PD-AAJ-187
ISN:146

650002500680 1

FINAL REPO

Harvard University

Harvard Institute for International Development
Rural Development Studies

REPORT ON THE

TRAINING PROGRAM IN ABYEI

William J. Donovan

30 September, 1981

Integrated Rural Development Project
Abyei, South Kordofan, Sudan

copy to USAID 1/7/82

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This project report has been prepared for the U.S. Agency for International Development under AID Grant No. Afr-G-1344, and for the Government of the Democratic Republic of the Sudan.

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PREFACE

The early exploratory papers by Harvard teams on brief visits to Abyei suggested a number of possible responses to the manpower needs of the area. Gordon and Joseph (April, 1976) stressed that a project in Abyei should take the form of a development center, one of the main activities of which would be to provide practical training and support for local development projects. If roads were being built, wells drilled, or fields tractorized, the center would train local people in the appropriate skills for construction, supervision, and maintenance. The emphasis was that training should support development activities by creating the trained manpower locally. The present final report by Mr. Donovan on the training program shows how this principle of local practical training in direct support of development activities remained one of the central and most successful activities of the Abyei Development Project.

The second Harvard team (Cole, Cash, Huntington and Villaume, February, 1977) included an education specialist (Villaume) who was able to demonstrate better the scope of Abyei's manpower problems. In particular, he examined the school system and drew up detailed estimates of what it would take in terms of personnel and facilities to bring it up gradually to the average standards of even a poor country such as Sudan. Villaume recommended as well a number of practical training programs both within the established school system and as separate programs run by the development center.

Villaume prepared a comprehensive study of Abyei's manpower needs and he drew up a five point program toward gradually meeting those needs.

(a) expansion of primary schools such that 20% of school aged children would be enrolled at the end of 10 years

(b) upgrading school facilities

(c) providing general secondary education in Abyei

(d) providing practical skill training at the primary level so that sixth form school-leavers who do not continue to secondary school will have acquired basic life and production skills. This was to be done through work-learning units jointly arranged between the school masters and the development center.

(e) a program in adult learning focused on practical skills. Literacy would be taught to groups of adults who requested it.

Villaume warned that such a program would be a "minimum possible" approach to expanding learning facilities in the area. Lesser programs may train people, but they will not develop the necessary human capital to have a measurable impact on self-sustained local development. Obviously, such a 10 year blueprint was not intended to be a program carried out by Harvard, but rather it was a map of the task to be addressed through a comprehensive cooperation of the Ministry of Education, national universities, donor-funded national training centers, and local efforts.

Under a small "Accelerated Impact Program" grant from USAID, Harvard continued throughout 1977 to explore ways of mobilizing facilities and programs for training and education for the people of the Abyei area. On the formal side of this work, Harvard had repeated discussions with officials of the Ministry of Education about the problems and possible help for the Abyei school system. As these discussions continued it became clear that the Ministry was unwilling and in many ways quite

unable to do very much about the situation. One problem they stressed was that they simply were unable to persuade teachers, Dinka or Arab, to accept assignment under the primitive conditions of Abyei. Harvard was not equipped (nor would it be appropriate) to take over a part of the Sudanese national school system with its Arabic language curriculum. However, it was agreed that Harvard could perhaps negotiate a small grant for up-grading the school facilities and especially the teachers' quarters in hopes of making the assignment a bit more attractive to teachers.

The first training person with the Harvard project, Steve Gulick, arranged for a small self-help grant to the people of Abyei from the European Development Fund. Working with school officials and local people, Gulick drew up the proposal for constructing two schools and teacher housing for two outlying communities. In other ways, Gulick worked closely with the established schools on garden programs and other activities. However, by mid-1978 there was hardly any school program with which to work. For the three years the Harvard Project was in Abyei, the schools functioned for a total of only six months. The actual situation was far worse than the depressing report originally written by Villaume.

During this period, work went ahead regarding the non-formal technical training to be run by a local Abyei Development Center. In the project paper of October, 1977, Harvard agreed:

(a) to experiment with different non-formal educational approaches so as to identify those most effective both in training residents for economic activities and in equipping them with new basic life skills;

(b) to train local residents in the skills required for income producing activities.

In December, 1978, the Sudanese/American project team further specified that this training should be in the areas of woodworking and metal-working. Also, there should be a vehicle maintenance facility organized with training on an apprenticeship basis.

Donovan took over as training advisor in November of 1979 and remained in Abyei until April of 1981 when the project was terminated. He brought to the program three professional principles that were largely responsible for the subsequent success. One was that the development center and workshop must be a place for experimentation and problem-solving rather than just a training program in routine carpentry and welding skills. Part of the rationale behind this principle is that areas like Abyei have no capacity to support large numbers of individuals trained in any particular skill. Related to this is Donovan's conviction that the workshop must be a service center for development activities and for the community. People would go to the shop with a technical problem and the staff and apprentices would try to design some machine or tool which would meet the need. Often they suceeded, but sometimes they failed, leaving some odd wood and metal monuments to their creative trial and error. The third professional principle of Donovan was that everything must be done to the finest standards. This principle sometimes caused conflicts, but it soon became the basis of pride in workmanship among those involved in the workshop and apprenticeship program. Things had been done wrongly and incompletely and sloppily for so long in this region that the idea of doing everything right was almost revolutionary.

When I was in Abyei in May, 1978, trying to help arrange for some minimal living and working facilities for the just-arriving project team, it took weeks of constant negotiation and sheer bribery to get a carpenter to make three small doorframes and six tiny windows for the circular mud huts. And these were badly made. Two years later, when I was arranging for a similar hut to be built for our anthropological research out in a small village, I simply sent a message to the workshop and the next time a tractor came out that way one of the Dinka carpenters was on it. He took measurements and went back to the workshop. He returned several days later and installed the windows, doors, screens, shutters, latches, etc. This may seem like a simple matter, and it was. But one of the symptoms of underdevelopment is that simple matters are a great wrangle and are eventually not done or are done badly or are done at great cost of time or wasted political leverage.

When the construction first began in earnest in early 1979, the expatriate construction advisor had to supervise the laying of almost every brick. If he turned away for 15 minutes something would have to be done over. In 1980, teams from the workshop worked totally independently, carrying out repair projects on the hospital and other civic structures in response to requests from the community.

The workshop was always like a four ring circus with various activities going on in each section. Donovan was always there, but not to look over anyone's shoulder. A carpenter might come to him with some question or problem. They would discuss it and perhaps call over one of the other fellows for his opinion. And so it would go as the shop welded an axle for the army, invented a new water carrying cart for a group farm, built benches for the hospital waiting room, repaired

the pump engine for an irrigated field, etc. There were people at all levels of proficiency learning more from each other and from the general mood of the place than from any direct teaching programs from Donovan.

Of course, there were problems and mistakes and insufficiencies, all of which Donovan documents carefully in the following report. However, those who visited the workshop of the development center, whether they were Dinka farmers, Arab military officers, or an American anthropologist; and those who worked and trained there always got the feeling that whatever "development" might mean, it is something like that workshop.

Richard Huntington

TRAINING

There were plans from the beginning of the project to include some form of vocational training. Primarily it was conceptualized as a non-formal education approach with the programs that were planned being those which seemed most necessary and practical. Some programs were designed to lead to improved community services and others to better jobs. The training type activities were to be centered around woodworking, welding, blacksmithing, vehicle maintenance, brickmaking, well pump maintenance, and building construction. In addition, training and skill transfer activities would be performed under other project components, including the training of medical staff for dresser stations, training of local residents in practical life skills (health and nutrition), and field training in agricultural operations, machine operation and animal husbandry.

Training Methods

The method of training used by the project was that of on the job training (or apprentice, if you like). This became the accepted method in the beginning of the project as it was a natural concomitant to all of the project's construction activities. The project was not using outside contractors to build the buildings but rather people from the local community. As a result, virtually all the people the project was taking on for the construction program had to be trained, as there were few to none who had skills in the type of construction methods the project was undertaking.

As the project began to grow, so did the need for training more apprentices in a variety of areas. With the addition of vehicles, mechanics, drivers and assistant drivers had to be trained; storekeepers to handle all the incoming supplies and materials; carpenters to build doors and windows, tables, and of course put on the roof structures; metal workers and welders to handle all the necessary steel work that goes into buildings; brick makers to manufacture bricks and masons to lay them. All of these individuals had to be trained, for the Abyei area simply did not have the skilled manpower the project needed, and

it was very difficult to attract skilled workers from other parts of the country to come and live in Abyei on a year round basis.

Selection of individuals to be trained in a certain area was often based on their desire to learn that particular trade. If there was an apprenticeship opening (the project had finite limits as to how many could be in a particular program), the individual was taken on and worked with a skilled craftsman for four weeks. After that amount of time, the individual was evaluated by those he worked with and either was kept on as an apprentice or rejected due to the lack of talents needed for the particular trade. Many times, individuals would arrive at the project stating they had previous experience or a certificate of training in a particular field. Even these individuals had to undergo the four week evaluation process, and more often than not would have to go through an apprentice program to undergo skill enhancement. Over a five month period in the workshop complex alone, the apprentice program went from three carpenters and one mechanic to 24 individuals learning skills in the fields of mechanics, metalworking, woodworking, blacksmithing, welding, painting, and specialized masonry work. In all but a few cases (storekeeper was one), there was no minimum requirement such as schooling for becoming an apprentice.

As is the case sometimes in this type of apprentice training, there is no particular format used in presenting new concepts. Basically, if new concepts were being introduced by the training specialist or other project staff who may have particular skills in that area, it was a one-on-one learning situation with the apprentice. New concepts were introduced usually when a particular situation arose and not in a planned weekly presentation. Examples of this are: Demonstration on how to install new brake shoes on a vehicle was done only when a vehicle needed new brake shoes; roof truss fabrication was taught only when a new building needed a roof structure built; installing window and door casings when a structure required it. As very few of the apprentices could read or write in Arabic or English, there was no way of introducing books into the learning process. Therefore, all skills acquired by the apprentice were done by direct observation and hands-on experience. As a result of this type of instruction, "saturation points" would be reached rather quickly in a new apprentice and therefore new concepts had to be spaced

out to insure learning. Therefore, training programs of this type require that the apprentice be involved with the program three years or more before they could acquire journeyman status.

