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MAGNESIUM-ALUMINUM-SILICATE MACHINABLE GLASS-CERAMICS

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Glass-ceramics are a class of materials wherein a large number of small crystallites are dispersed /embedded in a glassy matrix. They are prepared by a controlled crystallization process such that a large number of small crystallites rather than a few big ones are grown. This is accomplished by the use of suitable nucleating agents. Magnesium-aluminum-silicate (MAS) belongs to a special class of technologically important advanced ceramics having applications in the areas related to ultra high vacuum, high temperature, high voltage, etc. It has high thermal stability, good mechanical strength and very high electrical insulation and is also vacuum compatible. The unique feature of MAS glass ceramic is its machinability, i.e., the material can be transformed into desired shape and size by machining to precise tolerance and surface finish with conventional carbide tipped tools. The unique property of machinability arises due to its microstructure having interlocking array of plate-like crystallites disperses in the glassy matrix. As these materials have zero porosity, the components fabricated do not require any post-firing.

In view of the various applications and strategic nature of this material, Technical Physics & Prototype Engineering Division, BARC, has undertaken indigenous development of machinable quality magnesium-aluminum-silicate glass ceramic. The material has been prepared in different shapes and sizes, such as, solid discs, solid cylinders and hollow cylinders. Components in the form of lugs, insulators, rings,

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BARC scientist honoured

nuts/ bolts, etc have been prepared from these by direct machining on conventional lathes. This is, however, to be done with special care. This development has been carried out by following two approaches: (i) sintering route MAS(s), and (ii) glass route MAS(g). In the first approach, controlled crystallization is carried out on a pre-shaped compacted sample through surface nucleation. On the other hand, in glass route we first prepare glassy material in desired shapes and sizes and then carry out the controlled crystallization by following special heating schedule through a process of bulk nucleation.

General steps followed in the preparation of the materials are:

- (I) Grinding and mixing of initial charge
- (II) Calcination
- (III) Grinding
- (IV) Spray drying
- (V) Sintering
- (VI) Glass melting and pouring
- (VII) Annealing of glass
- (VIII) Controlled crystallization

First three are common for both approaches while IV and V are followed in sintering route and VI, VII & VIII in the glass case.

Table 1 : Range of compositions for starting

SiO ₂	Al ₂ O ₃	MgCO ₃	K ₂ CO ₃	B ₂ O ₃	MgF ₂
45 -50	14 -18	20 - 27	14 -18	7- 9	6 - 8

charge of MAS in wt%

In both the cases, the basic charge is first prepared by taking the various constituents either in oxide or carbonate form in predetermined proportions as per details given in Table1, and calcined after thorough mixing and grinding for a period of time extending to 4 – 8 hours in a planetary ball mill using alumina jar and balls. Magnesium fluoride has been added to this charge as nucleating agent. The material thus obtained is spray dried to get dry, spherical, free flowable particles for sintering process. During spray drying, the material is mixed with suitable binder and plasticiser for better compaction. The

powder material is compacted in different sizes upto 50mm dia x 50mm length using semi - automatic hydraulic press and maximum pressure used is 4000 kg/mm². The green phase compact is then sintered in a resistance furnace following a pre-determined heating schedule.

For preparing glass ceramic from glass route, the calcined powder is taken in Pt-Rh crucible covered with a lid and melted in a raising – lowering (R-L) hearth furnace at about 1500 °C and kept for 1-2 hours for thorough convective mixing. The molten charge is poured in different shapes and sizes using graphite / brass moulds. The sample is immediately transferred to the annealing furnace. After annealing for several hours, the sample is cooled to room temperature in a programmed manner. It may be mentioned that annealing is one of the important steps. If it is not carried out properly, the cracks are developed on glassy parts, which would further increase during crystallization. This base glass is subjected to controlled crystallization in two stages: (i) nucleation, and (ii) crystallization, carried out at about 550-600 °C and 950-1000°C, respectively.

Formation of fluorophlogopite phase and inter locking plate-like micro-structure is primarily responsible for giving machinability. Fig. 1 shows the XRD pattern representing the fluoro-phlogopite phase and Fig. 2 shows the microstructure of this phase. Other important parameters like density, average thermal expansion coefficient (α_{avg}), microhardness, high voltage break down strength (V_B), out gassing rate (R), surface roughness, etc have been measured on a number of samples. Some representative data are given in Table 2.

Our present facilities can handle about 0.4 -0.5kg of material, of which about 95% material can be poured at a time. With this capability we have prepared glass samples of :

