931-[illegible]3
PD AAO-481
ISN 38695

January 17, 1979

ACTION MEMORANDUM FOR THE DEPUTY ASSISTANT ADMINISTRATOR, DSB

THRU: DS/PO, Robert Simpson, RC for

FROM: DS/HEA, Lee M. Howard, M.D.

Problem: To approve a small activity for development of a low-cost PVC well screen which can be manufactured in less developed countries.

Discussion: A satisfactory well screen is necessary for efficient operation of either manually or mechanically operated water pumps. Operation without a screen allows sand and silt to enter the pump mechanism leading to excessive wear or clogging and failure of the pump. The use of an improperly designed screen causes a loss of efficiency in the pumping operation and wastes human or other energy used to pump the water.

Well screens are currently made mostly from metal or plastics and are too expensive for widespread use in LDCs. Additionally, current manufacturing techniques are complicated and costly with the result that most screens are made in developed countries and must be imported by LDCs, representing a foreign exchange drain and resulting in either few screens being used or no replacement parts being imported.

Dr. Sternberg's project (summary attached) proposes to develop a low-cost, low technology method to produce well screens from standard plastic (PVC) pipe which is readily available in most LDCs. The proposed manufacturing technique would use simple machinery which would allow production by very small LDC industries with relatively low technical skills. Dr. Sternberg estimates, we believe realistically, that this technique could produce satisfactory screens for a cost of about $2.50 per foot. This compares with presently available screens which cost from $30 to $157 per foot.

The research is divided into two phases. The first theoretical and experimental phase will determine the optimum design for the screen to balance the requirement for open space to allow maximum water intake with the need to retain solid material for strength. In the second phase, the broaching tools and machinery to produce the screen will be developed and tested. At the end of the project, AID will receive 125 feet of screen and three sets of the broaching tools for field testing. The regional bureaus and missions enthusiastically support this proposed activity.

Dr. Sternberg and his colleague, Mr. Knight, have undertaken two previous small projects for AID, and several for the World Bank, for development of

low-cost water supply equipment. Results in all cases have been outstanding. They have demonstrated a good knowledge of and sensitivity to the needs of LDCs for locally manufactured, low-cost, low technology yet efficient devices for small scale water supply systems.

Dr. Sternberg and his research team have previously been awarded the AID small research project, "Development and Testing of the Robovalve," AID contract AID/ta-c-1461. During the project Dr. Sternberg stayed on time and money track throughout the project. The final report was of exceptionally high professional quality. The project manager was very pleased with the project output, detailed designs of operating and functioning Robovalves that really work. The Robovalve was a low-cost, locally manufacturable appropriate technology device. It has been met with considerable interest and enthusiasm among the international community. This new type of well screen and broaching device will undoubtedly meet with similar success if funded. On a scale of 1 - 100 of probability of success for the new Roboscreen project, the project manager notes it at a 95% success probability. The LDCs need a screen like this.

Recommendations: (1) That you approve up to $40,000 for a small activity to fund a contract with Dr. Sternberg to carry out the work in the attached proposal.

Approved: Stephen L. [illegible]

Disapproved: _____

Date: 1/24/79

(2) That you sign the attached memorandum to Gerald Gold requesting non-competitive procurement.

Attachments:

1. Memo to Gerald Gold
2. Dr. Sternberg's proposal

DRAFTERS:DS/HEA:VWehman/JRoyer:1/17/79:pjn:X58929

FILE

January 17, 1979

MEMORANDUM

TO: CM/COD/PE, Mr. Gerald Gold

FROM: DAA/DS/HRD, Stephen C. Joseph, M.D.

SUBJECT: Justification for Non-Competitive Procurement of Unsolicited Proposal, "Development of Broached Plastic Well Screens for LDCs"

The subject proposal is an unsolicited proposal. The substance of the proposal is not available to the Government without restriction from another source nor does it resemble any pending competitive solicitation. The substance is sufficiently unique to justify acceptance as an unsolicited proposal.

The project officer certification with reference to A.I.D. Pr Notice 78-4 follows:

> I certify that neither I nor, to the best of my knowledge and belief, any other A.I.D. employee solicited the proposal or had any prior contact with the proposing institution, other than to convey interest in the field of small scale water supply technology, relative to the efforts described in the unsolicited proposal.

Victor Wehman, Project Manager

I request that you award this contract on a non-competitive basis to Dr. Yaron Sternberg without consideration of other sources.

Clearance:
DS/HEA, L. Howard
DS/PO, R. Simpson

Worksheet

AID 1350-1X (1-78)

PIO/T

DEPARTMENT OF STATE
AGENCY FOR
INTERNATIONAL DEVELOPMENT

PROJECT IMPLEMENTATION ORDER/TECHNICAL SERVICES

1. Cooperating Country: DSB Interregional

2. PIO/T No. 931-1 0003-3698073

3. [X] Original or Amendment No. _____

4. Project/Activity No. and Title 931-0003
Small Activity Program - Development of Broached Plastic Well Screens

DISTRIBUTION

5. Appropriation Symbol: 72-1191021.6

6. Allotment Symbol and Charge: 946-36-099-00-20-91

7. Obligation Status: [X] Administrative Reservation [ ] Implementing Document

8. Project Assistance Completion Date (Mo., Day, Yr.) 3/15/79

9. Authorized Agent: AID/W CM/COD

10. This PIO/T is in full conformance with PRO/AG _____ Date _____

11a. Type of Action and Governing AID Handbook: [X] AID Contract (HB 14) [ ] PASA/RSSA (HB 12) [ ] AID Grant (HB 13) [ ] Other