The project attempted to cross-train individuals in more than one skill, such as carpentry and masonry. There was a bit of opposition by many of the workers, though, towards this type of training. It appeared that their sole goal was to be proficient only in their chosen trade. However, there were certain individuals who were receptive to this "jack of all trades" type of training. One example of how cross training worked is this. One of the project's ox drivers requested another ox cart to be made. It was decided that this ox-driver would benefit greatly if he were involved in the whole process of manufacturing a cart. He provided all the necessary dimensions such as height, width, length that the cart and tongue should be to fit the oxen; cut all the steel parts out for the undercarriage, assisted the welder in the welding, made his own steel bolts, forged steel harnessing hooks, shaped the teak tongue to fit the steel undercarriage and assembled the wooden carrying platform. With that complete, he went on to assist in building a 220 gallon water-carrying ox cart built from 55 gallon fuel drums mounted on a steel undercarriage. Working on this cart, this same man picked up additional skills of pipe cutting, threading and assembly.

As stated, many of the apprentices and journeymen were unable to read or write. There were some, though, who could read both English and Arabic script. Those who coud read English were taught how to use service manuals (the project had no service manuals written in Arabic) when repairing and maintaining equipment. As every vehicle, generator, pump, piece of agricultural equipment, and machine had a service manual and parts list catalog, it became very important that at least one of the mechanics could read and comprehend these publications. After over one year of instruction, the project succeeded in training one mechanic who could go to a parts catalog, look up a particular part, obtain its serial number and identification code, and correctly re-order that new part. This was a major achievement for this individual, as English is a foreign language which used a foreign script.

One technique used in training apprentices which worked very well was a method by which one apprentice would teach another apprentice a

new skill. This pass-along, sharing method freed up time for the training specialist and the other craftsmen so that repetitive demonstrations were avoided for each new apprentice. It worked this way: if, for example, bolts had to be made, a metal worker with previous experience in threading bolts would be asked to demonstrate to the new apprentice how to go about it. This method insured that individuals were understanding the concepts, for if the apprentice assigned to demonstrate a technique was unable to do it correctly, it was an indication that he needed further training.

After the workshop complex was completed and with more workers having acquired more skills, a new approach to training was introduced. This approach involved the concept of problem solving. An idea or problem was presented to the workers and it was up to them to come up with the solutions to the problem. As example: the metalworkers were asked to devise a dolly or cart that would be capable of slipping under a full 55 gallon drum of fuel. The dolly or cart also had to be capable of travelling over rough terrain and be able to be handled by one individual. The metalworkers acting on their own came up with such a device that easily fulfilled the requirements requested. This concept was applied quite often in many different areas with a fair amount of success. The advantages of this approach are that it provides an outlet for creativity, develops a thought process which is very valuable, expands and sharpens skills, promotes group cooperation when coordinating a variety of different skill trades, and provides a product that has a value of which the individuals can be proud.

Training Accomplishments

For the different skilled trades, the question arises as to how much an apprentice really learned and what were his qualifications as a result of being trained by the project. To answer this question, it is necessary that two points be stated: First, virtually all the individuals who came to work for the project had no previous experience and therefore any skills acquired were done through apprentice training. Second, although there was training begun as early as mid 1978, the major thrust in the program (i.e., more trainees in a variety of areas)

occurred in 1980 as a result of new tools and equipment, facilities and field staff personnel being added. Therefore, the majority of the apprentices have received approximately a year and a half of work experience in what should be a three year program. A summary of skills that were introduced to the apprentices and workers in the different skilled trades areas is as follows:

SKILLS TAUGHT

Carpenters:	Joinery, cabinet and furniture construction methods; door and window fabrication and installation; roof truss building, concrete forming, zinc roofing and assorted other building construction techniques.
Metal Working:	Electric and gas welding; torch cutting; grinding and drill press techniques; installing re-bar for concrete pours; taping and thread cutting; blacksmithing; sheet metal work; layout and cutting of steel; tool use; and other metal work techniques used in fabricating steel items.
Mechanics:	Routine maintenance techniques for gas and diesel engines; tire and tube repair; brake servicing and repair; installing bearings and oil seals; motorcycle maintenance; tune-up procedures for land rovers and tractors; tool use; cylinder honing; and other automotive techniques.
Drivers:	Operation and daily servicing of landrovers, tractors and medium duty diesel trucks.
Construction:	Building layout techniques and transit use; mixing and pouring cement floors and footings; mixing mortar and laying bricks; building foundations; use of leveling and measuring devices; installing window and door casings; pouring cement lintels and ring beams; cement plastering; and other general construction techniques.
Brickmaking:	Setting up a brick site; clay selection and preparation; mixing, moulding and drying techniques; kiln building and firing.
Water Well workers:	Techniques in hand operated drilling methods; welding p.v.c. pipe; pipe cutting and threading; installation procedures for MARK II, Robbins Myers, and I.D.R.C. hand pumps.
Storekeeper:	Record keeping and inventory control.
Painters:	Priming, mixing, and painting techniques for wood and metal.

Numbers Trained

SKILL AREA	PERSONNEL
Carpentry:	3 - Journeymen 5 - Apprentices
Metal Working:	1 - Welder (Journeyman) 1 - Welder (Apprentice) 2 - Blacksmith (Apprentices) 5 - Metal workers (Apprentices)
Vehicle Maintenance:	1 - Mechanic (Journeyman) 3 - Mechanics (Apprentices)
Transport:	4 - Tractor Drivers 3 - Land Rover Drivers 2 - Heavy Diesel Truck Drivers 6 - Assistant Drivers (Apprentices)
Construction:	1 - General Foreman (Journeyman) 4 - Masons (Journeymen) 5 - Masons (Apprentices) 16 - General Construction workers (Apprentices)
Brickmaking:	4 - Moulders 9 - Runners 4 - Kiln Builders 15 - General Laborers (stackers, firefeeders and transport personnel)
Water Wells	1 - Driller (Apprentice)
Hand Pump Installation:	5 - Drilling Assistants (Apprentice)
Storekeeper:	2 - Storekeepers (Apprentice)
Painters:	2 - Painters (Apprentice)

* Note: Training occurred in other areas of the project. Refer to health and agriculture reports for further listings of trainees.

Uses of the Training

One problem that arises with any training program is what happens to the trainees after they've finished the program? Will there be jobs for them in their particular field? Can the local community absorb all the graduates? The workers who have been trained by the project will face many problems if they decide to work in the Abyei community. If one just looks at the amount of government buildings (hospital, schools, rural council offices, police facilities, etc.) that are in need of maintenance and repair in Abyei, there appears to be enough work to keep quite a number of masons, carpenters, metalworkers and others busy for years to come. The project has trained all sorts of individuals who could work for the different government agencies. But the reality is, these agencies simply do not have the money for salaries and for purchasing the necessary materials and supplies needed to carry out the repairs. Workers who may attempt to establish themselves in the private sector of Abyei face the difficulty of obtaining raw materials, tools and spare parts. Not only is it difficult to obtain materials but the capital investment of starting up a welding shop, carpenters shop or vehicle repair shop can be prohibitive. In addition, the reality may be that the local economy can't support their trade, regardless of the need. Coupled with that is the fact that the roads to Abyei are closed almost six months of the year due to the rains. Unfortunately, as a result of these problems, many skilled workers are forced to leave the community in search of work elsewhere (Wau, Juba, Muglad, Khartoum, etc.)

Attempting to alleviate somewhat the problems of lack of tools, facilities and materials that often prevent needed repairs being done in the community, the project set up a system whereby any apprentice or journeyman working for the project could borrow tools or use the project's workshop facilities any time after working hours. As a result of this system, the borrowing of tools became a daily occurrence (carpenter's tools were the most borrowed items). Many of the project's workers were hiring themselves out, doing odd jobs in the community. When certain facilities and project materials were used (i.e., welding equipment, vehicle spare parts, steel, timber, etc.), a special fee was charged to cover the costs incurred by the project. (Fee charges are listed in the report on support services.) A special arrrangement was

made whereby the supervisor of the workshop would estimate the cost of the service (i.e., welding a bed frame together) and add to that the salary of the worker doing the service. This total cost estimate was presented to the "customer", who then would have to pay the project in advance before services would be rendered. When the worker had finished the work, he would receive his salary due from the project. In this manner, the project was reaching out into the community by sharing its trained workers, facilities and materials which aren't available in Abyei.

To evaluate this program of training and compare its success to another type is difficult. There is no logframe matrix with goals and verifiable indicators, nor is there even a curriculum guide to evaluate success. How then does one determine if this type of apprentice training is valid? Was anything accomplished? Was the training program a distinct project output? The only real way of answering these questions is by going to Abyei and seeing first hand the results of the training program and remembering that the goal of this program was to design programs which seemed most necessary and practical and would lead to improved community services and better jobs. There are then verifiable indicators that this program was a success: The 16 newly constructed buildings built from bricks manufactured by the project and set in place by apprentice masons; the tables, chairs, desks, bookshelves, doors and windows in these structures built by apprentices; the 12 different types of vehicles and engines kept operable under harsh conditions by apprentice mechanics and drivers; ox carts, cement storage jars, fuel tanks, trailers, water storage tanks, hospital and school furnishings, seed dressers, agricultural tools, and much more, manufactured by apprentices who only two years ago did not possess the skills they now have. What would be difficult to see, but yet was the most successful aspect of the program, was the confidence that was being instilled in each apprentice, a confidence that he had the potential to solve through his skills the many problems that afflict the community.

Recommendations

If the Abyei Development Project were to be continued and funded for more years, a training program should be included as one of the project's activities. What follows are recommendations as to the possible directions this particular program could take.

- The training program should continue to be a natural concomitant of the overall project's activities. No matter what direction the project takes, there will be a need for some sort of support services activity. If vehicles are used within the project, there is the need to maintain them and mechanics could be trained to do this. If community out-reach programs in the form of building dresser stations, schools or grain storage facilities are initiated, there will be a need for masons, carpenters, and metalworkers, all of whom can be trained.

- If the training program inititated by H.I.I.D. were to be continued and expanded, there would be a need for a training specialist(s) to oversee apprentice programs in the areas of carpentry, cabinet making, metal working, welding, blacksmithing, mechanics, masonry, driver training, and building construction. The training specialist(s) should have proven abilities in the above areas obtained through teaching in a vocational school (three years or more) or having six or more years work experience.