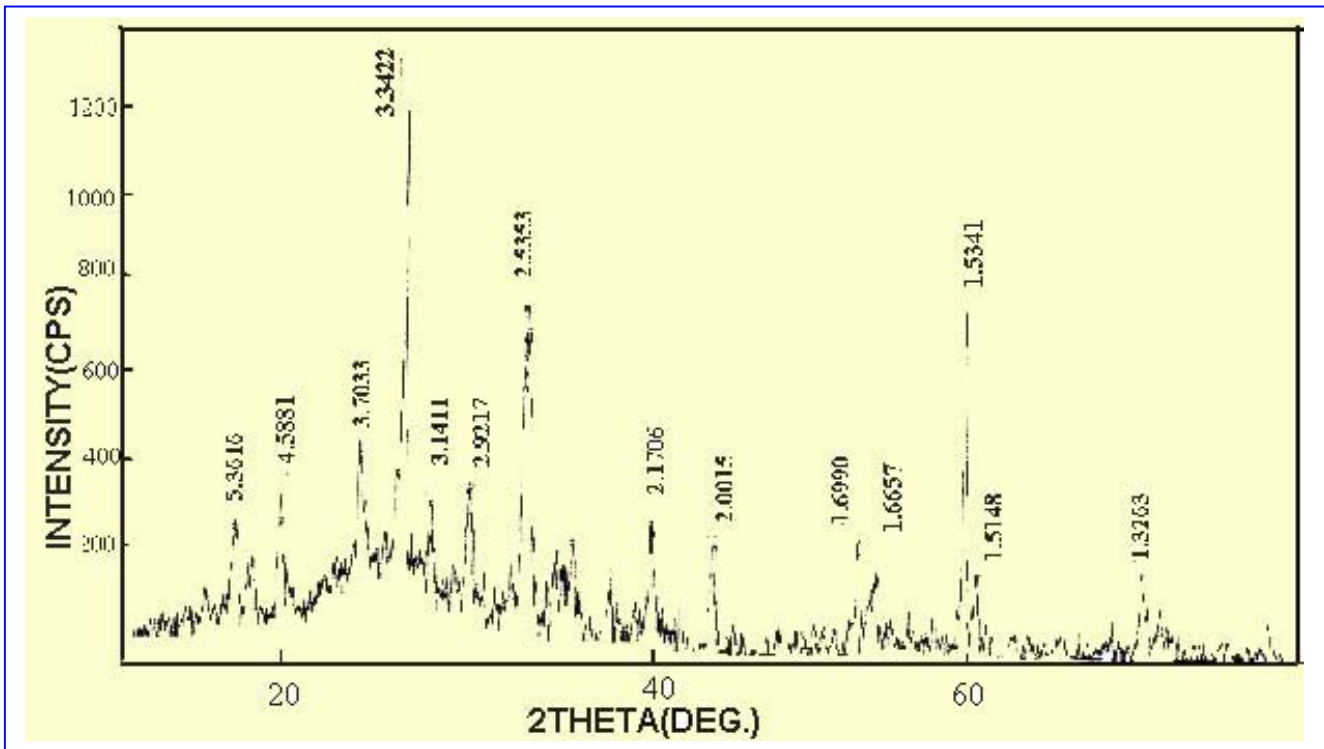


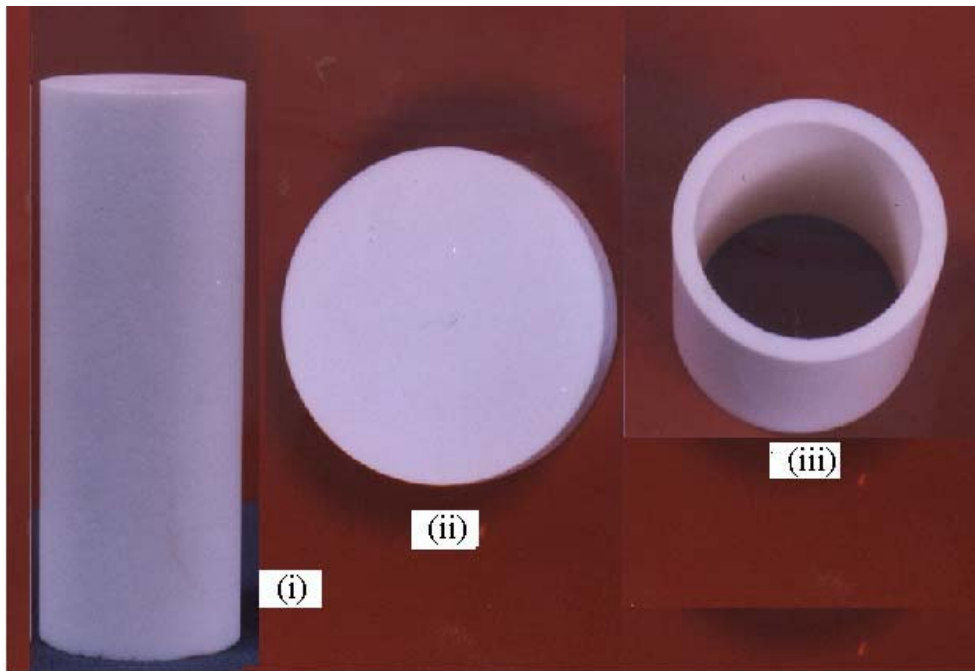
Fig.1 XRD pattern of MAS glass ceramic confirming the formation of fluorophlogopite phase



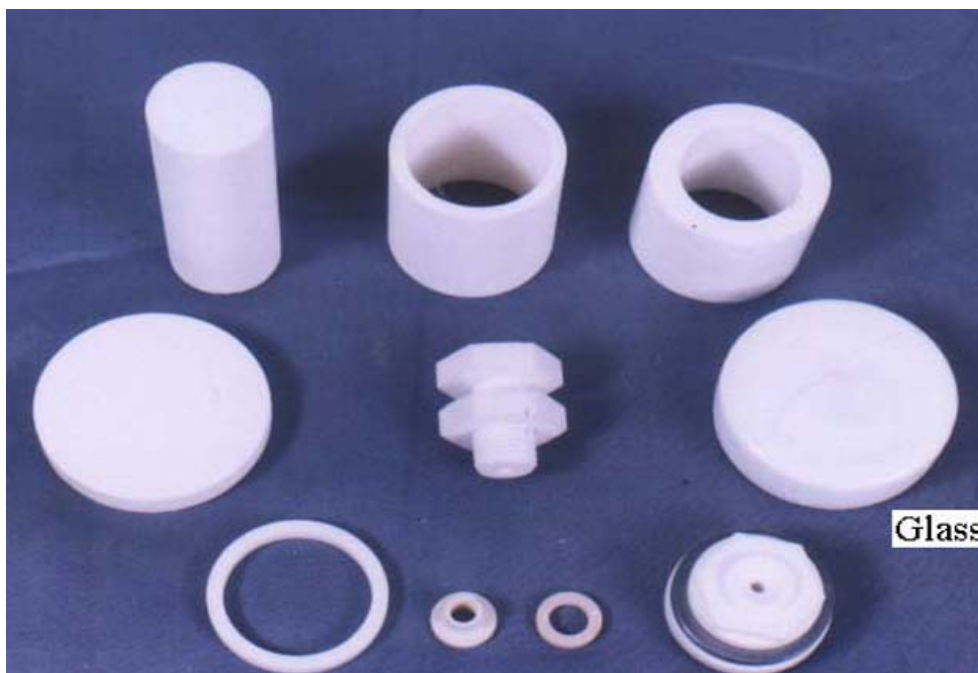
Fig.2 Microstructure of machinable quality MAS glass-ceramic having interlocking plate-like structure

Table 2 : Various physical parameters of MAS Glass-Ceramics

Type of material	Density (gm / cc)	α_{avg} ($10^{-6}/^{\circ}\text{C}$)	Outgassing rate ($\text{Tor.l.sec}^{-1} .\text{cm}^{-2}$)	Microhardness (GPa)	(V_B) (kV/ cm)	Surface roughness (micron)
MAS(s)	2.44	-	8.3×10^{-8}	4.95	11	0.79
MAS(g)	2.55	9.8	7.9×10^{-9}	4.21	22	0.3



(a)



(b)

Fig.3 Manganese-aluminum-silicate glass-ceramic in different shapes and sizes : (a) (i) solid rod, (ii) disc, and (iii) hollow cylinder. Some components fabricated are also shown in Fig. 3(b)

- (i) 30 mm dia x 70 mm length solid cylinder
- (ii) 70 mm dia x 25mm height disc
- (iii) 60mm OD x 45 mm ID X 90 mm length hollow cylinder

The photographs of some of these items, both in glass and glass ceramic forms, along with some fabricated components, are shown in Fig. 3.

The high voltage insulators/spacers are needed in different shapes and sizes. We have fabricated them with careful machining /cutting /

drilling for use in various analytical instruments, sputter ion pumps, vacuum systems and electron beam evaporators. Large number of small lugs have been used in sputter ion pumps developed in TP&PED. In addition, for another special application (of cascade plasma gun under development at L& PTD, BARC), we have fabricated spacers with dimensions of 55mm OD x 40 mm ID x 5mm thickness. The material is quite comparable with imported commercial material called MACOR.

ENGINEERING & MANAGEMENT SERVICES FOR EQUIPMENT & FACILITIES : FOR IMPROVED PERFORMANCE IN A LARGE RESEARCH / INDUSTRIAL ORGANISATION

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Introduction

The performance of an organisation is a measure of how effectively, efficiently and productively its resources are deployed to achieve its objectives or targets. Depending on the type of the organisation, these objectives / targets can be: Research objectives (BARC), Industrial products (NFC), Services (BEST), Social responsibilities (NGOs). Typical resources employed are: Manpower, Materials, Money and Machines (Equipments), which are popularly called the 4 M's of an organisation.

The performance and availability of the equipment can and does greatly influence the performance of an organisation. In an industrial organisation, the targeted output (products) during a period of time can be impaired if the reliability and availability of the existing equipment is not as per expectations, while in research institutions / organisations, the R&D pursuits can get adversely affected by this vital resource. Further, wherever high cost & strategic/special purpose equipment are deployed to meet the objectives, as is the case in

most of the organisations in DAE, a significant component of the input costs of operations is the equipment cost, which, in turn, comprises the initial investment, depreciation and the management (maintenance) components. Systematic equipment management activities can not only result in a significant reduction in the maintenance cost but can also improve the availability / uptime of the equipment which can further reduce the input costs; e.g., an extension of the life of a high cost of equipment, by say repairs / restoration / up-gradation, can lead to reduction in the cost of operations, through a postponement of the heavy investment.

Over the years, the equipments have become increasingly versatile, automated and complex in engineering design. Electronics and computers, in particular, have formed an increasingly important part of the control systems of these equipments across the globe, in synergy with ever-growing requirements of research and manufacturing activities, during the last few decades. Requirements in the area of productivity, material evaluation, quality,

reliability, defects, material handling and economics have necessitated a growth in the basic demands of speed, accuracy and automation. These basic demands have in turn led to the higher performance requirements of the equipments, which the developments, in control systems and in engineering design, are striving to meet. These developments and rapid strides in technological progress have resulted in fascinating new techniques, of resolving many problems and have provided an ever-growing list of equipment and instruments. Consequently, the Equipment Engineering and Management activities, assume an important role in the performance of our organisations.