11b. Contract/Grant/PASA/RSSA Reference Number (If this is an Amendment) _____

12. Estimated Financing (A detailed budget in support of column (2) is attached as attachment no. _____)

		(1) Previous Total	(2) Increase	(3) Decrease	(4) Total to Date
Maximum AID Financing	A. Dollars	- 0 -	$ 40,000.00		$ 40,000.00
	B. U.S.-Owned Local Currency				

13. Mission References

14a. Instructions to Authorized Agent

CM/COD is requested to negotiate a contract with Dr. Yaron M. Sternberg, to carry out the activity described in the attached unsolicited proposal.

14b. Address of Voucher Paying Office

DS/HEA/EH

15. Clearances—Include typed name, office symbol, telephone number and date for all clearances.

A. The project officer certifies that the specifications in the statement of work are technically adequate
DS/HEA, V. Wehman — Phone No. 235-9020 — Date 1/24/78

B. The statement of work lies within the purview of the initiating and approved agency programs
DS/HEA, L. Howard — Date 1/29/79

C. DS/HEA, J. Royer — Date 1/24/79

D. Funds for the services requested are available
DS/PO, M. Egan — FUNDS RESERVED BY Michael C Egan — Jan 30, 1979 — POSTED _____ — DER/AFM/CSD

E. for DS/HEA/EH, J. F. Thomson — Date 1/24/78

16. For the cooperating country: The terms and conditions set forth herein are hereby agreed to

Signature _____ Date _____

Title

17. For the Agency for International Development

Signature Kenneth A Milow — Kenneth Milow — Date 1/30/79

Title Chief, Prog. Div., DS/PO

11

Project/Activity No. and Title 931-001
Small Research Program - Development of Broached Plastic Well Screens

SCOPE OF WORK

19. Scope of Technical Services

A. Objective for which the Technical Services are to be Used To develop a plastic well screen which can be produced by broaching standard PVC pipe and to develop simple tools and techniques for the broaching operation.

B. Description

The contractor will carry out the tasks described in paragraph 5, "Research Project Design and Methods" of the attached proposal.

C. Technicians

(1) (a) Number	(b) Specialized Field	(c) Grade and/or Salary	(d) Duration of Assignment (Man-Months)

(see illustrative budget, page 5)

(2) Duty Post and Duration of Technicians' Services

N.A.

(3) Language requirements

None

(4) Access to Classified Information

None

(5) Dependents ☐ Will ☐ Will Not **Be Permitted to Accompany Technician** N.A.

D. Financing of Technical Services

(1) By AID - $ 40,000.00 **(2) By Cooperating Country** –

AID 1350-1X (9-70) PIO/T	Cooperating Country DSB Interregional	PIO/T No. 931-[redacted]	Page 3 of 5 Pages
	Project/Activity No. and Title 931-001 Small Research Program - Development of Broached Plastic Well Screens		

20. Equipment and Supplies *(Related to the services described in Block 19 and to be procured outside the Cooperating Country by the supplier of these services)*

A. (1) Quantity	(2) Description	(3) Estimated Cost	(4) Special Instructions

(See illustrative budget, page 5)

B. Financing of Equipment and Supplies

(1) By AID – $ (2) By Cooperating Country –

21. Special Provisions

☒ A. This PIO/T is subject to AID (contracting) (PASA implementation) regulations.

☒ B. Except as specifically authorized by AID, or when local hire is authorized under the terms of a contract with a U.S. Supplier, services authorized under this PIO/T must be obtained from U.S. sources.

☒ C. Except as specifically authorized by AID/W, the purchase of commodities authorized under this PIO/T will be limited to the U.S. under Geographic Code 000.

☐ D. Other *(specify)*:

22. Reports by Contractor or Participating Agency *(Indicate type, content and format of reports required, including language to be used if other than English, frequency or timing of reports, and any special requirements)*

Contractor shall submit three copies of the final report to the documentation coordinator, DS/DIU or his designee. No interim reports (other than phone calls or visits to the DS/HEA project manager's office for informal discussions of progress) will be required. Final report will be in English and include at least: (1) Summary of successes and failures during development of the product; (2) description of procedures actually followed versus those originally contemplated; (3) a projected cost estimate for LDC manufacture of the screens, including estimated cost of specialized equipment required; and (4) design/working drawings suitable for reproduction and distribution.

A draft of the final report shall be reviewed with the DS/HEA project manager prior to final printing.

30 copies and [redacted] one reproducible master of the final report including an author prepared abstract, shall be submitted to the DS/HEA Project Manager within 15 days after [redacted] contract termination.

23. Background Information *(Additional information useful to Authorized Agent and Prospective Contractors or Participating Agency; if necessary cross reference Block 19.C(4) above.)*

24. Relationship of Contractor or Participating Agency to Cooperating Country and to AID

A. Relationships and Responsibilities

N.A.

B. Cooperating Country Liaison Official

N.A.