- A support salary should be paid to all apprentices and those involved in short term training programs. If an attempt is made to establish a program where students or apprentices are not given support salaries, this will discourage their participation. For, if this were the case, not only would the individual be expending money while attending these programs, but he would not be able to provide support for his family at home. As a result, many individuals could not afford to attend this type of training program.

- Short term training (five days or less). Using the fine facilities of the workshop complex and the new skills of many of the apprentices, items could be created and tested out and then shown to the community. As example: a charcoal cooker could be designed and made from locally available materials. Community members who desire such an item could be brought into the workshops and taught how to make the item. The outcome of this type of concept would be the ability to reach more individuals, promote self-help and teach new skills.

- Meaningful work experience for the apprentices should be provided. One way might be to coordinate with the local government agencies so that the project could act as a contractor, using its apprentices to repair or construct new buildings, repair vehicles, and construct items for these agencies.

- Develop a program whereby every apprentice would have the opportunity of obtaining free or at a low cost a set of tools for his particular trade. Funding for this program could be accomplished by selling articles (beds, chairs, stoves, etc.) made by the apprentices or charging for services rendered by them to the local community.

- There should be an attempt to identify some method of assisting those trained workers who may desire some day to establish workshops or other independent businesses in Abyei. Problems to overcome would be loans for acquisition of tools, equipment, raw materials and facilities, and establishing reliable supply routes and markets for the particular goods and services. A small-business advisor would be required to oversee such a program.

- Establish adult education classes for the apprentices. Some courses that should be taught are: reading and writing in Arabic and very basic English, mathematics (shop and business), and simple technical drawing methods. These courses could also be open to anyone from the local community.

- The blacksmith training program should be expanded so that more apprentices could be taken in on short and long term training. The program should focus on teaching how to make blacksmith tools and forges and how to make and temper agricultural tools.

SUPPORT SERVICES

With the project implementing activities in agriculture, construction, training, water supply, health, field studies and a communication program, it became obvious that in order to insure these activities would be successful there was a need to establish a workable support services program. With the purchase of vehicles, supplies and equipment to implement these new activities, it became apparent that certain issues would have to be confronted and dealt with before any of these programs could operate smoothly. There would be a need for a workshop to service all vehicles to keep them operating properly and for assembling much of the equipment that was arriving. Storage areas were needed to receive all the incoming supplies of spare parts, equipment and fuel. Trained workers, tools and raw materials were required to fabricate on site items that were needed by the various programs.

Endeavoring to implement the various new programs and at the same time attempting to establish support services for them caused a number of problems and a lot of hard feelings among the staff in the early stages of the project. As an example, the building of the support services infrastructure (warehouse and workshop) required extensive use of vehicles to move workers and construction material. These very same vehicles were required by the water, health, livestock and other programs to do their work. Programs were requesting items to be built, but the craftsmen who were capable of building them were involved in building the workshops, warehouse and fuel stores. There was a period when developing these services actually hindered the various programs' output, but in the longer run, the support services were essential to the successful operation of those programs.

It took about two years to establish the project's support services of infrastructure, tools and equipment, radio networks, logistics, procurement and supply procedures. Although that may seem like a long time, one must consider the remoteness of the area and the reality that roads in and out of and within Abyei are closed five to six months of the year.

Support Services Infrastructure:

Workshop Complex

The workshop was designed by the HIID field staff to meet certain criteria:

(1) maintenance of vehicles, machines, and equipment
(2) fabrication of items to support project programs
(3) providing a center for training carpentry, metalworking, vehicle maintenance, blacksmithing and welding
(4) allowing easy supervision of all work areas by the training advisor

This building, 35.7 meters (117') long by 9 meters (29.5'), was designed to house the following work areas: vehicle maintenance, metalworking, welding, blacksmithing and woodworking. The walls of the workshop were knee walls of one meter height. The zinc gable type roof was supported by a series of three inch steel poles set in concrete. This low walled structure insured adequate ventilation and lighting and provided a very cool work center during the hot dry season. The east gabled end was enclosed to prevent blowing rains from entering the shop. The use of two walled areas, separating the woodworking and metalworking shops, was designed for fire protection, noise reduction and eye protection from the electric arc welding area. Two tool rooms with steel doors were used to house the various tools and equipment securely. Each tool room has large steel tool panels to hang the tools from. These panels provide easy access and a fast, reliable means of taking visual inventory daily. The entire structure was outfitted with fluorescent lights and electrical outlets. Power was generated by a 5kva generator located in a brick generator house 30 meters from the workshop. The three phase 240 volt wiring system ran under ground (inside 3/4" PVC pipe) from the generator house into one of the tool rooms where it was broken down into fused circuits. The vehicle maintenance area is large enough to handle two DAF diesel trucks at the same time. Each area of the workshop is outfitted with a special work table to suit its needs. The woodwork shop has three large work benches, each mounted with two heavy duty wood vises. The metalwork shop has two heavy duty steel frame work benches outfitted with machinist's and pipe vises; an electric arc and gas welding bench; a bench for mounting the guillotine (bench shear); and a bench for mounting

a grinder and small drill press. The mechanics section has two large steel benches for engine repair. All of the tool panels, benches and steel doors were manufactured in the project workshop. (Refer to pages 59 a&b for drawings of this building.)

Warehouse

The warehouse is a 28.12 meter (92.25') long by 9.5 meter (31.2') wide structure which is divided into two separate parts. The main part is a brick structure (13.12 meters long) with steel door and window shutters and is used to house inventory records, parts and service manuals, vehicle and equipment spare parts, medi·ines, hardware, veterinary supplies, tools, and other smaller miscellaneous items. The remaining part is a pole building structure which used three inch steel pipe for the poles and corrugated zinc roofing sheets for the walls. There are two 3.6 meter wide steel double door openings which allow pipe, timber, structural steel, cement, agricultural equipment and other large items to be brought in and stored inside. Inside the main structure are four shelves four meters long by two meters high by one meter wide built from angle iron and timber. These are used to store all the small items. All along the walls, special hooks have been mounted into the brick from which rope, cables and winches are hung. Special mortared brick bins of 50 x 50 x 25 centimeters were constructed along one wall to hold all the different nails required. A large service counter was built at the main entrance to keep unauthorized individuals from roaming about inside the warehouse. All shelving, steel doors and window shutters, storage cabinets and the service counter were manufactured in the project's workshop. (Refer to pages 59 a&b for drawings of this building.)

Fuel Store

The fuel store is a 15.8 meter (52') long by 3.96 meter (13') wide shed roof structure used to house all fuels (diesel, gasoline, kerosene, jet A-1 and aviation gas), greases, transmission and hydraulic oils. The structure was built as an angle iron frame, sheathed with corrugated zinc roofing sheets on the walls and roof and a floor of local limestone "gravel". The building is partitioned off into two parts: one part for diesel storage, and the other for the remaining fuels and oils.

Two fuel tanks were constructed in the project workshop and are housed in the fuel store. One tank is for gasoline and has a storage capacity of 2,668 liters (704.89 U.S. gallons). The other tank is for diesel fuel and has a storage capacity of 3,617 liters (955.6 U.S. gallons). Both tanks have two two-inch fittings, one for screwing in a fuel pump, the other for filling the tank. Each tank is outfitted with an air vent and a 3/4 inch drain plug. The tanks were placed on a sloping platform to provide easy drainage and sediment control. In addition to these fuel tanks, a rubber bladder having a capacity of 2,100 liters (554.82 U.S. gallons) is used to store diesel fuel. Additional space is available inside the building for the storage of 34 210-liter (55 U.S. gallons) drums of other fuels, oils and greases. The project's workshop manufactured special drum handling cradles. These drum cradles can be slipped up to a standing drum and allow it to be smoothly tipped over from a vertical to a horizontal position. The drum rests on this drum cradle at a height that allows a jerry can to be filled under its spout. A drum of each different type of fuel or oil was placed in one of these cradles. This allowed the storekeeper to dispense oils and fuel from the drums through a 3/4 inch bronze locking-lever faucet without the risk of contamination or inhalation presented by the use of a siphon.

On Site Fabrication:

One area in which the support service program was very successful was that of "on site" fabrication of equipment and items required by the various program areas. Due to the difficulty of locating specialized items in Khartoum, the project was able to fabricate many items within its own workshop. In order for this type of approach to be successful, the project had to keep on hand a large variety of raw materials (timber, steel, cloth, fasteners, etc.). The warehouse had been designed to handle this diverse inventory and the workshops had been designed a bit larger for handling and assembling over-sized items and had been stocked with special tools and equipment to facilitate fabrication.

This approach allowed flexibility of design and specifications and allowed the project to become independent of some outside suppliers. One program that benefited greatly from this approach was the well program, which was able to have a "rolling design" approach when fabricating

necessary drilling equipment. In fact, a major portion of the well drilling equipment, bits and all, was manufactured in the project's workshops.

To give the reader an idea of what types of fabrication took place through the workshops, a partial list of the fabricated items is given below:

- Steel doors and window shutters
- Ox carts with steel undercarriages
- Water ox cart with 220 U.S. gallon capacity
- Two 2,965 liter (783 U.S. gallons) water storage tanks (steel) for mounting on trailers
- One 3,617 liter (955.6 U.S. gallon) diesel fuel storage tank
- Furniture (both steel and wood)--desks, tables, chairs, cupboards, beds, bookshelves, benches, shelves
- Land rover trailer
- Wood lathes
- Seed dressers
- Grain thresher

Radio Communication

The project established a radio communication link Abyei - Khartoum in May 1978, shortly after the first field team arrived in Abyei. Initially, the radio was operated on a limited basis on the Chevron frequencies, but after one year, the project was assigned its own frequencies and was then able to operate on a regular daily schedule. Over the years, a variety of antennas, power sources, frequencies, and transceivers were experimented with. Additionally, a network of mobile "C.B."-type radios were tested for short range field communications in Abyei.

Communicating via radio Abyei - Khartoum was done six days a week for one hour a day (7:30 AM to 8:30 AM). This radio time was used to pass on supply orders, messages and basically to give a daily update of what was occurring in the field and in Khartoum. The Abyei project radio also served as a relay station between AID in Khartoum and their Juba office. The AID radio system, even after considerable expenditure on radio equipment and technicians, was incapable of transmitting directly from Khartoum to Juba or match the quality of performance of our project radio system.