A dedicated, systematic and integrated management of the equipment in an organisation can give rich dividends. Activities for “womb to tomb” equipment-care can improve productivity, profitability and scientific output in the industrial and research organisations, alike. It is possible to make significant improvements through marginal managerial inputs.

What follows is a brief review of the organisation needs, diversity of the equipments in use, problems, possible approaches, future scenario and salient features of equipment engineering and management services along with potential, needs and benefits of these activities.

Review

Organisational needs

The needs of our research and industrial organisations are inbuilt into our objectives. Some of them can be identified as: (a) Technological excellence: to maintain a degree of efficiency, quality and excellence in our activities. This makes it necessary that our new equipment and facilities, which will have to keep coming in, keep pace with the advancements in the field, towards increasing electronic controls and automation. It is equally necessary to remain prepared for the productive use of these facilities / equipment, through an appropriate plan for their systematic maintenance; (b) Up-gradation: Many of the high cost equipment cannot and NEED

NOT be replaced, as soon as better equipment is available. Generally, they can be upgraded at astonishingly low marginal cost, through an analysis of their designs for possible improvements in their performance. This can lead to large savings in investments, without sacrificing the advantages of the latest technologies of the new version; (c) Optimum utilisation: In spite of the best organisational efforts, there can always be constraints of various kinds, for the proper upkeep and restoration of the high cost equipment. It is, necessary, therefore, to ensure optimal utilisation of the available facilities to maximize the availability of equipment for reducing the cost of our operations.

Equipment diversity

Against the evolving requirements of the basic research and industrial activities, a large variety of equipment, of increasing complexity and automation and originating from different sources, is presently available and continues to be procured. The continuous growth and development in engineering, particularly in electronics and computers, will ensure that this diversity will increase in future.

Examples of this diversity in the equipment in use in the industrial and research organisations:

- (i) *Scientific and Industrial Equipments:* vacuum induction heating / melting, resistance heating & welding, arc melting & welding, EBW, m.f. power & r.f. power sources, laser systems, machining, extrusion, hydraulic and pneumatic processes, process parameters measuring and control instruments.
- (ii) *NDT Equipment / Instruments:* Ultrasonic, eddy current, X-ray, mass spectrometers, SEM, acoustic emission instruments, for material evaluation / characterisation and other equipment for quality surveillance and in-situ testing activities.
- (iii) *Special purpose equipments:* for vacuum heat treatment of materials, rolling, pilgering, drawing, autoclaving, etc., for fabrication of reactor fuel and components.

It is possible and useful to categorise these equipment into a few specialty areas in engineering, for developing individual expertise and for efficient resolution of problems and for an improved professional satisfaction and growth of the deployed manpower at all levels.

Problems

Some of the problems experienced in the area of equipment engineering and management may be enumerated as:

Limited indigenous sources / technical support: Non-availability of the right kind of equipment due to limited indigenous infrastructure, necessitates imports from few limited sources of special equipment. This gives rise to attendant problems of limited technical support from the manufacturers amidst restrictions of various kinds.

System complexity: Growing complexity as a result of demands of higher speed, accuracy and automation gives rise to following requirements:

- a. To have a closer interaction with equipment manufacturers
- b. To deploy analytical and qualified minds for their management
- c. To provide relevant facilities and infrastructure

Constraints of qualified manpower and facilities : Just as human resources in an organisation are looked after for their health, equipments (machines) are required to be maintained for their intended functioning. However, unlike human beings, since the designs of equipment are diverse, their study and understanding of the specific features for the different equipment is required in many cases. And that often requires qualified and analytical manpower, which cannot be provided adequately at all places.

Reluctance of qualified manpower and motivation: In spite of the importance of the maintenance work particularly in high cost installations, it remains a fact 'that the job is not

sought after'. It should be important and interesting to look for the following reasons :

- a. There is no doubt that the job is challenging. The maintenance or the restoration of an equipment often requires an in-depth analysis of its system design and exploitation of an engineer's abilities, based on his qualifications and experience. However, a successfully completed job may sometimes be termed as "routine" – having just restored earlier working equipment. This is in contrast with the activities of a medical doctor, who is "quite capable", "an expert" in similar restoration of a human system. As a result, most qualified persons, who should otherwise work enthusiastically in the important activity of restoration of sick equipment, may be reluctant to undertake this type of work. This problem can certainly be remedied by motivation through recognition of the job to generate and maintain the enthusiasm of the concerned persons. And enthusiasm, I wish to submit, is fundamental to get the best and innovative output of any human being.
- b. Troubleshooting operations for restoration of the equipment on adhoc basis are considered to be frustrating and demotivating, with no sense of achievement for the doer of a difficult job. These operations must give way to systematic equipment engineering and management activities, which provide (i) a sense of belonging and involvement, (ii) satisfaction from a related up-gradation of equipment for an improved utilisation, and (iii) opportunities for professional growth.

Equipment data: Absence of equipment data not only increases maintenance costs and reduces efficiency, but also leads to an earlier 'demise' (scrap) of the equipment. It is necessary that the data regarding nature and category of existing equipment and to-be-procured equipment and their specification / capabilities along with the information regarding the suppliers, documentation available, dates and installation and commissioning, spares availability, etc., is

generated and maintained. An equipment database in a large organisation to provide information with respect to suppliers, equipment category, location, etc., can support efforts and decisions for: standardisation, choosing a supplier for a new procurement, reduction in spares inventory, improved utilisation of expertise and efficient restoration.

Importance: It is necessary that the worth of equipment engineering and management services be fully appreciated. If an optimum-equipment-utilisation becomes one of our objectives, the restoration activities will have acquired their proper status through the equipment engineering and management services to meet the objective, which can change the enthusiasm of the staff deployed, in a very significant manner and can be highly rewarding.

Approaches

Repairs, replacement and related development: To ensure that the equipment and facilities are available, any or all these approaches need to be explored for the restoration of sophisticated high cost or hard-to-get facilities. Some aged / low cost or freely available instruments and facilities are perhaps better replaced. In some cases, however, related development work may be required to be done to modify / replace the relevant sections of the equipment for necessary restoration / upgradation. In the case of high cost equipment, it is necessary that this choice is efficiently and judiciously exercised. This can best be done by qualified and dedicated - to - equipment persons who must understand the functioning of such facilities and who are deployed to carry out the important job of keeping equipment "healthy" in the organisation.

Dedicated manpower and facilities, vendor labour/contract work: Large variety in the equipment necessitates the division of the engineering activities for repairs, replacement and development into a few selected areas of specialisation. It is necessary to reduce dependence on foreign sources for technical support amidst the increasing restrictions and unwillingness of these resources to support our

programmes. Again, this can only be done best by dedicated - to - equipment engineering manpower and facilities for the health care of the equipment, quite akin to DAE medical facilities for another resource, i.e. "human beings". Such a facility should be able to effectively exploit vendors' labour, wherever possible, and effectively organise contract work where necessary or possible, through proper technical liaison with the manufacturers.

Womb-to-tomb approach: An equipment / facility (machines) can be designed / fabricated, installed and commissioned, whereas a man is naturally born. Hence, while restoration of health of a man requires effort, which has little to do with his birth, restoration of the "health" of a machine (back to normal operation), considerably depends on its "birth". Equipment quality can be selected before its "birth", while the in-born qualities of the man are, as yet, out of control. And the trouble-free functioning (good health) and the consequent utilisation of the equipment through its life depends on its design and quality. It is in this context that "womb-to-tomb" approach is relevant to the utilisation of the equipment in our organisations.

The engineering staff dedicated to the maintenance and upkeep of the equipment must properly understand any new high cost equipment facility to be procured / developed. This requires that the supporting engineers are fully involved, first in the equipment specifications and subsequently with the equipment design, fabrication and layout, at the time of procurement. This approach also provides the sense of belonging and of responsibility for the upkeep of the equipment, through monitoring during its life.

Future Scenario

It is relevant to look at the future scenario in respect of (a) industrial equipment, (b) scientific equipment, and (c) changes in the maintenance practices.