C. AID Liaison Officials

DS/HEA, Victor Wehman

AID-1300-1X (7-69) CONTINUATION SHEET	DEPARTMENT OF STATE AGENCY FOR INTERNATIONAL DEVELOPMENT	[X] Worksheet [ ] Issuance	PAGE 5 OF 5 PAGES
		1. Cooperating County DSB Interregional	2.a. Code No.
FORM SYMBOL	TITLE OF FORM	2.b. Effective Date	2.c. [X] Original OR Amendment No:
		3. Project/Activity No. and Title 931-[redacted] Small Research Program - Development of Broached Plastic Well Screens	

Indicate block numbers.

Use this form to complete the information required in any block of a PIO or PA/PR form.

BUDGET

A. Salaries and Wages:

Dr. Y.M. Sternberg	105 days @ $135 per day	$14,175.00	
Mr. R. Knight	112 days @ $110 per day	12,320.00	
Secretarial Assistance	10 days @ $40 per day	400.00	
Part-time Assistance	500 hours @ $3.00 per hour	1,500.00	$28,395.00

B. Tooling:

Drills, milling cutters, grinding wheels, heat treatment, expanding mandrels, slitting saws. 5,000.00

C. Materials and Supplies: 4,250.00

Tool steel, PVC pipe, frame materials, hydraulic jacks.

D. Drafting and Duplicating, etc.: 1,250.00

Reports, photographic, etc.

E. Space Rental 1,500.00

To include use of equipment and utilities

TOTAL $40,395.00

DEVELOPMENT OF BROACHED PLASTIC WELL SCREENS FOR LDC'S

Activity Proposal

Submitted to

the

Agency for International Development

Office of Health

Development Support Bureau

by

Yaron M. Sternberg, Ph.D.
11905 Viewcrest Terrace
Silver Spring, Maryland 20902

A. PROJECT SUMMARY

1. Basic Identification and Fiscal Data

Project Title: Development of Broached Plastic Well Screens for LDC's

New or Extension: New

Contractor and Address: Dr. Yaron M. Sternberg
11905 Viewcrest Terrace
Silver Spring, Maryland 20902

Principal Investigator: Dr. Yaron M. Sternberg

Duration: 12 months

Total Estimated Cost: $40,395.00

A.I.D. Project Manager and Sponsoring Office: Mr. Victor Wehman, Jr.
Office of Health
Development Support Bureau

2. Abstract

Various plastic pipes such as PVC, ABS, etc., are used for well casings and screens. Commercial plastic screens are produced by either winding c coil of plastic material around an arrangement of support beads, or stiffeners, then welding the two materials together to form a screen, or by changing a solid plastic pipe to a screen by various slotting techniques. Commercial plastic screens are expensive and offer limited open area; spirally wound screens have an open area of approximately 8-10%, while slotted ones vary from 1-5%. A new approach to screen manufacture has been investigated, which is inexpensive, (approximately one-fifth of the cost of commercially available plastic screens) rugged, with an open area of 20-25%. The new screen can be produced from any commercially available plastic pipe using a broaching technique. The slotting operation requires the use of simple and commonly available tools. In phase I the optimum dimensions of the screen's webs will be determined. Phase II will include the development of the broach, the broaching fixture, and the accompanying hardware.

B. EXPANDED NARRATIVE STATEMENT

1. General Background and Rationale

In many regions throughout the world, alluvial aquifers of great extent are used for water supply. These aquifers are composed of unconsolidated alluvial materials that range from silts, clays and fine sand to gravel and boulders. In aquifers where fine sand is the predominant constituent, screens must be provided to prevent the sand from entering the pump. Well screen is a recognized and accepted technique to control the migration of soil particles carried by the water from the aquifer, through the various well components, and into the discharge side of the pump.

Water will pass more freely through a screen with a large total open area than one with a small open area. A large open area also insures low inlet velocities which results in smaller head losses and lower drawdown.

Commercial screens are manufactured from either metal or plastics. Metal screens have a range of openings from 0.006 inches to 0.25 inches, exhibit a large open area (20 - 35%), and are rugged. Commercial metal screens are expensive (3 inch stainless steel screen costs approximately $30.00 per foot) and, therefore, have only limited applications in LDC's. In addition, very few LDC's have capabilities of producing good quality metal screens and therefore, have to utilize foreign exchange for the purchase of metal screens.

Commercial plastic screens are less expensive than metal ones, (4 inch continuous slot ABS screen costs approximately $17.00 per foot) but also have smaller open area (8-10%). Commercially available plastic screens are produced by either perforating a plastic pipe by cutting slots or drilling holes into it, or by winding and spot welding a continuous

filament of plastic material around a set of fixed stiffeners. The former is used by a number of small manufacturers and requires relatively simple production machinery. The latter requires sophisticated equipment and is produced by a few large manufacturers (Johnson screens). Spirally wound plastic screens are strong but their high cost coupled with their relatively low open area limits their wide spread use for LDC's.

Perforated or slotted screens are inexpensive but in general exhibit low open area (1-5%). Because of the difficulties encountered in sawing the plastic pipe to produce the slots, the minimum slot size is about 0.05 inches. The slots are not uniform and attempts to increase the open area by providing additional slots results in a weak screen that may collapse under normal operating conditions. Perforated screens are produced by drilling a plastic pipe. This type of screen has limitations on the minimum size hole, strength and intake efficiency.

Initial development of a new type of well screen, Broached Roboscreen, has been conducted by Dr. Sternberg and Mr. Knight.