Transceivers: The project used two types of radios for long range communication. One type was a TWC 10S manufactured by Trans World Communications (1080 W. Washington Avenue, Escondido, California, 92025). The other was a Collins KWM - 2A. The project originally purchased two TWCs and used them on the Chevron frequencies. Then we borrowed Collins sets which had the UN frequencies, so we stopped using Chevron's. When we finally got our own frequencies, we installed appropriate crystals in both the TWCs and the Collins and used the Collins as back-up to the TWCs.

Although the Collins radio is world renowned for its reliability and fine quality operation, the project encountered a number of difficulties when operating it. One major difficulty was that it was overly complex to operate and tune by individuals who had no previous radio experience. Reading and comprehending the radio manual was a chore for anyone who lacked a technical background. (HIID had sent an individual to set up the radio systems and he wrote a simplified version of the manual, but still this was frustrating to follow.) Another problem that was encountered with the Collins was that the antenna had to be matched quite accurately or the transmitter could be easily damaged. (One Collins was damaged this way.) Additionally, it consumes a good deal of power and therefore batteries had to be constantly recharged.

In comparison, the TWC 10S was simple to operate and maintain, had ample range, low power consumption, and had a number of accessories and options that were very useful. Its ease of operation and reliability brought praise from all who operated it. A general description of the unit is as follows:

- 4 or 6 channel single sideband transceiver
- Frequency range: 2-16 MHz
- Range: 1,500 kilometers (Dependent on terrain and antenna systems)
- Modes of operation: Simplex USB or LSB
- Power supply: AC/DC model - 115/230v, 50/60Hz or 13.6v DC neg. ground
- Power consumption: Receive 100-300 ma, Transmit 12 amps
- Power output: 150 Watts PEP
- Accessories and options: USB/LSB, semi duplex (2 frequency simplex), mobile mount, C.W. adapter, spare parts kit, telephone coupler, and automatic antenna tuner.

Frequencies: The project was licensed by the government of Sudan to operate on two different frequencies, 8.105 MHz and 4.893 MHz. The cost of this license for one year was £s 1,000. In addition, we had permission to use the following other frequencies if the need arose: Chevron Oil Co. network and Soil Conservation Department (Juba). With the 8.105 MHz frequency we were able to maintain contact Abyei - Khartoum from about 0630 hrs to 1800 hrs. The quality of reception was often quite good up to about 1100 hrs; from then on, the signal strength deteriorated to a fade-out at 1800 hrs. The 4.893 MHz frequency was meant to be used for night time communication. However, the project never succeeded in getting adequate reception out of it.

Power Sources: Both the radios in Khartoum and Abyei were operated off of 12-volt automobile batteries. Although the TWC 10S can be equipped to operated off of 115/230 volts AC, the project decided that, due to power outages in Khartoum and lack of generating equipment in Abyei, the 13.6v DC model would be used. The battery in Khartoum was kept charged by a battery charger located in the radio room. The battery in Abyei was kept constantly charged by a solar-power photovoltaic array. The solar panel, mounted on the antenna mast, was matched well to the needs of the radio, and was capable of keeping the battery fully charged. (Refer to the section on appropriate technology for further information on the panel.) The only difficulty with batteries as power sources was that they had to be maintained. The terminals had to be cleaned of corrosion often and the electrolyte level checked regularly. This was a simple task, yet one often forgotten by the radio operators. Additionally, it was discovered that a good quality battery with a high ampere-hour (90 ahr) was well worth the investment because a high storage capacity is a necessity for lengthy daily transmissions (when transmitting power consumption is quite high compared to receiving). As in Abyei, if a solar panel is used for charging, there must be ample storage capacity to bridge a number of days when cloud cover affects the generating capacity of the panel.

Antenna: There are a number of different antenna configurations that one can establish and the project experimented with a few of them. In Abyei, an inverted "V" dipole was used for all frequencies. This was chosen as there was a need to work mobiles (the airboat was equipped with a radio) and to work a number of stations sharing our frequency. A 3" x 40' galvanized steel mast hinged to a ground support base for

raising and lowering the mast was erected in Abyei. The mast was outfitted with a Citizen's Band multi-directional antenna mounted at its peak and at 35 feet above ground a special pulley arrangement for raising and lowering the 8.105 and 4.893 MHz antennas and coaxial cable. With this arrangement, Abyei was able to communicate with AID/Chevron/ADP Khartoum (650 miles), Chevron Muglad (125 miles), AID Wau (163 miles), AID Juba (700 miles), AID Rumbeck (300 miles) and Yambio (500 miles). The project's office in Khartoum had a similar antenna arrangement but was never tuned well because it required access to a neighbor's roof which was a sensitive issue. Because of the space limitations and poor antenna configuration, a special Automatic Antenna Tuner was ordered to overcome these problems. The tuner, however, arrived just as the project was being terminated and as a result no testing was done of this unit.

C.B. Radios: The field staff were involved in several projects widely spread out over the Abyei project area. It was thought that if mobile radios were put into operation, better coordination of vehicles and their movement could be accomplished, thereby saving valuable fuel. Four Citizen Band 40 channel, 4 watt units were tested in Abyei. The units proved to be of no use, as it was found that the maximum range obtainable was only about five miles. What the project required were units that had a range of 20 or 30 miles. The C.B.'s were used though for local short range communication much like an intercom system with radios located in the workshop, radio room and the project office.

Equipment and Tools Necessary for Establishing and Maintaining Radio Base Stations: The radio network for the Abyei Development Project was installed by Mark Patterson, an experienced radio operator and undergraduate student at Harvard. His foresight in having on hand a number of tools, equipment and supplies necessary for establishing and maintaining radio stations was appreciated by those who had to maintain the equipment after he left. Over the years, additional supplies were added. With two years experience operating and maintaining radios under harsh field conditions, it is felt that the project can recommend a valuable list of supplies for installing and maintaining base stations in the field. Such a list follows. Please note that this list is for an individual base station and therefore the list should be duplicated for each station site.

Radio equipment:

Transceiver - TWC 10S 13.6v D.C. model

Extra microphone

Spare power cord

Spare crystal for each frequency

Spare coaxial connectors (2) for radio

Installation and service manual for radio

Spare transistors and basic spare parts kit for transceiver

C.W. key and modulator

Heavy duty (90 amp-hr) battery—12 volt

Solar panel model G-3672 from Solar Power Corporation

Antenna Supplies:

400 feet 50 ohm coaxial cable RG8/AU (amount required will depend on need, but have enough to replace cable if damaged)

500 feet of copper wire (for antenna wire)

Insulators (6) for each antenna frequency

Antenna mast (2 and 3 inch diameter pipe makes a good mast; 40 feet high or more is ideal)

Guy wires - steel 3/8ths inch (length to be determined)

Turnbuckles (for guy wires for mast)

Copper plated grounding stakes with heavy duty conductor cable

Mobile whip antenna with mount

Portable roll out antenna

Nylon rope and pulley (for raising and lowering antennas)

Maintenance tools and equipment:

Power and SWR meter (additional coaxial connectors (2) will be required to connect this in line with the antenna signal)

Multimeter (VOM)

12 volt soldering iron

Medium size soldering copper

50' of solder core

Set of jewelers screwdrivers

Color TV alignment tool kit

Set of color coded alligator clip leads

"Exacto" knife

60' roll electrician tape
Small alligator clips
Needle nose pliers
Wire clippers
Slotted and Philips screw driver
Heat sink
Tape measure (for measuring antenna lengths)
Battery terminal cleaning tool
Battery hydrometer--temperature compensated
Battery charger
Battery terminal clamps (3 pairs)
Solderless terminal master kit (assorted sizes)
Wire stripper
Allen wrench set
Distilled water
Sulphuric acid

Ordering and Purchasing Supplies and Equipment

The project has developed a system for obtaining and maintaining supplies in the field which, although in some cases is not unique, was very successful. What follows is a summary of these procurement procedures and some recommendations that other remote area projects may find useful.

Due to the fact that roads were closed six months of the year during the rainy season, it was necessary that each program coordinator plan six months in advance and submit to the project co-directors a program outline and a list of supplies and materials that would be required. From these lists, a master list was drawn up to which an additional list of support supplies was added. Support supplies are those materials which are required to maintain a particular item that may have been ordered for a program. For example: the health program orders bicycles for its personnel. It becomes necessary, then, to ascertain what types of spare parts will be required to maintain these bicycles over a one year period and order those parts in advance. When vehicles and engines (pumps, generators) are required, it is necessary to estimate and have on hand adequate supplies of fuel, spare parts, filters, lubricating oils, etc. To operate any mechanized agricultural program, there has to be

on hand the necessary tools, hardware and raw materials to repair and fabricate new parts for equipment.

- For every piece of equipment and machine ordered, a service manual and a parts catalog was obtained. From the service manual it was easy to identify special tools and spare parts that would be mandatory to have on hand to maintain a particular item.

- Each individual item ordered by the field staff was assigned an order number. The request was put on a special form which included the order number, a description (usually that given in the parts catalogue), size, unit (how it was to be purchased--i.e., by the kilo, gross, cubic feet, liters, etc.), quantity required, serial numbers (if applicable), section (the particular program requiring it--i.e., health, agriculture, etc.), date ordered, date received (at the field site), quantity received, and comments (this might be where to purchase the item, acceptable alternatives, etc.). Some of these orders were relayed over the radio if the purchase was required immediately. But in all cases, a copy of the order was sent (via mail) to the Khartoum office, one copy kept in the Abyei radio room and one copy in the project's warehouse. Due to the delay between ordering and receiving the goods (3 months or more), this form provided an excellent means of keeping track of goods. It assisted the storekeeper in identifying and shelving correctly the large variety of goods that were constantly arriving. In addition, the storekeeper, based on the facts on the form, was able to inform program coordinators of the arrival of goods and whether or not the correct size and quantity was obtained. (A sample order form is found on page 31).

- If possible, all goods purchased in Khartoum for shipment to Abyei were packaged into wooden crates. These crates were available in a wide variety of sizes and shapes for a minimum cost from many Khartoum merchants. For each item sent, there was an attempt to label the item (by tag or by writing on it in felt pen) with its order number. Failure to do this often resulted in frustration for the storekeeper and others whose job it was to identify, up-date inventory cards, and shelve the goods that arrived. (Attempting to

identify vehicle parts can be difficult as is, but then when you have to identify the type of vehicle--motorcycle, diesel truck, landrover, etc.--that's frustrating.)