Industrial equipment - Automated Manufacturing Systems (AMS) : These are being increasingly facilitated by the new engineering designs based on electronic and control systems. These require the operators, maintenance personnel and supervisors to develop their skills to work productively and safely. AMS generally include – machine tools and related equipment brought together, to form a new or a modified manufacturing system and is often linked by a material handling system. Components of an AMS are interconnected with and are operated by an electronic / computer system, which can in turn be programmed to control the manufacturing of a single part or assemblies. These components of AMS are:

- a. CNC machine, which can be programmed easily to guide the machine tools.
- b. Automatic material handling and transport systems: Conveyors and Automatic Guided Vehicles (AGVs) and Rail Guided Vehicles (RGVs) provide transport systems for material handling for automated operations. Since 1985, AGV usage has been increasing in manufacturing in the various industries and has a great relevance in our nuclear operations. (AGVs offer advantages in product routing over conveyor systems because they can move materials more easily).
- c. Robotic equipments: A robotic equipment consists of industrial robots, end-effect actuators and any equipment, devices & sensors, required for a robot to perform its tasks. Industrial robots are finding increasing applications to perform regular and repetitive tasks and are providing a choice of automation in potentially hazardous or overly strenuous working environments for human beings. They are here to stay and play an important part in automatic manufacturing, in spite of their hazards arising from the possible malfunctioning of the peripheral equipment, casual approach to robots by humans and from erroneous actions during manual operations, checking and during repairs.

- d. Computer Integrated Controls: In automated manufacturing operations, the functions are carried out in co-ordinated manner under computer control. A control computer facilitates information flow, co-ordinates operations and increases efficiency & flexibility through programming.

However, computer-based Automated Manufacturing Systems can have barriers (like absence of standard programming languages, data formats, communication protocols and well defined off-line programming capability, even though these issues are presently addressed by the manufacturers) against their purchase or use. Absence of a proper support base for maintenance and upkeep of such equipment can either totally keep us away from these systems or lead to their ineffective utilisation. These systems necessitate the training of persons in proper operation and maintenance procedures to utilise these equipment effectively and safely.

Scientific Equipment - Developments: Scientific equipment and instruments, which encompass all of the tools of a scientist like instruments, apparatus, techniques of experimental measurement and related mathematical analysis, etc. are, today, dependent on the electronics and computers for their elevated capability, versatility, accuracy, power and relative independence from the user. They are all set to be even more so, in the coming years, to provide data analysis and interpretation capabilities to facilitate concentration of the user scientist on his activities. The use of such equipment is generally simple, user friendly and their operating procedures are widely advertised.

However, the design, construction and the functioning of these equipments are often more complex, designer friendly and (in many cases) their description is guarded and proprietary in nature. This creates problems in the repairs and restoration of such equipment and necessitates deployment of qualified and trained manpower, to understand and manage these equipments effectively at least in the high cost category.

Computerised Maintenance Management System (CMMS): With increasing automation, CMMS is becoming popular because of its money saving potential and is likely to get established in the coming years. Under this system, maintenance management is automated and the organisations use microcomputers and sophisticated software to plan and control maintenance and re-conditioning. Work orders, materials purchasing and scheduling are tracked through computer reports. Machine history can be traced and scrutinised through data based sorting of work orders and equipment failures can therefore be analysed. CMMS reporting can provide machine downtime figures and cost data to support decisions: repair, modify, retrofit, upgrade or replace.

CMMS can shorten downtime and consequently reduce costs by providing easy to retrieve information from databases on replacement parts, vendor contact information or repair instructions. Modules on preventive maintenance (based on performing routine tasks at fixed intervals) and on predictive maintenance (based on monitoring process conditions), may be developed as part of CMMS, which may also often need to increasingly fulfill real time maintenance requirements.

Engineering & Management Services for Equipment & Facilities

What is presented above is an introspection of many years of experience in the field of maintenance that has stirred some thinking to draw lessons for the future. It is believed that the Equipment Engineering and Management Services, organised and supported to provide the womb-to-tomb equipment health care, have the potential to improve the productivity and profitability of any large industrial or research organisation in a big way. Further, it would be rewarding to make marginal managerial inputs in this field to organise and operate these services.

Centralised equipment engineering & management services

The mandate, "to organise and systematically pursue the engineering diagnostic, restoration / up-gradation and management services to manage the diverse high cost equipment and facilities", establishes the objectives of a suitable structure for its manpower to focus upon. The thrust of this structure should be "to provide quality equipment and its health care to resolve problems and to efficiently ensure its high and reliable availability at low costs".

The Services will consist of:

- (a) Equipment Engineering Services, which will need to include: equipment restoration / repairs, modifications (where necessary), up-gradation (at marginal costs) and realising equipment / facilities – equipment manufacture, where necessary, to achieve, high equipment up – time (that leads to faster / more outputs) and improved utilisation of available assets (that leads to lower costs).

Every one in the Equipment Engineering and Management Services may work with "all options open" approach to resolve the equipment related problems.

- (b) Equipment - Management Services, which include generation and maintenance of equipment data, equipment design analysis – ("know your equipment" programme), preparation and maintenance of service manuals / circuits, trouble-shooting charts, equipment failure records with remedies, spares - inventory monitoring / control, training for update of staff with respect to obsolescence and development of vendors for component supplies / retrofitting or up-gradation / replacement.

The functions of such a structure therefore include everything that needs to be done to provide equipment health-care services, i.e., to maintain the equipment and facilities in the organization as per requirements and to carry out necessary equipment engineering and management activities, for this purpose, on womb-to-tomb basis:

- Scrutinise equipment specifications w.r.t. maintenance at procurement
- Install and commission the equipment independently or in association with the manufacturers
- Generate and maintain equipment data
- Study and understand equipment design
- Compile or generate trouble shooting charts
- Procure and maintain spares inventory
- Monitor equipment performance
- Carry out preventive and predictive maintenance
- Provide the engineering services for repairs and restoration equipment under breakdown.
- Train and motivate maintenance staff
- Organise R & D jobs for equipment up-gradation
- Arrange import substitution wherever possible
- Design, develop and realise the required specific equipment / instruments

The Centralised Equipment Engineering & Management Services may be seen to be very analogous to medical facilities under the CHSS, in DAE.

Need

Some of the reasons that make it essential for a large organisation to support and strengthen a centralised equipment engineering and management services are:

- Large variety of equipment at various Divisions/ plants in the organisations.
- New equipment expected to be more complex and will be based on electronics (and computer) controls (like it or not!) – need exists for preparedness for upkeep and use.
- Electronics dominates equipment design. Restoration of most breakdowns can only be resolved or initiated by troubleshooting in a few specialised areas, for which skills need to be developed.

- Adequate qualified electronic staff in the few identified areas of specialisation cannot and need not be deployed in every plant/ Division, but is required.
- Electronics is a fast changing discipline, making equipment obsolete much earlier than their life is over. Therefore, need exists for upgradation of equipment projects/ activities, which also provide the necessary retraining / exposure to developments.

Nothing of the above is insurmountable but requires initiative and the will to make a difference and to overcome the resistance to change.

Potential and benefits

There is a large potential for significant contributions and benefits that are possible through CEEMS, which can offer :

- Improved equipment availability / utilisation at reduced capital investment
- Development of expertise in relevant specialised areas has the potential to reduce the total requirements of manpower through their optimum deployment
- Availability of qualified, trained and dedicated - to - equipment manpower, well versed with designs and functioning of the diverse equipment and trained to become in-house manufacturer's representatives, to provide competent, cost effective and reliable equipment engineering services. This will also facilitate: (i) self reliance, (ii) realising critical/special purpose equipment, (iii) equipment up-gradation at marginal extra costs (reduced capital investment), and (iv) large potential for developing and implementing automation and material handling techniques.
- No user's distraction
- Improved motivation and professional growth of the staff deployed.
- Higher productivity / profits – improved performance.