A ten inch length of 3" P.V.C. pipe was machined to produce the cross section shown in figure 1. This machining was a time consuming and painstaking process. It did, however, prove that an ordinary piece of P.V.C. pipe could be transformed into an excellent well screen. The goal now is to develope a broaching technique which will be simple and inexpensive. Thus, lending itself to "cottage industry" applications. The new screen will be inexpensive (3 inch P.V.C. screen will cost approximately $2.50 per foot assuming the cost of 3 inch P.V.C. pipe at $2.00 per foot), rugged, and provides an open area of 20-25% depending on the selected slot width. The raw material for Roboscreen is a standard P.V.C. pipe which is produced in most LDC's.

Discussion with representatives of various international organizations confirm that PVC pipe is available in almost all areas in LDC's. Samples obtained indicate that the gage of PVC pipe produced in LDC's is somewhat lighter than standard. However, the extrusion is generally good with concentricity between the outside diameter and base equal to, or better than, PVC pipe produced in developed countries. The manufacturing of a screen from a standard pipe will include two operations. The first will involve the use of a broach to remove predetermined segments of plastic material from the inner circumference of the pipe, forming webs. This operation will use a standard jack (1-1/2 tons), a broach, and a jig to hold the pipe. The second operation will include the cutting of a continuous slot using a simple lathe.

The screen, in addition to its use as well screen, can also be used as efficient and economical intake device in rivers, lakes and reservoirs. Broached Roboscreen can successfully replace timber cribs, concrete caissons and other inefficient and costly intake structures.

Roboscreens can be produced by LDC's by small cottage industries. The machining operations do not require large investments in equipment or materials. In addition, the process of making the screen is simple and does not require a high degree of skill. It is estimated that a two man operation will produce about 5 feet of screen per hour.

2. Research Purpose and Expected Results

a. To further develop the manufacturing technique, and test the Broached Roboscreen and its application and utilization for wells, infiltration galleries and surface water intake.

b. The final products of this study will include a complete set of drawings and instructions on how to set up and fabricate the

Roboscreen. In dddition, 125 feet of 3 inch Roboscreen, 3 broaches, and 3 holding jigs will be produced to be used for future field utilization.

3. Relevance and Significance of Proposed Work to A.I.D.

At the present time millions of wells throughout the world lack proper screens, thus permitting sand to enter the pump assembly. Sand and other soil particles act as abrasives leading to rapid wear of the pump, early failure and, consequently, and inoperative well. In wells equipped with inadequate length of plastic screen (a common phenomenon because of the high cost of such screens) necessary to provide the required open area, the operation is inefficient. For a given energy input the discharge of such wells is less than anticipated. To realize the discharge desired, additional energy inputs must be provided - a condition which is not compatible with the present day high energy costs.

Efficient plastic screens are also required for millions of hand pumps in use throughout the world. Lack of screens causes early failure of the cylinder and frequent replacement of the leather cups and other components. Most users either do not have access to readily available spare parts or do not have the money to purchase them. The results are inoperative hand pumps. The lack of appropriate screens is also responsible for the continuous loss of human energy and diminishing discharge rate. A dug well equipped with an adequate screen can provide a larger discharge for a given human energy input than one without a screen.

Commercially available steel and plastic screens are suitable materials but are too expensive for general use in LDC's. Resorting to inexpensive but inadequate locally produced plastic or metal screens wastes energy and often leads to the rapid wear of the pump. Under such conditions, the well

will either be abandoned or the pump be repaired, or replaced. Unless a proper screen is installed, the new or repaired pump will not last longer than the old one.

Groundwater development projects are planned or are underway in many LDC's. Aquifers in many of these countries are predominantly fine sand and silt indicating that screens must be employed if wells are to function properly. The new Broached Roboscreen will be rugged, inexpensive, with large open area; the same characteristics good metal screens have. Broached Roboscreens can be manufactured in almost all LDC's, requiring little capital investment and when installed as well screens or surface water intake, will insure a sand free water and long pump life.

4. Relation to Existing Knowledge

There are no known studies on development of well screens for use in LDC's. Dr. Sternberg and Mr. Knight were engaged in development work for an extruded plastic screen with support of IBRD. This type of screen requires manufacturing extrusion capabilities as the proposed design of a solid pipe, webs and stiffeners must be extruded in one single operation. Slotting of the extruded material is done on a lathe.

No additional development and/or laboratory testing of the above screen will be funded by IBRD. For the last 12 months. IBRD, WHO, and UNICEF have attempted to locate a site for field testing of the screen. At the present time no site has been located, and the likelyhood of locating one in the near future is slim. U.S.A.I.D. Development and Support Bureau has purchased 150 feet of the above screen for preliminary testing in a number of LDC's.

Since 1975, Dr. Sternberg was the principal investigator of a number of successfully completed projects for improving water resources supplies in

LDC's. A project on hand operator bamboo slotter (IBRD) resulted in a prototype model currently manufactured in Assam, India. Development of PVC valve (AID/ta-c-1461) was successfully completed on time. Presently, U.S.A.I.D. Development and Support Bureau is planning to purchase 300 "Robovalves" for field testing in a number of LDC's. A user activated water meter project (AID/ta-c-1461) resulted in a working prototype. Interest in such a device has been expressed by numerous representatives of international lending agencies and national governments of LDC's.