- A catalog system was established whereby identical reference volumes of major suppliers (Granger, Langley, McMaster & Carr, Broadhead-Garrett) were kept in Abyei, Khartoum, Harvard (HIID), and London (Lifeline). These reference catalogs were used to provide specifications for those who were purchasing items. Thereby, if the purchasing agent has no idea what a particular item looks like, he/she could be directed by the field staff to refer to a particular catalog on page such-and-such to find a picture and a description of the desired item. This helped, as often a certain item may be named differently in Sudan than in the U.S. Often in Khartoum the catalog would be taken to various merchants and the picture of the item shown to them. This insured that the merchant understood exactly what the item was that was desired.

- There was radio communication six days a week for one hour each day between Abyei and Khartoum. During this time, purchase orders were sent and updates on what was happening with previous orders obtained. If necessary, advice would be given by the field staff as to what to do when specific specifications for items were unattainable in Khartoum. This daily communication was invaluable.

- Every item in the project's warehouse had an intentory control card. These inventory cards contained the following information: description of the item, serial number (parts code number), use (for land rover, Massey Ferguson, Suzuki, Veterinary drugs, health drugs, etc.), ordering points (max.-min. goods would be reordered when the inventory level reached the same level as stated by the minimum ordering point and the amount ordered would be the amount stated in the maximum category), bin number (this stated where the item was stored in the warehouse). In addition, the card was divided into columns which had the following headings: date (date of transaction), number ordered (if goods had been ordered from Khartoum, the quantity ordered

would be listed here along with the order number), quantity received (number of new goods added to inventory), quantity out, and on hand (after every transaction, the quantity currently in stock). These card were invaluable not only for providing current information on stocking levels but with the min/max ordering points, which provided the storekeeper a simple means by which he knew when to report critically low stocking levels on certain items. The cards also provided a beneficial yearly record. By reviewing the cards and noting demands on certain items at different times of the year, they provided a reliable means of estimating how much to order in advance. (A sample of this type of card is found on page 30).

It was learned rather quickly in the beginning of the project the importance of selecting power tools wisely. The following policy was developed: all tools must be compatible for Sudan's power systems--220-240 volts AC at 50 cycles. If possible, tools should be purchased that are capable of operating off AC/DC power. (Our portable welder-generator provides only DC power; therefore, tools had to be able to operate off the welder and the workshop's AC generator.) Tools should be of the heavy industrial type of a reliable brand and not the home shop type. (Wolf Electric Tools Ltd., Black & Decker Ltd., and Stanley Power Tools Ltd. not only provide high quality tools, but their dealerships are located throughout the world.)

Recommendations for Ordering and Purchasing Supplies

The purchasing and ordering of supplies in Khartoum was not the responsibility of one person but rather was accomplished by a joint senior staff effort. This combined effort was often ineffective. Follow-ups on back orders were seldom done and sometimes, if the individual didn't understand what was being requested, he would just "shelve" it in hopes that someone else would come along and handle that order. What was needed for a project of this type was a full-time purchasing officer in Khartoum. This position would require a person who has been trained in technical matters and understands the terminology used in connection with tractors,

SAMPLE CARD:

WAREHOUSE INVENTORY CONTROL CARD - ABYEI PROJECT

PART NUMBER 6H-423-4578 DESCRIPTION OIL SEAL

USE FRONT HUB - LAND ROVER STOCKING LEVEL 8

BIN LOCATION LAND ROVER ORDER POINT 3

Date	Ordered	Rec'vd	Issued	On Hand	Date	Ordered	Rec'vd	Issued	On Hand
9/3/80	#246 8	—	—	0					
10/1/80	—	8	—	8					
10/4/80	—	—	2	6					
11/21/80	—	—	4	2					
11/23/80	#457 8	—	—	2					
12/4/80	—	—	2	0					
12/8/80	—	8	—	8					

Inventory control cards were printed on both sides of heavy duty card stock. The cards were printed on a variety of different colored card stock to aid in identifying quickly different areas such as tractor parts, well digging supplies, health goods, etc.

ORDER NO.	ITEM DESCRIPTION	SPECIFICATION	UNIT	QUAN	SECTION	DATE ORDER	DATE REC'VD	QUAN REC'VD	COMMENTS
325	BICYLE INNER TUBE	26"x1 3/8"	EACH	11	WORK-SHOP	23/1/81	4/3/81	11	
326	OIL FILTER - M.F. TRACTOR	341-5278-01	EACH	9	WORK-SHOP	23/1/81	—	—	NOT AVAILABLE IN KARATHURU
327	METRONIDAZOLE TABLETS	200 MG.	PACKAGE OF 10	70	HEALTH	24/1/81	18/2/81	70	TRADE NAME FLAGYL
328	TIMBER	2"x4"x4 METER	EACH	100	CONSTRUCTION	24/1/81			
329	SHIFT KNOB - L.R.	GS-141552	EACH	2	WORK-SHOP	26/1/81	4/3/81	2	
330	STEEL PIPE - WATER	GALVANISED 2"Ø x 6 METER	EACH	3	WATER WELLS	27/1/81			

ARYET DEVELOPMENT PROJECT - ORDER SHEET (SAMPLE)

building supplies, health medicines, herbicides, vehicle spare parts, hydraulic systems, tools, office supplies, drilling equipment, etc. This person must have sufficient skills to make independent decisions regarding the interchangeability of parts, equipment and other supplies.

At the end of the rainy season, there is a big demand to replace exhausted inventories. As the project had but a small room for warehousing goods in Khartoum, it was unable to store up goods through the rainy season. As a result, everything had to be purchased when the roads were opened, which caused delays. If there had been a larger warehouse, it would have been possible to purchase goods throughout the rainy season, thereby avoiding shipping delays when the roads opened.

Tools and Equipment

In other parts of this report there are numerous descriptions of some on-site fabrication done at the Abyei workshop. The ability to manufacture fuel and water storage tanks, maintain vehicles, build structures, and construct tables and chairs was the result of not only having skilled craftsmen but providing these individuals with the necessary tools and equipment for them to function at their best.

When setting up workshops, whether for training or for manufacturing, the job of equipping the workshop is often left to individuals who have very little knowledge of machine shop equipment and tools. To compound the problem, a low budget may be assigned to the purchasing of this equipment, thereby resulting in low quality, unsuitable tools--or more commonly, the failure to purchase the more specialized tools which make the job much easier and less frustrating for the worker.

What follows is an equipment guide that can be used in establishing a remote area workshop. The list is based primarily on the experience of Harvard field staff members who have worked all over the world. The list contains all the tools and equipment one would need to duplicate the types of fabrication and maintenance done through the A.D.P. workshop. The guide is broken down into different areas such as woodworking, welding, and masonry. There is no quantity given on the lists, as it is hoped that it will be used only as a guide and not as a definite inventory/purchase list. The tools recommended are suitable for any general purpose workshop. For establishing machine shop enterprises, one would have to

add more specialized tools.

Before purchasing any tools, the following points should be considered:

- Buy only quality tools of well known brands. Industrial type is the best. Stay away from the cheap quality "home shop" equipment as it simply can not stand up to the demands of daily field use.
- When buying tools and equipment, make sure that replacement parts are available within the country. If not, they should be purchased with the tool or equipment.
- If machines are purchased, obtain only the high quality industrial type and not the cheap model making type.
- Machines are expensive and sometimes are not economical unless used very often. The same work can often be done with hand tools.
- When ordering tools and equipment, it should be done by an individual who has experience in the use of these items and knows the particular needs of the workshops where they will be used.
- Check voltage, wattage, polarity and cycles of power tools before buying to insure that they are compatible with the local supply mains or the workshop generator. Some power tools are capable of operating off of AC or DC power and a variety of cycles (50 - 60). These are ideal to purchase, as some portable generators only put out DC power.

<u>Woodworking tools, equipment and supplies</u>:

- Woodworking bench vise, cast iron, 4" jaw size, 12" jaw opening
- Rip saws, 26" - 5½ point
- Crosscut hand saws, 26" - 10 point
- Back saws, 12"
- Compass saws, 12"
- Keyhole saws, 10"
- Coping saws with a variety of different types of blades
- Nail hammers, claw - 16 ounce
- Nail hammers, claw - 13 ounce
- Nail hammers, claw - 10 ounce
- Nail hammers, claw - 7 ounce
- Hand drill, 3/8"
- Twist drills with stand, 1/16 to 3/8" in 32nds

- Ratchet brace, 10" swing
- Auger bit, sizes 4-16 complete
- Expanding bit
- Brace counter set bits
- Hand chisels, ¼", 3/8", ½", 3/4", 1", firmer, bevel-edge and mortise
- Marking gauges and mortise gauge
- Tape, 2 meter metal roll up
- Tape, 5 meter
- Tape, 30 meter
- Try squares, 6" and 10"
- Framing squares, 24" x 16"
- Combination squares
- T bevel, 6" and 10"
- Wing dividers
- Wood rasps with handles, 10", variety of shapes
- Wood files (cabinet), variety of shapes and sizes
- Pinchers
- Wooden mallet
- Screwdrivers, standard, 4", 6", 8" blades
- C-clamps, 6" and 8"
- Bar clamps, 1 meter long
- Adjustable handscrews
- Pipe clamp fixtures, 3/4" size with a variety of threaded pipe lengths
- Saw set
- Triangular files (for saw teeth)
- Pry or ripping bars
- Jack planes, 14"
- Smooth plane, 9"
- Block plane, 6"
- Spokeshaves
- Combination India oil stones
- Hand axe
- Felling axe
- Hammer holders
- Straight edge, 300mm
- Fast action clamp

- "T" bar clamp
- Mitre box
- Drawknife
- Bucksaw/Bow saw
- Grinding wheel, hand-turned, with wheel dresser
- Chalk line
- 24" spirit level
- Aviation snips
- Work benches (can be built by carpenters)
- Tool cupboards (can be built by carpenters)
- Oil can
- Gouges
- Slip stone, tapered
- Glass cutter
- 10" table saw, 2 h.p., appropriate voltage and cycles

Woodworking start-up supplies and materials:

- Nails, common head, 1", 1½", 2", 2½", 3", 4", 5"
- Nails, finishing, 3/4" 1", 1½", 2", 2½", 3"
- Wood screws, assorted gauges and lengths
- White glue for wood
- Sand paper, variety of grits
- Oil for sharpening stones
- Hinges, variety of sizes
- Hasp and staples
- Wood finishes, varnish, linseed oil, paint, etc.
- Lag bolts
- Assorted screw anchors