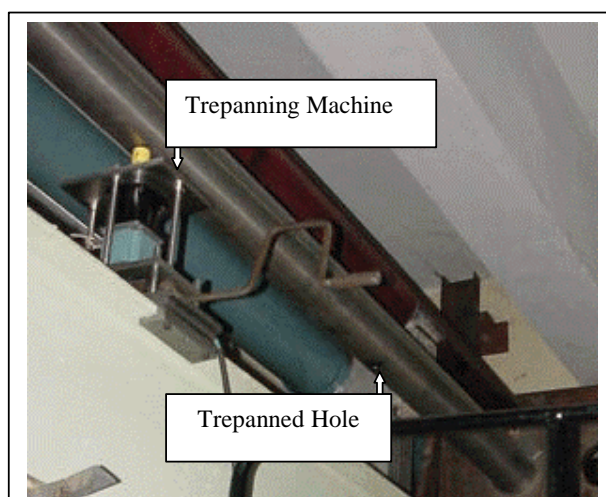
Conclusions

- The performance of an organisation is influenced by the utilisation of the deployed equipment, which depends on the available equipment, engineering and management services.
- Equipments are a vital resource of the organisation to satisfy the objectives with a sense of technological excellence.
- Electronics dominates the functioning of equipment control systems today. Face of equipment will further change in future.
- Diagnostics, restoration, upgradation and relevant development activities for the diverse equipment in a large organisation require manpower with qualifications and training for system analysis.
- It is necessary to motivate, deploy and optimally utilise the qualified, dedicated-to-equipment staff for its maintenance and upkeep to maximise the availability of equipment in the organisation to achieve an improved utilisation of operating staff.
- Equipment management services that need to be rendered amidst various problems and constraints are to be better recognised. Motivation of qualified and skilled staff in this activity is possible through a sense of achievement, specialisation and professional growth.
- Dedicated-to-equipment staff is most suited to explore all available options to resolve equipment related problems.
- Technological developments in scientific and industrial equipment to facilitate greater speed, accuracy, versatility, flexibility and automation in the operations necessitate maintaining and training specific staff in maintenance procedures to utilise these equipment effectively and safely.
- It is necessary to provide competent, cost effective and reliable services for a

IN-SITU PORTABLE TREPANNING MACHINE TOOL

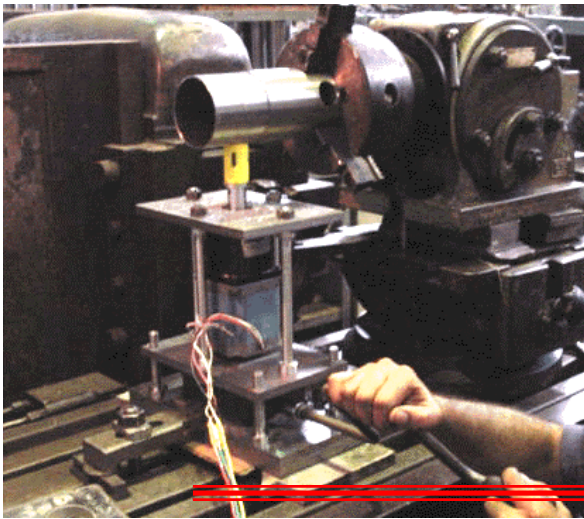
systematic “health care” of equipment and facilities in a large organization through a Centralised Equipment Engineering and Management Services, which have a large potential and benefits, leading to significant improvements in performance of the organization.

A good beginning has been made at BARC by constituting CEEM to initiate the equipment management activities. NFC (Hyderabad) which has a large number of high cost equipment and which has profits as one of its objectives, has also organised its maintenance activities on similar lines. In years to come, Engineering and Management Services for the health care and management of sophisticated, diverse, high cost and strategic equipment and facilities, will need to be continuously strengthened, so as to become self-reliant, cost effective and more productive. This will also need to be done because of the need to minimise the total manpower that has to be deployed, for all elements of our activities, through their optimal utilisation through an inter Divisional mode of functioning, since separate effective groups of persons for these services, just cannot be deployed in every plant/Division/Group in a large organisation. Further, nurturing and strengthening of the engineering services will also eliminate an often frustrating distraction of the users, into areas of equipment health care, repairs/ restoration and up-gradation. These services, which are analogous to the medical services of our staff under the CHSS, can play a significant role in improving our productivity in DAE organisations.



In-situ trepanning at Engineering Hall 7, BARC

Centre for Design and Manufacture (CDM) has designed and manufactured an In-Situ Portable Trepanning Machine for making 32 mm diameter holes (in-situ) in the Calandria Tube of the 500 MWe Coolant Channel, being tested at Integral Thermal Facility in Engineering Hall 7, BARC. The Coolant Channel has already been installed at a height of about 4 metres from ground level and all the four holes have to be made from the bottom side (at 6 O'clock position) of the Calandria Tube.



Mock-up trepanning trials at CDM, BARC

These holes are required for fixing the vibration transducers which are to be attached to the Pressure Tube (pre-installed inside the Calandria Tube) for vibration measurements on the Pressure Tube.

Overall size of the machine tool is 350 mm x 350 mm x 375 mm and it can be mounted in any direction (vertical, horizontal or any other angle). The machine tool consists of a variable speed motor for rotation of the trepanning tool, a precision mechanism for fine depth of cut / feed, guide rods and bushes, clamping plates and trepanning cutter (hole saw).

This machine was earlier tested at CDM and finally has been successfully used on January 21 and 22, 2003 for making four numbers of holes (in-situ) in the Calandria Tube of the 500 MWe Test Coolant Channel installed at Hall-7.

The entire work (design, manufacturing, assembly, testing and actual trepanning in-situ) was completed within a period of three weeks.

IN-SITU BORING AND GROOVING OF MAPS-II CALANDRIA TUBE SHEET

R.L.Suthar

Centre for Design and Manufacture

Centre for Design and Manufacture (CDM) was entrusted with the task of developing a Boring and Grooving Machine (BGM) and also to develop the machining process for carrying out 3 numbers of new grooves in the bores for rolling of the spargers, which were designed by Reactor Engineering Division (RED), BARC. The machining operations were needed at 6 bore locations, i.e. at S5 (N&S), T11 (N&S) and S16 (N&S). It was necessary to obtain the size of the bores and the grooves within the close geometrical and dimensional tolerances and the bores were needed to have a very good surface finish. The radioactive chips generated during the

the in-situ Boring and Grooving of the MAPS Calandria Tubesheets (CT). These operations involved enlarging the existing CT bore size from 120 mm to 122 mm (+0.3 / -0.00) and making of Boring and Grooving operations were also to be collected safely. This task cannot be accomplished by any conventional machine tool. The in-situ machining work was also difficult since this was to be a totally blind operation and that too in a high radiation level area, where operators cannot stay for long periods of time near the BGM.

The BGM was developed and machining trials were first completed at CDM. A core team of MAPS technicians were also trained in the operation and maintenance of the BGM under a MoU signed with NPCIL. Operation and Maintenance manual of the BGM was also

2002. Finally, during the period from December 15 to 21, 2002, in-situ Boring and Grooving operations in MAPS-II were successfully completed under the supervision of engineers from CDM. Three numbers of spargers were also rolled in position by MAPS on 23rd and 24th of

Table-1

Bore No.	Specified diameter 122.00 / 122.30 Obtained diameter (A)	Specified Cylindricity (0.100 mm) Obtained Cylindricity	Sparger Tube O.D. (B)	(A-B) Clearance with Sparger 1.3 / 0.9
S5 (N) 15-12-02	121.99 / 122.05 (Av. 122.02)	0.060	120.73	1.29
S5 (S) 17-12-02	121.47 / 121.60 (Av. 121.57)	0.130	120.60	0.97
S16 (N) 16-12-02	122.00 / 122.09 (Av. 122.06)	0.090	120.80	1.26
S16 (S) 21/21-12-02	121.73 / 121.81 (Av. 121.77)	0.080	120.82	0.95
T-11 (N) 18-12-02	121.40 / 121.44 (Av. 121.42)	0.040	120.53	0.89
T-11 (S) 19-12-02	122.00 / 122.12 (Av. 122.07)	0.120	120.74	1.33

prepared. These manuals, with full set of detailed drawings of the BGM, were handed over to NPCIL. Two numbers of identical BGMs and their control panels were made. The first BGM was tested at CDM and sent to MAPS in August 2002. MAPS utilised the first BGM for training of additional technicians in view of radiation dose exposure limits for the operating personnel. The second BGM was sent to MAPS in November

December, 2002 under the supervision of engineers from RED, BARC.

