possibility of effective operation of the former in the present configuration is extremely remote.

DR 11: Before any test to generate pipeline data, a preliminary de-scaling run must be conducted. A fine sand slurry, containing at least 15% sand by volume, must be circulated through the pipeline for several hours at a velocity of at least 3.5 m/s. The pressure drop should be observed during this run, which is intended to remove corrosion products. Immediately after de-scaling, a pipe roughness determination is required. This requires headloss and velocity measurements. Only after the roughness has been determined in this way can slurry be added to the pipeline. Immediately after completing the slurry flow determinations, a duplicate set of water velocity and headloss measurements must be taken. Some difference from the first set is to be expected in this run. However without both runs, data collected will have to be regarded as suspect. It goes without saying that reliable data cannot be obtained for slurry left in the system for several days.

DR 12: Surface thermometers (insulated from the atmosphere) should be mounted on the pipelines so that temperatures can be recorded without climbing to the top of the tanks.

DR 13: Duplicate pressure drop measurements are most desirable in all test pipelines to indicate malfunctioning equipment or obstructions in the test sections.

DR 14: Floor drains allowing solids removal are necessary to allow good housekeeping. Without good house - keeping, problems at electrical junctions are inevitable.

DR 15: Some form of temperature control will ultimately be required, especially when the loop volumes are reduced. A refrigeration system should not have cooling coils in the tanks: instead, recirculation of fluid between a cooling jacket on the test pipelines and a refrigeration system is suggested.

DR 16: A water meter (nutating disc or other displacement device) should be included in the water supply to the pipeline so that a mass balance can be made during the charging process described in DR 2.

DR 17: Pressure transducers will probably require some form of microprocessor for averaging purposes. For this reason, they should only be installed when a need for them can be demonstrated. Such a need does not exist at present.

DR 17: More sophisticated instrumentation such as gamma ray absorption and particle velocity measurement should not be installed until after temperature control has been perfected.

DR 18: L-shaped probes for sample withdrawal should be used for concentration and particle size determinations. Sampling velocity effects should either be eliminated (by preliminary training, during water runs) or examined experimentally (by sampling at various velocities).

DR 19: A mini-workshop, including a portable pipe vise should be located in the building housing the pumps. For the next few months at least, welding equipment will be required.

Viscometry

DR 20: The viscometer should be located in an air-conditioned room and the thermostatic bath should be connected as soon as possible to eliminate evaporation losses.

DR 21: Whenever slurry settling is significant, a portion of the slurry should be placed in a 25 or 50 ml cylinder at the same time as the sample is placed in the viscometer cup. This sample will give an indication of settling in the instrument so that measurement can be discontinued.

DR 22: Slurry samples from the pipeline should be transported to the viscometer in tightly sealed containers and tested as quickly as possible. Aliquots can be removed and the remainder sent for concentration and size distribution determinations.

DR 23: For the Haake viscometer, the T vs D mode, cycling up and down in velocity should be used first. The sample can then be stirred and subjected to successive T vs t runs at various D values. The choice of D values is determined partly by the need to avoid turbulence and partly by the range of pipeline wall shear stresses of interest. EIL personnel should provide the viscometer operator with an estimate of the range of interest for any given slurry.

DR 24: If settling is the only problem, it may be possible to obtain useful data by extrapolation to zero time. If thixotropy occurs, it may be possible to extrapolate the T vs t curves to infinite time to obtain steady flow simulations. However, in the latter case, tube viscometry (See DR 25) may be required.

DR 25: If funds permit, the 25 mm pipeline should be replaced by a horizontal tube viscometer of similar I.D. for the use with thixotropic (in the Haake viscometer) slurries. This tube should be of short length, resistant to corrosion and preferably driven by a Moyno (or other) screw pump whose speed of rotation gives the slurry velocity. Such a tube viscometer is in fact a small pipeline and would require a different operator than the bench-top devices.

DR 26: To gain experience in viscometer operation, it will be necessary to conduct tests with mineral oils and slurries of glass beads in mineral oil (which will demonstrate settling at various rates, without slurry thixotropy).

DR 27: Because the components of viscometers can sometimes change their calibration and because the Haake viscometer is complicated and not manufactured in India, special precautions must be taken to ensure data reliability. In particular,

(a) A standard fluid, preferably a mineral oil of low vapour pressure kept in conditions likely to prevent polymerization, should be run at least once a month.