<u>Basic Metalworking Tools, Equipment and Supplies</u>

- Ball peen hammers, sizes: 24oz., 16 oz., 12 oz., and 8 oz.
- Ball peen hammer, 32 ounce
- Rubber mallet
- Sledge hammer
- Straight cut snips
- Duck bill snips

- Aviation snips
- Hacksaw frame
- Cold chisels, ¼", 3/8", ½", 5/8", 3/4"
- Center punches and prick punches
- Metal punch
- Line-up tools, variety of sizes
- Files--flat, triangular, half round, round--with different cuts
- File handles
- Wire brushes
- Breast drill, ½" capacity chuck
- Hand drill, 5/16" capacity chuck
- Hand operated post drill
- Set of twist drills, 1/16" to ½" in 32nds, with drill stand (high speed type)
- Set of twist drills, 2mm to 12mm with drill stand (high speed type)
- Locking pliers (vise grips), variety of sizes
- Needle nose pliers
- Diagonal cutting pliers
- Slip joint pliers
- Screwdrivers, slotted and Philips, variety of sizes and lengths
- Scratch awl
- Combination squares
- Try squares
- Calipers, inside and outside
- Dividers
- Steel rulers, 300mm and 600mm long
- Steel measuring tapes, 2m and 5m lengths
- Steel square, 24" x 16"
- Vernier caliper, standard/metric
- Micrometer
- Crescent wrenches, variety of sizes
- Combination wrench set, standard/metric
- Tap and die set, standard nc and nf threads, with screw pitch gauge
- Tap and die set, metric, 4mm through 12mm, with screw pitch gauge
- Machinists/bench vise, heavy duty
- C clamps, variety of sizes

- Pipe vise, 2" capacity
- Pipe vise, chain type, 4" capacity
- Pipe cutter, 2" and 3" capacity
- Pipe threading tools, ½", 3/4", 1", 1 1/4", 2"
- Pipe wrenches, 1", 2", 3" capacity
- Chain wrench, 5" capacity
- Soldering coppers, variety of points and weights
- Tubing cutter
- Screw extractor set
- Slip joint pliers
- Channel adjustment pliers
- End cutting pliers
- Bolt cutter
- Bench shear (guillotine)
- Goggles
- Leather gloves
- Metalworking tables (could be made locally)
- Tool boxes
- Tool cupboards (could be made locally)
- Blind riveter
- Oil cans
- Marking pens
- Drill press vise
- Hand grinder, with wheel dresser

Power Metalworking equipment:

If electricity is available, the following equipment is a must.

- Electric hand drill, 3/4" capacity, industrial type
- Vertical drill press stand for hand drill, with drill press vise
- Bench grinder (for tool sharpening), with drill sharpening attachment and wheel dresser
- Angle grinder, industrial type, with cutting and grinding discs

Additional power equipment (ADP workshop did not have these items)

- Pedestal grinder, industrial type, 250mm diameter wheels
- Floor mounted pillar drill press
- Power hacksaw

Basic Metalworking Supplies:

- Rivets - variety of types and sizes
- Stove bolts - variety of sizes with nuts
- Hex machine bolts w/ nuts - variety of sizes
- Washers - round and lock - variety of sizes
- Sheet metal screws - variety of sizes
- Soldering supplies - solder, sal-ammoniac, acid
- Machine and thread cutting oil
- Hacksaw blades
- Emery cloth - variety of grits
- Angle iron - 1", 1 1/2", 2"
- Plate steel - variety of gauges 16 - 28
- Round and square welded tubing
- Round iron and strap steel
- Broken vehicle leaf springs
- Set screw assortment

Blacksmithing Tools, Equipment and Supplies:

- Forge - factory made or of the indigenous type
- Anvil - "London" pattern ideal but makeshift one can be used
- Machinists bench vise - 35 lbs. or over
- Sledge hammer - 8 pounds
- Flat and cross peen hammers - 2,3 and 4 pounds
- Flat and ball peen hammers - 32 ounce
- Blacksmith tongs - for flat and round stock
- Vise grips (self locking pliers)
- Hot chisels
- Hardies
- Swages (top and bottom) assorted types
- Fullers (top and bottom) assorted types

Welding Tools, Equipment and Supplies:

Oxy-acetylene for welding and cutting.

- Regulators - two stage for both oxygen & acetylene tanks
- Oxygen and acetylene cylinder tanks
- Gas hoses (color coded) with brass fittings - 25 feet length

- Welding torch with mixer
- Welding tips - 1,3,5,7,9
- Cutting torch attachment
- Cutting tips - sized for plate thickness up to 1"
- Welding goggles
- Spark igniter
- Tip cleaners
- Welding gloves
- Cylinder wrench
- Cylinder truck (could be made by the welder if wheels were provided)
- Soap stone
- Flux for brazing and welding
- Brazing and filler rod
- C clasps
- Vise grips (locking pliers)

Electric Arc Welding:

- Welder - portable - 15 to 200 amps
- Electrode holder
- Grounding clamp
- Electrode cable
- Electrodes - variety of sizes and types
- Chipping hammer
- Welding helmets
- Welding gloves and apron
- Welding and C Clamps

Masonry and Building Construction Tools and Equipment:

- Framing hammers - 16 to 24 oz.
- 18-power tilting transit level
- Tripod for transit
- Leveling builders' rod
- Compass
- 30 meter measuring tapes (winding reel type)
- Steel measuring tapes - 2 and 5 meter

- 48 inch level
- 36 inch level
- Brick trowel - london pattern - 11 1/2"
- Brick hammer
- Trowel for cement finishing 12" x 4" & 16" x 4"
- Plumb bobs with string
- Layout string & mason's lines
- Floats - aluminum and wood
- Bricklayer's chisel
- Hand level scope
- Earth auger/post hole digger, adjustable 6"-18" x 3'-6'
- Shovels - for mixing cement & digging foundations
- Pails or buckets for carrying water
- Wheel barrows
- Bolt cutter - for 1/4" rebar
- Pick-mattock
- Clay pick and digging/pry bars
- Ladders
- Wrecking bar - 36"
- Line levels
- Nail pullers, large and small type
- Hand-drilling hammers - 3 lb.
- Sledges - 6 & 8 16, and iron wedge
- Hand-powered cement mixer
- Headpans
- Assorted sieve screening for sand and gravel
- Carbide-tipped masonry drill set - for 1/2" chuck drill, maximum
- Block press or CINVA-ram, if required

<u>Vehicle Maintenance Tools and Equipment</u>:

- Standard combination wrench set - 1/4" through 1 5/16"
- Metric combination wrench set - 6mm through 32mm
- Standard open end wrench set - 1/4" through 1 1/8"
- Metric open end wrench set - 6mm through 32mm
- Standard box-end wrench set - 1/4" through 1 5/16"
- Metric box-end wrench set - 6mm through 32mm

- Ratchets - 1/4", 3/8", 1/2", 3/4" square drive
- Socket sets - standard to fit above ratchets - regular depth & deep
- Socket sets - metric to fit above ratchets - regular depth & deep
- Socket extensions & drive accessories for ratchets
- Tappet wrench set
- Ignition wrench set - standard - 5/16" to 7/16"
- Ignition wrench set - metric - 4mm to 11mm
- Starter/manifold wrench
- Hex key wrench set- standard
- Hex key wrench set - metric
- Flare nut wrenches - standard and metric sizes
- Pickup tool
- Flexible magnetic pickup tool
- Tape & die sets - metric/standard
- Screw extractor set
- Adjustable hook spanner wrench
- Distributor wrench
- Adjustable wrenches - 6", 8", 10", 12"
- Torque wrench - ft-lbs. or newton - meters (click-type)
- Torque wrench - inch-lbs. or newton - meters (click-type)
- Tap and die set - standard set - NC & NF threads
- Tap and die set - metric 2mm through 24mm
- Screwdrivers - Philips -variety of sizes
- Center & pin punches - assorted sizes
- Cold chisels - assorted sizes
- Needle - nose pliers
- Diagonal cutting pliers
- Locking pliers (vise-grip brand)
- Snap-ring pliers - internal/external
- Nose pliers - thin
- Slip joint pliers
- Nut drivers set standard and metric
- Offset screwdriver
- Pry bar and rolling head bar
- Hand impact driver

- Battery filler
- Battery terminal puller
- Battery terminal cleaners
- Battery charger - 6/12 volt
- Battery booster cables w/ spare clamps
- Hydrometer - temperature compensated
- Wire stripper
- Feeler gauge - metric and standard
- Ignition point file
- Spark plug gap wire gauge
- Go-no-go gauge
- Cylinder hone (requires electric drill)
- Valve grinder - suction cup with stem
- Piston ring expander
- Valve spring compressor
- Ratchet type ring compressor
- Gasket scraper
- Oil filter wrench
- Brake spring pliers
- 2/3 jaw puller
- Flywheel puller
- Ball peen hammers - 4 oz. to 32 oz.
- Rubber mallet
- Timing light
- Micrometer
- Standard/metric vernier calipers
- Compression tester gauge
- Battery carrying strap
- Tach/Dwell meter
- Vacuum/pressure tester
- Nut splitter
- Suction/pressure oil gun - for transmissions & differentials
- Transmission funnels
- Pump oilers

- Funnels
- Level type grease gun - with flexible extension
- Tire pressure gauge
- Tire irons
- Jacks
- Hydraulic jacks - 5 tons
- High pressure hand pumps & foot pumps
- Tire valve repair tool
- Hoist (chain)
- Mechanics tool chest
- Tool boxes
- Electrical repair kits - containing terminals and connectors
- Automotive wire - variety of gauges
- Hand truck - 400 or 500 lb. capacity
- Hot patch vise
- Auto electric testing kit - circuit tester, continuity & spark plug (12v)
- Cotter key puller
- Fence pliers - heavy duty
- Flaring tool kit & small tubing bender
- Hose clamp pliers - 8"
- Jack stands
- 5-ton chain fall hoist
- 3-ton cable rachet-action winches (come-alongs)
- Barrel pumps for 55-gal. (U.S.) drums
- Lockable barrel taps for fuels & oils in drums
- Multi-pulley block & tackle units

<u>Vehicle Maintenance - Basic Supplies</u>:

- Cotter key assortment (split keys)
- Hose clamps - variety of sizes
- Grease fittings - straight, 45°, 90° - variety of sizes
- Battery terminal clamps
- Baking soda for cleaning battery
- Gasket paper & cork sheet
- Gasket seal / form-a-gasket gel & compound (type 1,2 & aviation)
- Hot patches
- Battery acid

- Distilled Water
- Gasket Shellac
- Brake & clutch fluid
- Silicone Rubber sealer - for battery cases, adhesive use, etc.
- Anti-sieze compound - for manifold bolts, etc.
- Dust & waterproofing acrylic sealer
- Automotive fuse assortment
- Loc-Tite & solvent cleaner, for nuts, bolts, screws
- Roll of aircraft safety wire for nuts & bolts
- Penetrating oil
- Hydraulic jack & shock absorber oil
- Assorted fuse wire, 2amp - 30amp

To assist those individuals who may not be familiar with the names of certain tools and/or need more information on the types of specialized tools available, a list of selected books follows.