5. Research Project Design and Methods

The requirements for a good screen are hydraulic efficiency, strength, ease in manufacturing and installation, and low cost. A hydraulically efficient screen implies that the screen must have a large enough open area to be compatible with the hydraulic conductivity of the aquifer, and the desired discharge. Operation of a screen can also be viewed as preventing the migration of fine particles into the well while allowing groundwater to enter the well with minimum energy loss. In practice one attempts to achieve a balance between the percent of particles retained by the screen and the energy loss associated with the constricted openings.

The idea of a broached Roboscreen was investigated by Dr. Sternberg and Mr. Knight in response to requests from various representatives of international lending institutions for a low cost screen. The process of manufacturing a screen from a standard PVC pipe will include two phases, broaching and slotting.

The tooling for broaching the PVC pipe will consist of a support fixture which holds the workpiece and provides guides for the broach. The broach, shown in figures 2 and 3 will be a convential type with six or more cutters as required and will be powered by a hydraulic jack. The broaching

operation will include loading the workpiece into the support fixture or jig and driving the broach one complete stroke using a hydraulic jack. Slotting of the above workpiece following the broaching operation is done on a convential lathe equipped with a grinding head. The grinding wheel is replaced with a slitting saw of the desired thickness. The ribs of the screen will be located on an arbor while the outer shell is firmly suspended and ready for slotting. The revolving cutter, set to the helix angle of the desired spacing, is fed into full depth and the lathe put into motion as per conventional screw threading operation.

The fabricated pilot model of the broached Roboscreen has been subjected to only limited tests for strength. The hydraulic characteristics of the screen and its behavior under continuous operation has not been investigated.

The basic objectives of this study are:

1. Optimize the design of the screen in terms of the number and dimensions of webs as a function of strength for a screen with slot sizes of 20, 30, and 40. (Slot size 20 means 20 thousands of an inch.) This phase of the investigation will be theoretical and experimental. The numbers and dimensions of the webs formed by the broach and the slot size selected will determine the strength of the screen. A number of different configurations of webs and slots will be tested for strength. The results of this phase will suggest what configurations are required to sustain a given load.
2. Based on the above results a number of broaches and jigs will be fabricated and tested. The goal of this phase of the investigation is to design and fabricate a simple broaching unit that could be duplicated in LDC's with locally available materials

and equipment. The major problem anticipated in the development of the broach is to minimize the amount of heat generated in the P.V.C. due to friction caused by the numerous cutting edges working simultaneously. This can only be resolved by experimentation. Optimizing the cutting angles, clearances, distance between blades, and speed of travel etc, can only be evaluated experimentaly. Supporting the workpiece will be a problem of lesser magnitude. The proposed closed loop loading frame is shown in figure 4.

3. Using the jig developed under objective 2, fabricate a number of 3 inch PVC screens using a lathe equipped with cutters of various widths. The pipe will be slotted using a simple technique which can be employed in LDC's as it requires only a standard lathe.

4. Provide a complete set of drawings, broach, broach jig and 125 feet of slotted screen, and all other information and materials necessary to demonstrate how to manufacture Broached Roboscreens in LDC's.

6. Research Competence and Resources

Dr. Sternberg and Mr. Knight resumes are enclosed. Since 1975 the above were involved in various research and development projects, funded by AID and thw World Bank, dealing with the application of "appropriate technology" rural water resources projects. Those projects include the development of a bamboo slotter, testing of wooden pump handles and pivots, development of a water valve (AID-ta-C-1461), and water meter (AID-ta-C-1460). The Broached Roboscreen is an inovation of Dr. Sternberg and Mr. Knight. The Broached Roboscreen will be a non-proprietory device and will not be patented.

Management Considerations

Work on this project will be conducted at the International Rural Water Resources Development Laboratory, College of Engineering, University of Maryland, College Park, Maryland 20742.

BUDGET

A. Salaries and Wages:

Dr. Y.M. Sternberg	105 days @ $135 per day	$14,175.00	
Mr. R. Knight	112 days @ $110 per day	12,320.00	
Secretarial Assistance	10 days @ $40 per day	400.00	
Part-time Assistance	500 hours @ $3.00 per hour	1,500.00	$28,395.00

B. Tooling:

Drills, milling cutters, grinding wheels, heat treatment, expanding mandrels, slitting saws.	5,000.00

C. Materials and Supplies:

Tool steel, PVC pipe, frame materials, hydraulic jacks.	4,250.00

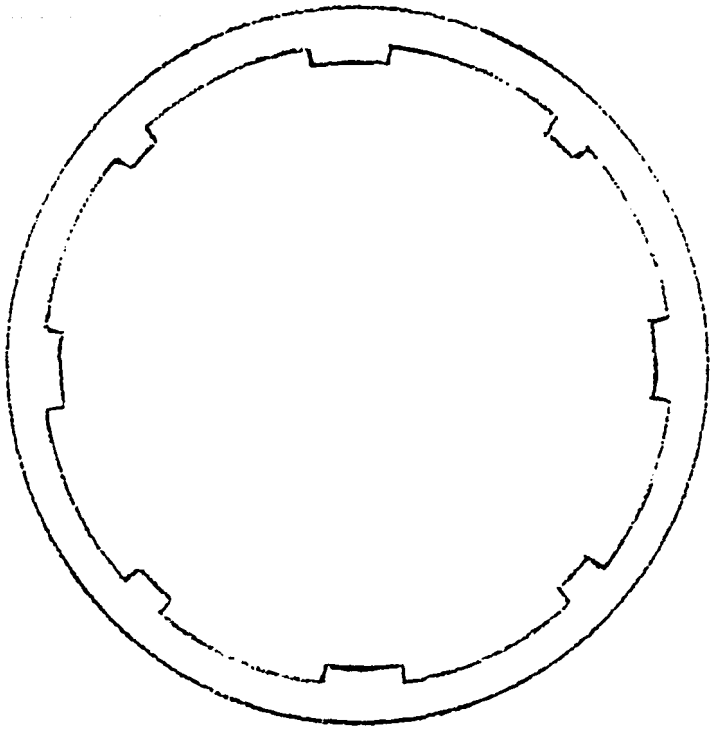
D. Drafting and Duplicating, etc.:

Reports, photographic, etc.	1,250.00

E. Space Rental

To include use of equipment and utilities	1,500.00

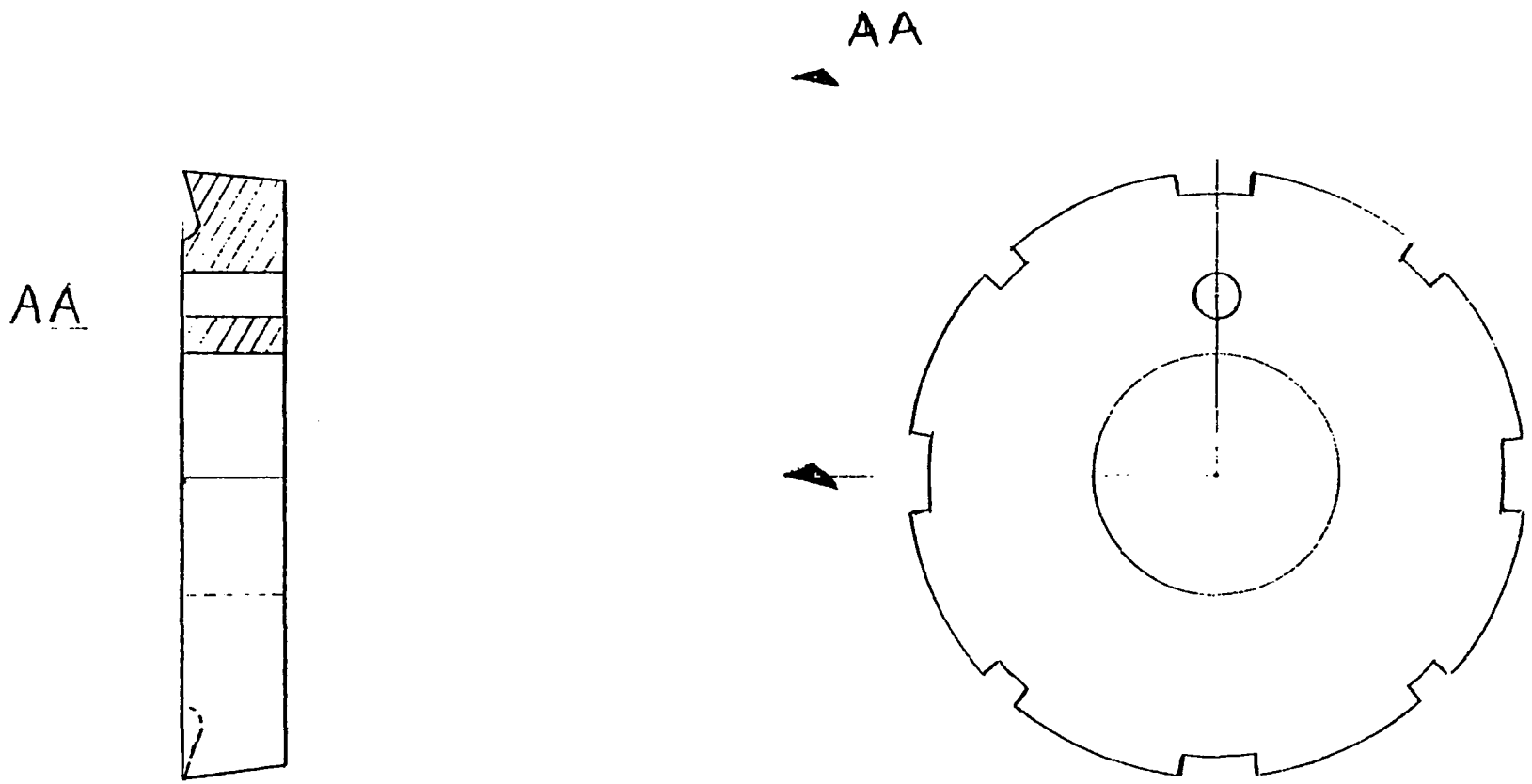