(b) The speeds of rotation of the spindle at its maximum settings should be determined stroboscopically and recorded. These values will duplicate the manufacturer's specifications and need only be checked if evidence of viscometer malfunction arises.

DR 28: The unique properties of RRL water should be examined in so far as they could affect the data generated in the test pipelines. In particular, during tests involving fine particles, duplicate series of measurements with RRL water and distilled water as the slurrying medium will be required.

Analytical and Bench Scale Tests:

DR 29: Because of the particular needs of the pipeline test group, it may be necessary to modify standard procedures such as those of the A.S.T.M. Such modifications should only be adopted after discussion with E.I.L. and other R.R.L. personnel concerned with the results of these tests. Such a modification is the use of saturation conditions to provide coal samples for in-pipe moisture and density determinations. A second such modification could involve the temperature at which coal is to be dried in these and other determinations.

DR 30: For particle size and slurry concentration determinations, samples can be dried completely and the necessary corrections inserted during calculations.

DR 31: The performance of the controlled-humidity drying oven should be checked before it is used to prepared saturated coal samples for density and moisture determinations. This assessment can use duplicate samples in an isothermal desiccator containing free water.

DR 32: Settling tests for particle drag coefficient need not extend to particle Reynolds numbers lower than 1. Such measurements are difficult, subject to serious consistent errors and of minimal practical value.

DR 33: The effect, if any, of the unique properties of RRL water upon slurry settling in the sloped pipe studies will have to be investigated. At the very least, a comparison with distilled water-based slurries should be undertaken. Such tests are of course, necessary before any studies involving sloping of the test pipelines are made.

<u>DR 34:</u> The Miller Index apparatus is located at a point where corrosion is to be expected. It should be moved to a more suitable environment.

<u>Crushing and Grinding</u>

<u>DR 35:</u> A water flush line should be incorporated in any pipe transferring the slurry produced in the proposed new circuit to the test pipeline.

<u>Dewatering</u>

<u>DR 36:</u> Since this is only likely to be of importance with a coalPipeline, activity in this area need not be intense. This is especially the case because a demonstration plant is to be built. Thus equipment manufacturers can be expected to provide information concerning the performance of their products and the need for independent testing by RRL is minimal. No expenditure on a centrifuge seems to be necessary at this time. Instead, effort should be directed towards predicting what the effect of imponderables (coal type, washing) on the dewatered product might be. This could include such additional dependent variables as cake stickyness and ease of subsequent handling. However, here again, detailed design data will have to be provided by equipment manufacturers and the laboratory function is essentially to conduct simple comparative tests to indicate what might be

expected to be produced by the manufacturers. Of course, the unique character of RRL water will have to be taken into account in such tests.

Corrosion and Erosion

DR 37: Tests such as those conducted with the Bomberger apparatus can only be regarded as measures of the relative tendencies of particular slurries, determined in a fixed geometry. The actual corrosion or erosion rate in a pipeline depends on this tendency as well as other factors not considered in these tests. Many of these factors involve fluid mechanics, including particle trajectories. It is important not to give the impression that the tests establish the actual corrosion rate. In fact, they provide information with which the designer, as a result of his experience, can estimate what the rate is likely to be. Claims concerning the measurements and their meaning are to be avoided.

DR 38: In order to obtain the experience necessary to link the laboratory measurements to field observations it would be necessary to embark on a program of field investigations. In such tests, wall thicknesses of operating pipelines (containing water, solutions or slurries) could be monitored as functions of time with the ultrasonic thickness gauge. The unique properties of RRL water suggest that the water pipes in the laboratory would be a good place to start this study. Other pipelines could be found in nearby power stations or mines.

DR 39: Simulations of pipeline wear situations should not be undertaken until these have been demonstrated to be of value in thorough studies elsewhere. At present, rotary devices do not have this status and should be avoided. Use of a recirculating test loop with removable spools, is, in the conditions of RRL, Bhubaneswar, impractical. No program of this type should be undertaken until the substantial problems of operating test pipelines for long periods (documented earlier) have been solved.