Boyd, John, EQUIPMENT FOR RURAL WORKSHOPS, Intermediate Technology Publications Ltd., 9 King Street, London WC2E 8HN, U.K., 1978.

Day, David and Albert Jackson, TOOLS AND HOW TO USE THEM, Alfred A. Knopf, New York, 1979.

Recommendations:

One difficulty with operating a project in a remote area is how to deal with the demands from the community for services and supplies the project possesses. As word spread of the project's maintenance facilities, equipment and supplies, there was a steady rise in the number of people coming to the workshops to have items repaired (beds, chairs, tables, etc.) or in search of replacement parts for some of the local vehicles. Not only was the local community putting demands on the project but the government sector (Rural Council, Police and Military) was demanding vast amounts of support services (vehicle maintenance, fuel and spare parts) that was placing the project, economically,in a difficult position.

The project at first was sympathetic and attempted to assist those individuals who requested simple services such as welding a broken bed frame together or extracting a broken bolt from a vehicle engine. The project felt compelled to maintain the police and military vehicles as there was a feeling that if we didn't they might requisition ours.

But sympathy waned after a few months of this service as the area around the workshop looked like a junk yard of discarded bed, bicycle, and metal chair frames (most of which were beyond repair) left by individuals desiring our services. Between the police and the military there was always at least one or two of their vehicles being serviced in the workshop each day. These services were taking up too much of the workshops time, using valuable materials not easily replaced and causing a bit of discomfort for the Dinka staff who, realizing the amount of time and materials being expended, were attempting to curb the amount of services by saying no to many of the requests.

After much debate amongst the staff, it was decided that a number of policies would have to be established. As welding was by far the most requested service and for the project an expensive service to provide, service charges would have to be made. However, there was a felt need to distinguish two different types of customers; the commercial sector, those who could afford to pay fair realistic service charges (these typically were the military, police, rural council and merchants) and the private sector, those who could not afford to pay actual costs and would have to be somewhat subsidized by the project.

In addition it was decided that all work (welding for example) would be done after normal project working hours - 2:00 pm.

The fees for welding are listed here and are the minimum service charge which includes welding supplies and the wages for the welders.

	Commercial	Private
Oxy-acetylene welding, brazing and cutting	£ 23.00/hr.	£ 8.00/hr.
Electric Arc welding	£ 20.00/hr.	£ 5.00/hr.

The Abyei Development Project had established by mid-1981 a very commendable system of support services. The workshops, warehouses, trained personnel, communications network, purchasing procedures, were impressive and would be envied by any rural development project.

Throughout the section on support services, there are a number of recommendations for establishing and improving various aspects of this program. But there are a few suggestions that can still be offered to those just starting up a new support services program in a remote area.

Consider purchasing or building a large steel container - about 7.5' wide, 6.5' high, and 10' long (sizes could vary but should be able to fit on a flat bed truck). Outfit the container with large double doors and built in storage compartments and shelves. Then this container could be filled with all the necessary tools and supplies to maintain vehicles, build structures, etc.; then shipped to the site, off loaded from the truck and provide instantly on arrival a very convenient, secure, temporary workshop. Additional similar containers could be sent with other project supplies. At the site these containers could be used as storerooms for the additional in-coming goods and materials. Shipping goods in these durable containers provides the extra benefit of reduced chance of pilferage and damage to the containers while on route to the project site.

Appropriate Technology:

With the completion of the workshop facilities there was an increasing concern among the field staff that we were not reaching out to the community as much as we should and possibly through this new facility we could. All the workers that had been trained in various skills were using their talents to mainly meet the needs of the project and not the community's. The project needs had been (1) a sizeable infrastucture building program for which we had needed a large number of men with construction skills and (2) a very time-consuming program of maintenance of our facilities and equipment which had involved fewer but more specially-skilled individuals. To attempt to compensate for this lack of community assistance we began to take some of our men and, using their acquired skills, focus their talents on helping to solve some of the local problems. By utilizing components from bicycles, wood, iron, pipe, old machine parts and various other items our workers were able to build a wood lathe, seed treaters, local style hoes, cement storage jars, grain threshers, and many other items. In all cases we were simply trying to focus on identifying alternative solutions to problems experienced by the local community. We then constructed devices, tested them in the workshops, modified them (utilizing local input), and then placed them on public display to see if our approach to the problem would be accepted. There was never any attempt to mass produce any particular item as we were simply acting as a research center. If our solutions were accepted and desired by individuals from the local community, we were prepared then to provide the necessary training, facilities, tools, and for a small fee the basic materials to construct the item.

Possibly the greatest success in our attempt to build appropriate tech. devices, other than the potential value of the finished product, was that of the experience gained by the men in the workshop in expanding and sharpening their skills, coordinating their various activities (welder, carpenter, metal-worker, etc.) towards one end and having the opportunity and outlet to express their creativity.

APPROPRIATE TECHNOLOGY DEVICES TESTED

CEMENT MORTAR STORAGE JARS:

Description: Two masons experimented with techniques of building small cement storage containers of a 250 litre size. Background information for

constructing these jars was provided by a book titled Ferrocement Water Tanks And Their Construction by S. B. Watt. These thin walled (1 cm. thick) unreinforced containers were easily constructed as follows:

A circular (60 cm) sand/cement mortar base is cast first and a tough, shaped cloth bag is placed on the base. The bag is then packed full of sand to form a mold. A circular former to provide a mold for the top opening is placed on top of the bag and a 2:1 sand/cement mixture is then plastered onto the bag in two 0.5 cm layers leaving a circular opening at the top. After the cement has set, the stuffing and bag are removed and are re-used for further jars. A cement jar lid is then cast for the container. Each container consumed 1/3rd of a bag of cement (16.5 kg.). It takes about one hour to make one container and 24 hours later another hour to remove the mold and repair if necessary slight cracking of the jar surface. The jar is cured out of the sunlight and drying winds, preferably under damp sacking or plastic sheet for at least 2 weeks.

Purpose: The cement mortar storage jars were designed with grain or water storage in mind. The storage of grain is a difficult proposition in Abyei as insects can cause damage to improperly stored grain. The storage of water is also difficult as the most common method of storing water is using 55 gallon fuel drums which are not only expensive (£S 20) but after a few years rust out. Specific advantages of developing this type of container can be stated as follows:

- Uses commonly available materials - sand, water and cement.
- Simple skills needed. The practical skills needed to use the materials can be easily learned and untrained people could easily make satisfactory jars after only a few days of supervision.
- Leaks resulting from bad workmanship or damage can be simply repaired and maintenance after construction is negligible.
- Simple tools required - shovel, trowel and float.
- Very functional as either a water container (250 litres) or a pest proof grain storage jar of 2 sack capacity.
- Cheap - A bag of cement cost the project about £S 10. Two jars with tops can be made from one bag.
- Durable. Should last ten years or more.

Results: The cement mortar jars were well received by everyone and that was evident by the demand of staff, workers and the community for them. The selling price of a jar was ES 9. The primary use of the jar, as observed, was for the storage of water. The agricultural part of the project used a number of them for storing grain and seed samples. There were some problems of jars breaking when first filled with water. This appeared to be a result of poor sand/cement ratios and improper curing. This problem was resolved by further training. There was a request for a lockable lid for the jars. The masons after a few attempts and some design modifications were able to incorporate a locking device for the lid which was accepted well by everyone.

Recommendations: The acceptance of the jars by the community warrants further investigation into whether or not there might not be a potential for establishing a small business to manufacture these jars. One would also have to investigate different sizes (these jars can be made in the manner described up to 3,000 litre size without reinforcement) to determine local demand. There are problems to consider though, those being (1) maintaining cement supplies, (2) having adequate amounts of water for mixing and curing of the cement, and (3) transportation of finished product.

CHARCOAL RETORT:

Description: The retort was made from 3 oil drums welded together to form one long chamber (volume being 600 litres). It was built from plans provided in a VITA publication (Stock No. 53E) with slight variations to suit our needs and supplies (one major difference is that we constructed only one of the two chambers called for due to a lack of drums). The retort has a dry wood loading capacity of .6 cubic meters; however, due to the loading techniques of the operator and the irregular shape of the timber it often was not possible to fit .6 cubic meters inside the retort. All wood placed inside the retort was cut to 50 cm. lengths. The retort was insulated by using mud and this had to be repaired after each firing. The fuel for firing the retort was scraps of wood from the carpenters shop,old thatch, and basically any rubbish on the compound that would burn. After sealing up the retort the fuel would be ignited and stoked and maintained by one man for about 2 1/2 hours. This retort is designed to do one of two things when in operation: during the charcoal production process gases and tar are given off; the retort can be made so that

these gases become fuel for part of the firing process (this is done by a tube welded to the underside of the retort) or, it can be made to collect the tars from the production process. We chose for the first retort to use the escaping gases as fuel. At about 2 1/2 hours after the fuel fire is ignited these gases begin to flow, igniting upon leaving the retort and provide sufficient heat to keep the process going. It therefore is not necessary to stoke the fire when this occurs. The gases continue to flow until all the timber inside has been turned to charcoal - about another three hours. The next day the kiln is emptied, loaded and fired again.