Total.....$40,395.00



Cross Section of Modified P.V.C. Pipe

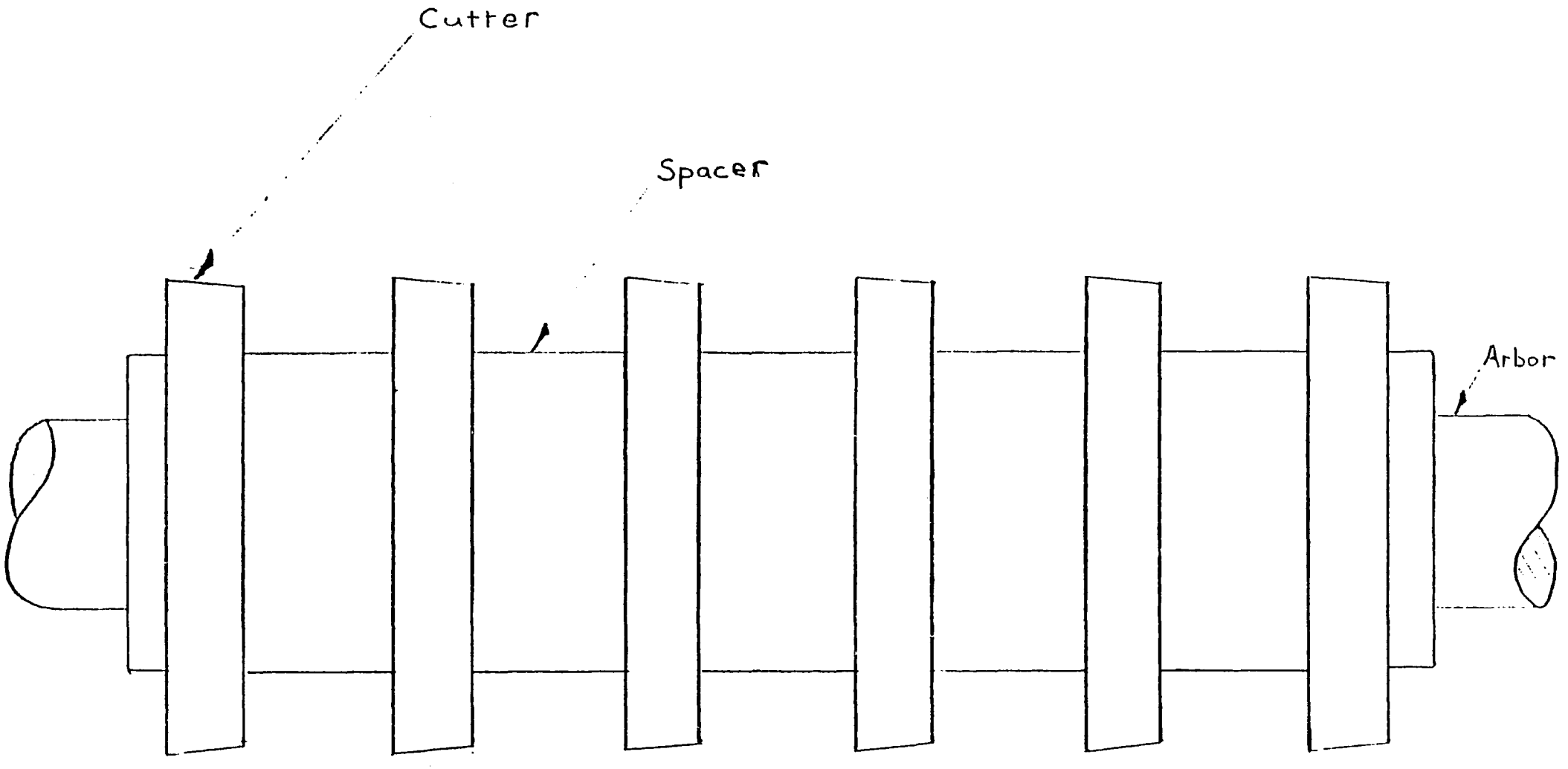
Scale 1 : 1

Fig. 1



Typical Broach Cutter - (one of a series)