General Observations: RRL Group

DR 40: In order to provide the stimulation of contact with others working in the same field, and to reduce the dangers of over-confidence, the investigators should be encouraged and perhaps required to present papers at appropriate symposia. In the first instance, Indian symposia would suffice. If suitable symposia are not available, it is in the interest of the RRL to organize them.

DR 41: A central filing system for the slurry group should be prepared for: reports by RRL and EIL, papers received from other laboratories and notebooks recording observations during training periods spent abroad.

DR 42: The test pipeline requirements are such that it is not possible for investigators to work on a variety of other projects simultaneously. At the earliest practical date these investigators should be relieved of other responsibilities until the problems facing the test pipeline have been overcome. Not all the solutions of these problems can be given at the present time, even by a consultant with 30 years experience. Instead, a period of trial and testing is required. Control over the day-to-day decisions of the pipeline operating group can only be financial since they are already the most knowledgeable in RRL. Here, liason with EIL R&D personnel will be important since the latter have the broader knowledge of the field.

DR 43: Since interest in foreign training remains high, it is important to ensure that individuals be sent abroad only after they have demonstrated a knowledge of the technical literature in the field as a whole and in their particular area. Failure to do so imposes a severe burden on the host agency and may make it difficult for others from the same laboratory to be accepted. An interview, including EIL personnel (whose knowledge of the literature was noted in the 1982 report) would help to achieve this end. Ideally, the performance in such an interview would determine whether or not an individual was recommended for training abroad.

DR 44: The following types of foreign training seems to be justified at the moment:

a) Pipeline operating group: Experience in a laboratory which studies a wide variety of slurries.

b) Viscometry: Training in interpretation of rheograms for time dependent and settling slurries. A university or research institute would be appropriate here.

c) Slurry preparation: Visits to a wide variety of laboratories and industrial milling operations processing coal and ores in slurry form. Notes of flowsheets and equipment performance should be taken.

General Observations: EIL

DR 45: More personnel should be trained to perform the functions of liason with RRL and participation in slurry testing. This would ensure that the EIL capacity grows rather than remaining vested in a few individuals.

DR 46: Notwithstanding DR 45, it is a fact that to the extent that EIL is a client of RRL, contact should be intermittent rather than continuous. Continuous presence in RRL can prevent the latter from developing as an independent entity. It must be the goal of both organizations to have two agencies with somewhat different aspirations collaborating frequently but not continuously.

DR 47: The predictive equations and models presently in use by the EIL R/D group are as reliable as those in use by any comparable group anywhere in the world. Nevertheless, they are still of limited accuracy and effort to upgrade these methods must continue. More sophisticated models are available in the scientific literature and these should be adopted as soon as data availability (from RRL and other sources) permits. The R/D group are familiar with these improved methods.

DR 48: Contact between the R/D group and the user-designer groups in EIL should be frequent. This contact will bring the designers abreast of recent developments such as the changes which are ncessary in the RRL Pipeline system, the design of which was in part an EIL responsibility.

II UTILIZATION OF THE RESULTS

In view of the previous experience, one can be confident that the results and recommendations of this project will be utilized to the fullest extent permitted by local circumstances. The activity is broadly based and appears to be particularly relevant to India: in the intervening period Planning Commission approval for a major demonstration pipeline of some 40 - 100 million dollars U.S. value has been granted. However, the critical test will be the extent to which this pipeline is designed in India since the project is large enough to attract considerable foreign interest. There is absolutely no reason why foreign designers have to be involved but it may be difficult for the EIL group to convince those responsible for making the decision.

Fortunately, even without this spectacular major project, there is a steady continuing demand for small and medium - sized projects which should keep the present nucleus alive indefinitely and indeed may allow it to grow.

III CONCLUSIONS

The major conclusion from this project is that success depends entirely on the level of interest in the project in the host agency. In the case of EIL, a thorough literature survey had been made fbefore the expert's first visit. This literature survey had been used in planning corporate activity so that the expert was really only required to provide changes of emphasis. Sufficient time had been allocated by the EIL group management to allow their personnel to develop competence and confidence before attempting to make decisions. Fortunately, the number and variety of the projects was kept low for any one worker so that he had the opportunity to understand the subject thoroughly. All the success of this project can be traced to that decision. Those responsible are certainly to be commended.

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