Table 1 shows the 'Specified' and 'Obtained' size and cylindricity of the bores. The dimensional clearance needed for the installation of the Spargers inside the CT bores was also obtained as required.

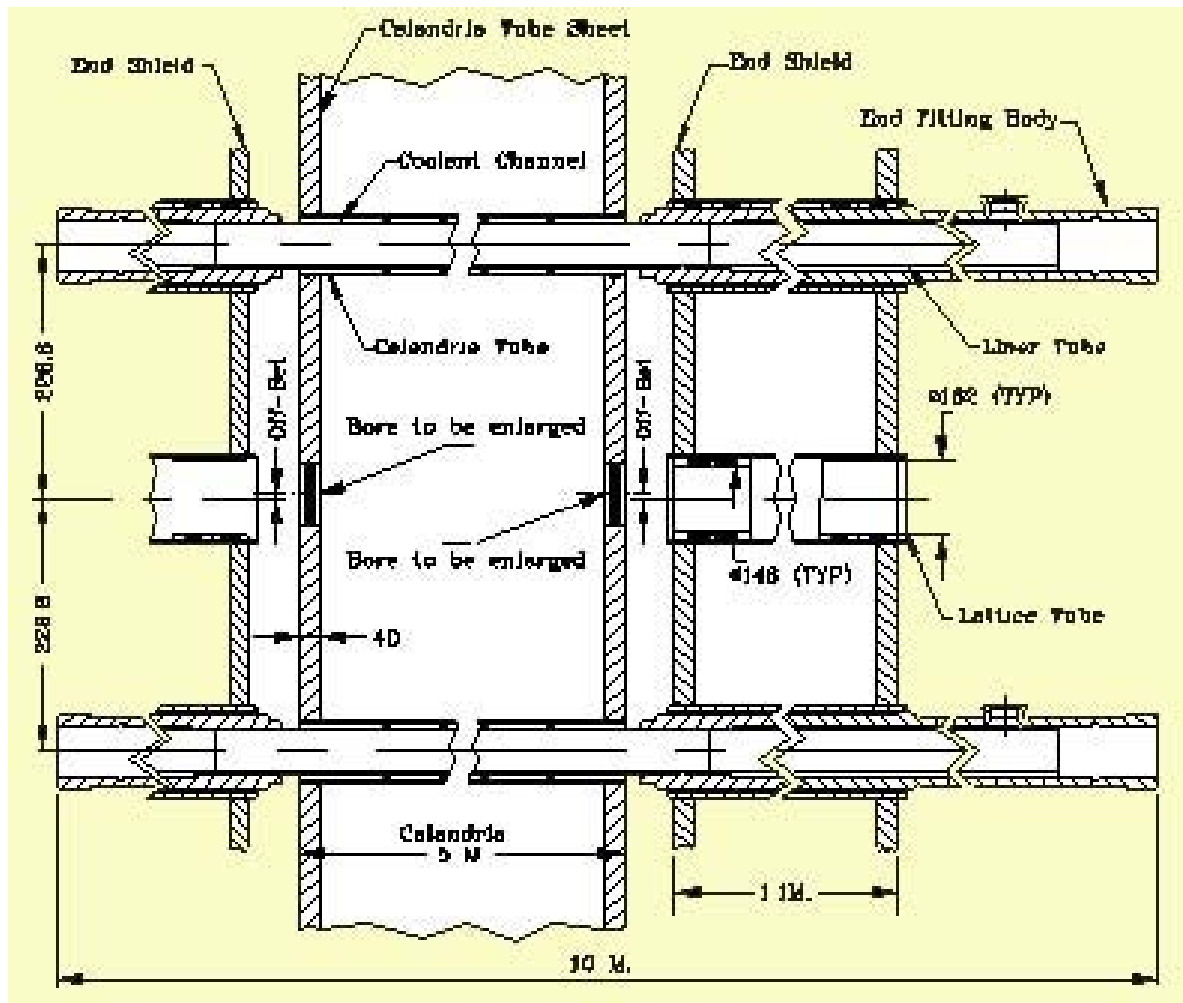


Fig. 1 Layout of the Calandria Tubesheet and Lattice Tube

In-situ machining operations on the reactor face are very difficult for the following reasons (Fig. 1):

- Machining operation is to be done from a distance of 3 metres approximately.
- Boring Bar / Tool Head has to pass through the long Lattice Tube of the End-shield (ES).
- Existing CT bore (which is to be enlarged) and the bore in Lattice Tube of ES are not concentric. Value of this offset / eccentricity and direction are not known.
- Enlarged new bore in CT should be concentric to the existing bore. Ref Fig. 2 for

finished dimensions of the enlarged bore and the new grooves to be machined in them.

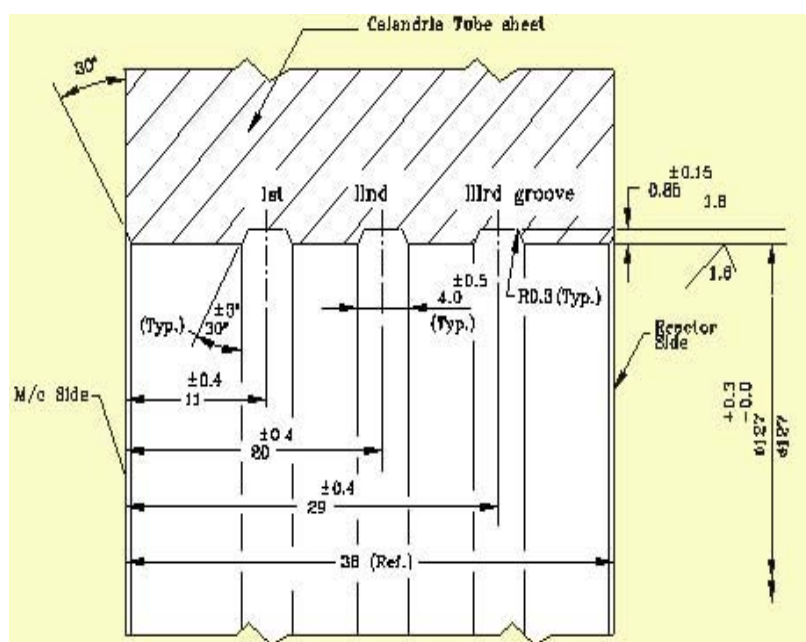


Fig. 2 Dimensions of the enlarged Bore and Grooves

- e) All the chips generated during the machining process should be collected in a shielded chip strainer-cum-container.
- f) High radiation environment.
- g) Totally blind operation.

To overcome the above-mentioned constraints, suitable Offset Measuring Gauges in addition to the BGM were also developed. Offset measuring gauges are required to measure the value and direction of offset of existing CT bore with respect to Lattice Tube bore in ES through which the machine tool has to enter. Following paragraphs describe the BGM and the machining process

time of machining operation. Sub-assemblies are (i) Tool head sub-assembly, (ii) Boring bar sub-assembly, (iii) Drive module sub-assembly, (iv) Chip suction vacuum system, and (v) Control console. Accessories of the BGM are (a) Liner tube, (b) Housing pipe, (c) Eccentric bushes, (d) Supporting system for Boring bar and (e) Guide rail. These accessories are required: (a) to make the Boring bar concentric to the existing CT bore which is to be enlarged, (b) to support the Housing pipe and Boring bar during the machining process, (c) to provide a smooth passage for flow of chips, and (d) to support the Boring bar when it is pulled outside.