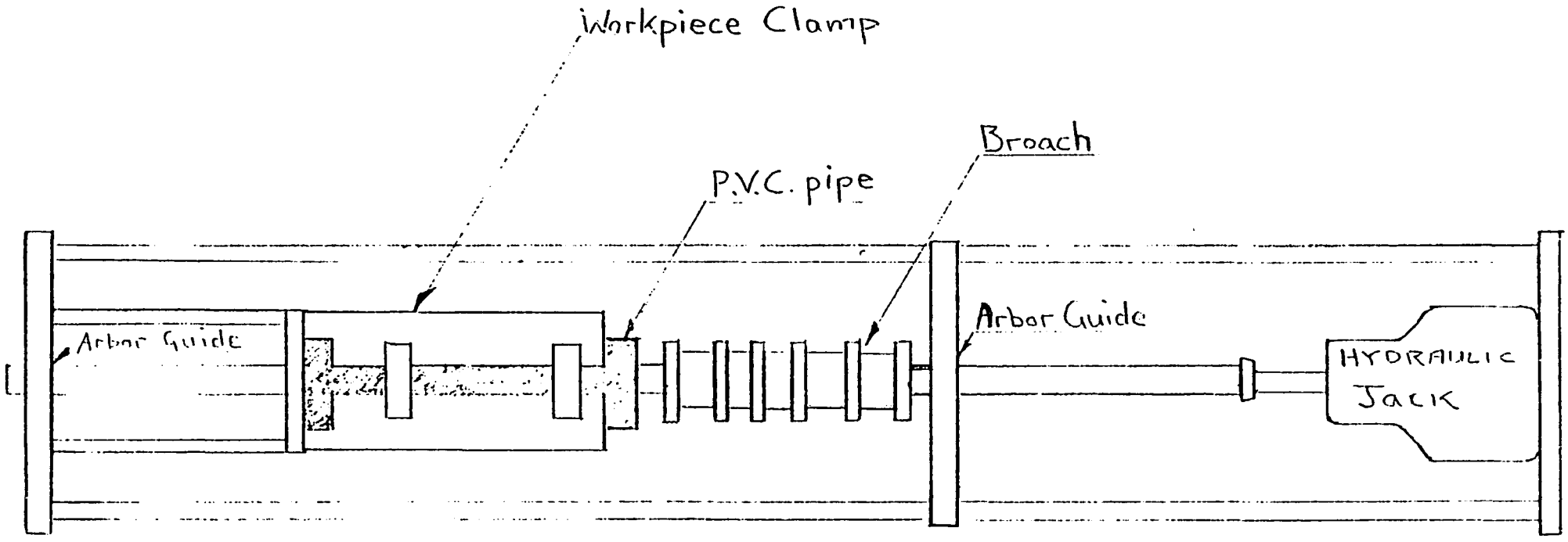
Fig. 2



Broach Assembly

Cutter diameters will increase left to right in $\frac{0.020''}{0.030}$ increments

FIG. 3



Closed Loop Loading Frame

Drawing shows probable configuration of broaching apparatus.

Not to scale.

Fig. 4

RESUME

YARON M. STERNBERG

Present Position:	Professor of Civil Engineering, and Director of International Rural Water Resources Development Laboratory
Address:	University of Maryland Dept. of Civil Engineering College Park, Md. 20742 301-454-2438
Education:	PhD, 1965, Engineering (Hydrology) University of California MS, 1963, Engineering (Hydrology) University of California BS, 1961, Agricultural Engineering University of Illinois
Distinctions and Fellowships:	Tau Beta Pi (National Engineering Honorary Fraternity) Chi Epsilon (National Civil Engineering Honorary Fraternity) Alpha Epsilon (National Agricultural Engineering Honorary Fraternity) Sigma Xi
Professional Affiliation:	American Society of Civil Engineers American Geophysical Union American Society of Petroleum Engineers
Professional Record:	
1977 - Present	Director, International Rural Water Resources Development Laboratory
1976 - 1977	Research Scholar, Office of Water Research and Technology, U.S. Dept. of Interior
1974 - Present	Professor of Civil Engineering (Water Resources) University of Maryland
1970 - 1974	Associate Professor of Civil Engineering (Water Resources) University of Maryland

1969 - 1970	Associate Professor of Geology Indiana University
1965 - 1969	Assistant Professor of Geology Indiana University
Academic Experience:	Director of a number of research projects; Maryland subsurface drainage study (1970 - 1974), Migration of pollutants in ground water (1973 - 1975), Environmental impact studies (1974 - 1976), Spray irrigation of effluent (1974 - present), Ground water modeling (1975 - present).
Professional Experience:	Consultant to various private, governmental and international organizations on surface and subsurface hydrology. A partial list of projects and clients is attached.
Publications:	See attached list.

YARON M. STERNBERG
WATER RESOURCES ENGINEERING
11905 VIEWCREST TERRACE
SILVER SPRING, MARYLAND 20902
301 · 681-7747

Partial List of Projects and Clients

1. Availability of ground water, city of Russell Springs, Ky.
2. Sources and direction of ground water which flooded a mine, U.S. Gypsum Co., Indiana.
3. Drainage of 3000 acre for a planned community, Washington Gas, D.C.
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EDUCATION

1944 High School Graduation, Dunfermline, Scotland
1949-51 Lauder Technical College, Dunfermline, Scotland (evening classes)
1958-61 Technical College, Kirkcaldy, Fife, Scotland (evening classes)
1966-68 Electronics I and II, University of Maryland
1975-77 Spanish I and II, Parkdale High School, Riverdale, Maryland
1976 Photography I, Parkdale High School, Riverdale, Maryland

EXPERIENCE

1944-1949 Lamond and Murray, Inverkeithing, Scotland - Apprentice Machinist and Toolmaker
1949-1950 British Aluminium Company, Burntisland, Scotland - Machinist
1950-1954 Royal Naval Aircraft Repair Yard, Fife, Scotland - Machinist
1954-1959 A.M. Carmichael, Building and Civil Engineering, Edinburgh, Scotland - Site Technician
1959-1961 Beckman Instruments Ltd., Glenrothes, Scotland, a subsidiary of Beckman Instruments, Inc., Fullerton, California - Machine Shop and Tool Room Supervisor
1961-1963 Costain (West Africa) Ltd., Lagos, Nigeria, West Africa - Plant Engineer
1963-1964 General Electric Company, Peterborough, Ontario, Canada - Tool and Die Maker
1964-1965 Thermalink, Laurel, Maryland - Tool and Die Maker
1965- Civil Engineering Department, University of Maryland - Research Associate

MILITARY SERVICE

1946-1948 Royal Air Force - Flight Mechanic

CORRESPONDENCE COURSE

1970-1972 National Technical Schools - Electronics

SEMINARS ATTENDED

1960 3-day Machine Tool, London, England
1961 1 week Carbide Tool Applications, Coventry, England
1961 Transportation (heavy equipment) Foden Motor Works, Staffordshire, England