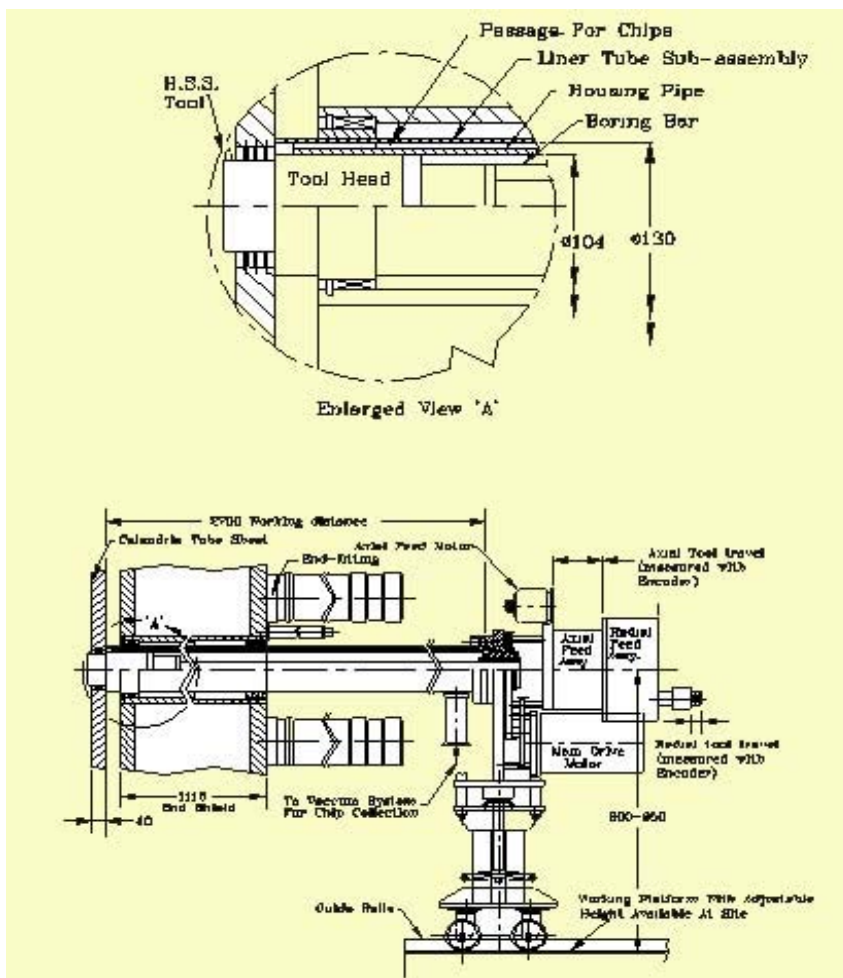


Fig 3 Boring and Grooving Machine

developed for the Boring & Grooving operations.

Description of the Boring and Grooving Machine

This special purpose remotely operated machine tool (Fig. 3) consists of five main sub-assemblies and some accessories, which are required at the

Tool Head Sub-assembly

Tool head sub-assembly consists of a tool holder, which is mounted on a specially designed guided screw and nut assembly. Rotation of the nut, through a pair of bevel gears, provides the radial movement of tool holder on which the cutting tool (Fig. 4) is fixed.

Boring Bar Sub-assembly

Boring bar sub-assembly consists of two concentric pipes. Main purpose of the Boring bar is to connect the Tool head sub-assembly to the Drive module for : (a) rotation of the Tool head, (b) obtaining the radial feed and (c) obtaining the required axial feed and positioning the cutting tool at the

desired location of the grooves. Outer pipe of the Boring bar is connected with the tool head and Inner pipe is coupled with the bevel gear, for radial feed motion.

Drive Module

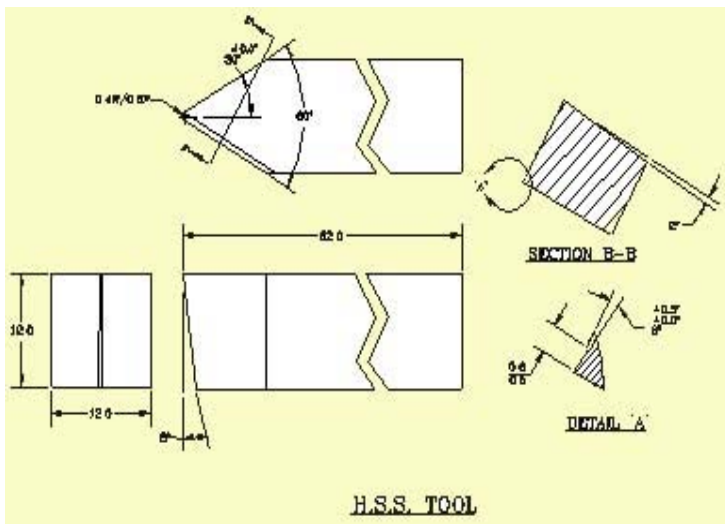


Fig 4 Cutting Tool

position of the cutting tool. Radial feed of the tool can be controlled within a few microns.

Vacuum Chip Suction System

Vacuum system consists of a heavy duty industrial vacuum pump, lead shielded chip strainer-cum-collector and PVC flexible hoses to connect (i) the Housing pipe to the chip collector, and

Drive module provides: (i) Rotary motion, and (ii) Axial motion, and (iii) Radial movement of the cutting tool. All these three motions are achieved by use of only two motors, a few spur gear sets and two sets of clutches. When Outer and Inner pipes of Boring bar rotate at the same RPM, the cutting tool only rotates, without any radial travel. Arrangement has been made in such a way that the difference in the rotational speeds of Outer and Inner pipes of the Boring bar provides the radial movement of the cutting tool.



Fig. 5 Boring and Grooving Machine as installed at CDM

An induction motor and suitable gearing rotate the Boring bar. Tool head can be moved axially by another variable speed motor at the desired axial feed rate. Radial feed of the cutting tool (for depth of cut) is obtained by manually engaging the radial feed clutch of the main Drive module. Differential gear arrangement between the Outer and the Inner pipes of the Boring bar, when activated by this clutch, changes the speed of the Inner pipe w.r.t. the outer pipe, resulting in the radial feed till the clutch is kept engaged. Axial and radial tool feeds are provided with optical encoders, for indicating the axial and radial

(ii) the chip collector to Vacuum pump. All the chips are sucked as they are being generated during the machining process and they do not fall inside the Calandria.

Control Console

The Control console is having "OFF" and "ON" buttons for (i) the Vacuum pump, (ii) the Main induction motor for Boring bar, and (iii) the axial feed motor. There are knobs also to vary the r.p.m. of the main induction motor and the axial feed motor.

Table-2 : Operating chart for boring, as per BARC design of spargers

Sl. No.	D.R.O. reading	Drum reading	Rotation of manual feed handle	Cutting time	Resetting time between two cuts	Starting positioning of tool (axial)	End positioning of tool (axial)	Feed r.p.m	Main monitor frequency
123.81 mm (radial setting of tool by ring gauge)		Retract tool in by 10 rotations from 123.81 dia position. Advance the tool to get tool position at 120 dia. Check the tool position by noting drum/vernier reading corresponding to 123.81 dia. as reference.							
01	119.6			30 min.	5 min.	+ 2.0 mm	-40.0 mm	6.0	25 Hz
02	120.1		Rotation = 3/4 of a circle	30 min.	5 min.	+ 2.0 mm	-40.0 mm	6.0	25 Hz
03	120.6		Rotation = 3/4 of a circle	30 min.	5 min.	+ 2.0 mm	-40.0 mm	6.0	25 Hz
04	121.1		Rotation = 3/4 of a circle	30 min.	5 min.	+2.0 mm	-40.0 mm	6.0	25 Hz
05	121.6		Rotation =3/4 of a circle	25 min.	5 min.	+2.0 mm	-40.0 mm	8.0	30 Hz
06	122.1		Rotation =3/4 of a circle	25 min.	5 min.	+ 2.0 mm	-40.0 mm	8.0	30 Hz
07	122.1		0 (for finishing)	40 min.	5 min.	+2.0 mm	-40.0 mm	5.0	18 Hz

For 8.0 r.p.m. of axial feed motor, the feed rate is 1.5 mm/min; One rotation of the radial feed handle = 0.33 mm. depth of cut

(Important Notes : Before main motor is switched " on " : (i) Please ensure the proper position of the clutches, (ii) Check PVC hose connections to the vacuum pump and the BGM from the chip strainer-cum-collector)

Control Console display (DRO) system indicates (i) the r.p.m. of the motors, (ii) the tool position in Axial and in Radial directions. In case of power failure, the cutting tool can be withdrawn manually. There is no change in DRO readings for the axial and radial tool positions even in case of power failure. On restoration of power, machining can be proceeded with from the point where it was interrupted.

Installation of BGM and Boring and Grooving Procedure

As mentioned earlier, Lattice tube bore and the CT bore are not concentric. With the help of specially developed Offset measuring gauges, the value of eccentricity/offset and its direction is first measured. Accordingly two eccentric bushes are machined and fitted on Liner tube sub-assembly and then the Liner tube sub-assembly

is inserted in the bore of the Lattice tube of the ES in proper orientation.

This operation makes the I.D. of Liner sub-assembly concentric to the CT bore, which is to be enlarged. This concentricity is confirmed by use of another smaller size offset measuring gauge. After that, Housing pipe is inserted inside the Liner sub-assembly. Annular gap between the O.D of the Housing pipe and ID of Liner tube sub-assembly provides the passage for flow of the chips. Tool head along with Boring bar and Drive module are kept ready to receive the Housing pipe, which is inserted on them and clamped with BGM. Proper cutting tool is clamped on the Tool head, which protrudes out of the Housing pipe. BGM is now inserted in the Liner sub-assembly and clamped with it.

After several mock-up trials of Boring and Grooving operations, machining parameters were finalized. Using these parameters and the properly designed cutting tool of required surface finish, dimensional and geometrical tolerances and small size of chips (which can be sucked easily by the vacuum system) were successfully obtained. Table 2 shows the details of the machining procedure developed to meet the requirements.

Conclusion

The portable and remotely operated special purpose machine (SPM) and the corresponding

machining process developed for operations in high radiation area have been successfully used in In-Situ machining of the MAPS-II Calandria Tube sheet. This same SPM (Fig .5) can be used for many other operations also by change of a suitable tool head and the cutting tool.

This portable SPM can be used for machining in vertical bores also. At present, the radial feed to the cutting tool is given manually, but the same can be controlled remotely also by providing a small pneumatic cylinder for actuating the clutch, which provides the controlled radial feed.

BARC TRANSFERS TECHNOLOGY OF DIGITAL POCKET RADIATION DOSEMETER

The technology of Digital Pocket Radiation Dosemeter, DIGIDOSE, developed by Radiation Safety Systems Division, BARC, has been transferred to M/s Ardee Hi-Tech Pvt. Ltd., Visakhapatnam, on December 19, 2002, and to M/s Nucleonix System Pvt. Ltd., Hyderabad, on January 16, 2003.

The Digital Pocket Radiation Dosemeter, DIGIDOSE, is a semiconductor detector based, low cost, digital radiation dosimeter. It provides continuous digital readout of X and Gamma Radiation dose over a wide range ($1\mu\text{Sv}$ to $99999\mu\text{Sv}$). It works on a pair of coin type Lithium battery cells. The dosimeter is available in two models, Model I and II, that differ in the size and type of LCD display used. In another very low cost variation (RADCLICK), the



At the conclusion of Technology Transfer Agreement signing, seen from right to left are : Ms S.S. Mule, TT&CD; Mr R.P. Agarwal, TT&CD; Mr A.M. Patankar, Head, TT&CD; Dr M.C. Abani, Head, RSSD; Dr R.B. Grover, Associate Director, TC&IRG; Mr G.V. Ramana, Director, M/s Ardee Hi-Tech Pvt. Ltd., Visakhapatnam; Ms Renu Gupta, Director, M/s Ardee Hi-Tech Pvt. Ltd., Visakhapatnam; Mr S. Kannan, RSSD; Ms Madhuri D. Lalsare, RSSD; and Ms U.P. Gaonkar, RSSD

LCD display is dispensed with and a beep tone is produced for every $0.05\mu\text{SV}$ of accumulated dose.

Technology Transfer & Collaboration Division coordinated activities related to technology transfer from advertisement of the technology and scrutiny of parties, to Technology Transfer Agreement signing including preparation of technical documents.



During a discussion at the end of Technology Transfer Agreement signing, seated from right to left are : Dr D.N. Sharma, Head, RSSD, Mr R.P. Agarwa, TT&CD, Dr V. Venkat Raj, Director, HS&EG, Mr J.N. Reddy, Managing Director, Nucleonix, Mr S. Kannan, RSSD, Mr K.C. Bajaj, RSSD, Ms Mahuri D. Lalsare, RSSD, and Ms S.S. Mule, TT&CD

The know-how has been transferred in the form of a Technology Transfer Document along with a sample of each model of DIGIDOSE.

भा.प. अ. केंद्र के वैज्ञानिक को सम्मान /BARC SCIENTIST HONOURED



डॉ. वी. वेणुगोपाल, अध्यक्ष, ईंधन रसायिनिकी प्रभाग, भाभा परमाणु अनुसंधान केन्द्र, को बुडापेस्ट, हंगरी में उच्च ताप उष्मागतिक एवं ठोस अवस्था रसायिनिकी (High Temperature

Thermodynamics and Solid state Chemistry) क्षेत्र में विशिष्ट योगदान के लिए मान्यता के रूप में तापीय विश्लेषणात्मक तथा कैलोरिमीटर पत्रिका (Journal of Thermal Analysis and Calorimetry)

(उष्मीय अध्ययन का अन्तर्राष्ट्रीय माध्यम) का प्रादेशिक संपादक नामित किया गया। इन्होंने अन्तर्राष्ट्रीय स्तर के 120 से अधिक वैज्ञानिक शोध-पत्र लिखे हैं तथा इनके निर्देशन में उष्मीय तथा उष्मागतिक विज्ञान (Thermal and Thermodynamics Science) क्षेत्र में 13 पीएच.डी. शोध-प्रबंध प्रकाशित हुए। डॉ. वेणुगोपाल नाभिकीय पदार्थ, एवं रसायिनिकी उष्मागतिक (Journal of Nuclear Materials and Journal of Chemical Thermodynamics) जैसी अन्तर्राष्ट्रीय पत्रिकाओं में लेखों के प्रकाशन हेतु नियमित समीक्षक रहे हैं। ठोस अवस्था प्रतिक्रिया (Solid State Reaction), एडवान्स-पदार्थ संश्लेषण (Synthesis of Advanced Materials), पदार्थ चरित्रिकरण (Material Characterization) एवं प्रावस्था आरेख गणना (Calculation of Phase Diagrams) इनकी अनुसंधान रुचि में सम्मिलित हैं

Dr V. Venugopal, Head, Fuel Chemistry Division, BARC, has been nominated as Regional Editor for the *Journal of Thermal Analysis and Calorimetry* (an international forum for thermal studies), Budapest, Hungary, in recognition of his outstanding contributions in the field of high temperature thermodynamics and solid state chemistry. He has authored more than 120 scientific papers in international journals of repute and the research work carried under his guidance has resulted in 13 Ph.D. theses in the field of Thermal and Thermodynamic Science. He has been a regular reviewer for papers for publications in international journals like *Journal of Nuclear Materials* and *Journal of Chemical Thermodynamics*. His research interest includes solid state reaction mechanism, synthesis of advanced materials, material characterization and calculation of phase diagrams.

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