Purpose: The charcoal retort was built when it became obvious that the project needed some means to insure that there would always be an ample supply of charcoal to sustain the blacksmith program, as it consumed about 50 kilos of charcoal a week. During the rainy season it is very difficult to obtain charcoal and as a result one has to stock pile it during the dry season, or risk going without it during the rainy season. Not only was the project interested in providing charcoal for the blacksmith program but also attempting to come up with a means of producing good quality charcoal cheaply and efficiently for consumption in the community. One problem with some traditional methods of charcoal production is that they are inefficient. Often times it may take as much fuel to heat the kiln as the kiln will produce. The charcoal retort utilizing scrape wastewood is very efficient and produces a good quality charcoal. The charcoal retort was designed to be portable allowing the four group farms to take advantage of the device, as for example after clearing land of trees, to make charcoal. This particular retort design was chosen because of the following advantages:

- Materials readily available in Sudan.
- Easy to build and maintain (note: welding was required).
- Portable.
- Requires less fuel to produce charcoal and fuel can be waste products.
- Quality of charcoal produced is high.
- Charcoal production time is short - can be loaded - fired - unloaded - and loaded again for firing in less than 24 hours.
- Two unskilled labourers can easily maintain daily production rates.
- Can produce useful tars as a by-product.

Results: The cost of manufacturing this retort was £S 130. Up to the point of the HIID staff departure there had been 24 firings. After the 24th firing there was an apparent need to redesign the door and enlarge the gas outlet, to prevent what appeared to be a blow torch effect that burnt a hole in the drum, both items easily repaired by the welder. The retort was averaging between 56 to 60 kilos of charcoal per firing. That amount was divided into two bags and sold at £S 2.50 per bag.

Recommendations: Due to the lack of pipe we were unable to fit on the tar condensers. This tar can be painted on fence posts for termite control. It can also be painted on pipes or corrugated iron to prevent rusting. As termites cause extensive damage to wood products there is definitely a need to investigate tar production and its uses. There could be the possibility of looking into establishing a small business utilizing the retort method of charcoal production. However one would have to proceed with caution as charcoal use for cooking is not widespread due to the cost - £S 3.00 per bag. In Abyei town charcoal is used for cooking, ironing of clothes and blacksmithing with the major consumers being the tea shops, laundry shops, the hospital, blacksmith shops, merchants and government officials. What could be looked into in conjunction with charcoal production would be a better design (more efficient) charcoal cooker that could be easily produced and made in Abyei. The current cookers sold in the market waste tremendous amounts of heat and charcoal.

FOOT POWERED WOOD LATHE:

Description: Two foot powered wood lathes were constructed for use in the woodwork shop. The lathes, adapted from a VITA publication (technical bulletin 26) are capable of turning out finished stock 42 inches in length and 6 inches in diameter. The lathe built from 2 by 5 inch construction timber incorporates an intriguing flywheel arrangement - a bicycle wheel in which the spokes have been embedded in cement mortar (this is a rear wheel with the free wheel sprocket still mounted). A chain is connected to the free wheel sprocket with one end of the chain connected to a spring and the other to a pedal which is pivoted on a hinge. By pressing down on the pedal the chain moves the flywheel free wheel sprocket thereby rotating the heavy wheel. By releasing the pedal the spring pulls the pedal to the top position. By pumping the pedal with a rapid series of strokes momentum is built

up on the flywheel. A bicycle front hub acts as the headstock and is connected to the flywheel by a pulley arrangement. All parts of the machine (excluding the bicycle parts) were constructed locally including all the necessary lathe tools - the blacksmith forged the steel tools and the handles were made on the lathe.

Purpose: There was a need for some form of machine that could make tool handles.

Results: The lathe operators produced an abundance of handles for all our tools. After some training the operators turned spindles of all shapes and sizes for table legs and chairs. Walking sticks made out of teak were popular lathe items. The lathe also made the molds for the opening of the cement mortar jars. Maintenance of the machine was easy and any damage that might occur can easily be repaired by the carpenters.

Recommendations: The making of this machine was an excellent exercise for the carpenters as working drawings had to be read and the concept of lathe operations could be presented without the need of imported lathes with electric motors. A lathe of this type is a must for any rural wood work shop.

FOOT POWERED THRESHER:

Description: A foot powered sorghum thresher was built. Working from plans provided by the Melanesian Council of Churches, Papua New Guinea, full scale drawings were constructed from which the carpenters worked. It took approximately four days for four men to construct the device. This thresher utilizes a rotating drum (12" diameter by 24" length) upon which 132 wire hoops are mounted. The drum is mounted on a wooden stand and connected to the treadle drive mechanism. When the treadle is operated the drum will rotate at 250 to 300 revolutions per minute. The wire hoops on the drum are the "teeth" which strike the grain off the stalks.

Purpose: The thresher was built with hopes of providing an alternative way over the traditional drudgery of hand threshing.

Results: The completed thresher worked quite well in threshing sorghum stalks. Although it was capable of threshing faster than hand methods it was not accepted by women who had opportunities to operate it. The main reason being that with hand threshing the women were not only able to clean the grain from the stalk but also remove the husk of the grain in the same operation. The machine however only removed the sorghum from the stalk. The husk still had

to be removed. This additional amount of work seemed to diminish any benefits of the machine. (This may have been due to sorghum type and moisture content.)

Recommendations: I would like to see further experiments done with the machine and attempts made to develop a mechanism that would husk the grain as it passed through the thresher. Additionally alternative power sources from bicycle powered to possibly even motor driven.

METAL-BENDING MACHINE:

Description/Purpose: A metal-bending machine was fabricated out of mild steel flat, angle, bar and pipe materials. The design for this pivot-principle hand-operated forming machine came from the Intermediate Technology Development Group Ltd. of London, England. The basic machine with all its special fittings and formers and special work table designed for it was constructed by two metal workers over a fifty hour period. The main feature of the machine is its ability to bend flat mild steel up to 101 mm x 9.5 mm cross section into a circle which could be used for making wheels for farm carts and other basic agricultural equipment. The machine is versatile in that it can be fitted up to carry out other bending operations in addition to forming hoop iron into circles. This includes: bending notched angle iron to any angle up to 90 degrees; bending mild steel flat to a smooth curve-cornered angle up to 180 degrees; and as it was primarily used for in Abyei was the bending and shaping of re-bar for ring beams and lintels.

Results: The machine was a nice addition to the workshop. Its only drawback was each different bending operation had to have its own formers, which had to be made, and which in some cases was time consuming.

SEED DRESSING MACHINES:

Design and Purpose: A hand operated seed dressing drum was manufactured from information provided by the Intermediate Technology Group who had been researching such a device in Malawi. Two seed dressing machines, each with a capacity of .1 cubic meters, were manufactured from a discarded 210 liter fuel drum. The drum was cut in half and a lid with a special fill spout was welded to each open end. The drum rotates on a 3/4 inch water pipe which

fits into wooden oil soaked bearings mounted on an angle iron frame. The drums are easily rotated by the handle attached. The advantages of this device were that seeds and a corresponding chemical could be accurately measured out, placed inside the drum, rotated and emptied in a relatively short time with full assurance that the individual seeds have been well coated. For further information on this device refer to the agricultural report.

55 GALLON DRUM HANDLING DEVICES:

Design/Purpose: The metalworking shop built drum racks that can be slipped up to a standing drum and allow it to be smoothly tipped over from the vertical to a horizontal position, which leaves the drum resting on the drum cradle (rack) at a height that will allow a jerry can to be filled under its spout. This allowed us to dispense oils and fuel without the risk of contamination presented by the use of a siphon. By installing lockable spouts we were able to control misuse and waste. The drum cradles were made from 3/4 inch water pipe with flat strap steel used as bracing. In all six drum cradles were made. The design for these came from a picture in a catalogue from which the metalworkers took the concept and were able, utilizing local shop materials, to construct the items.

A drum dolly was built allowing one man to move over rough ground one full 55 gallon drum. Previously the drums were rolled along the ground posing the potential of damage to the drum. Using an axle and wheel unit from the ox-cart making materials the workshop was able to "free design" a dolly with the result being quite excellent.

OX CART DESIGN:

Design/Purpose: There were attempts made to solve local transportation problems by investigating means of manufacturing carts that could be pulled by oxen. The first attempts utilized Land Rover axles with the undercarriage made solely from wood. Shackle bolts were made by the local blacksmiths along with the harness hooks for the oxen. A number of carts were made in this manner with design changes constantly being made. With the arrival of welding and axle parts from Mouson Freres, Marseilles, France, an entirely new approach of utilizing a steel welded undercarriage was used. After much design work on the under carriage a simple means of manufacturing them was developed where-

by even the most unskilled worker with just a little training could cut out all the different steel components from angle iron. With the under carriage problem apparently solved different types of carts, for different functions, were built with this basic ox cart frame. The most notable cart built was the 220 gallon water cart fabricated from four 55 gallon fuel drums. Much design modification went into this cart due to problems encountered by poor balancing of the load (220 gallons of water is a lot of weight, plus different problems arose when the tank was full, half full and empty.) Two steel 2 inch pipe tongues were broken right off at different times during the design modifications. The water cart was pulled by two oxen seven days a week on a two mile water delivery route every day of the dry season. It's impossible to operate the water cart during the rainy season as the cart simply sinks into the mud.

Results/Recommendations: The manufacturing of the carts by the project was easy especially after ox cart wheel and axles were imported (trying to locate used vehicle axles in Sudan is very difficult.) The only problem encountered, and a major one, was the non-acceptance of using oxen for traction (refer to other sections of the report as to reasons why.) The carts were accepted and desirable but they will have to be re-designed for use by donkeys as donkeys are accepted for this type of work by the local community.

SOLAR PANEL:

Description/Use: Although not built by the project, the use by the project of a solar panel to power a transceiver falls under the category of appropriate technology. The solar panel was manufactured by Solar Power Corporation of Woburn, Mass. The solar panel (model G 3672) had a rated output of .62 amps at 13.8 volts (at 100 mw/cm^2 of sunlight). The panel was mounted on a 40 ft. tall antenna mast at 12 feet above the ground. Cables ran under ground to a battery storage system made up of two 12 volt 40 amp. hr. batteries placed in parallel, inside the room. A TWC 10S SSB Transceiver was connected to this battery storage system. This 150 watt transmitter which ran on 13.6 v DC had a power consumption of : receive 100-300 ma and transmit 12 amps. The transceiver was normally operated for 1.5 hours per day.

Results/Recommendations: Once the solar panel had been mounted on the antenna mast it has continued to operate excellently into its second year. The solar panel was matched well to the needs of the radio as it was capable of

keeping the batteries fully charged at all times. In addition, a 12 volt 13 watt fluorescent light unit was wired into this solar panel/battery system providing a cool bright reading light in the radio room at night. There was some difficulty in the beginning with the system as a result of poor quality batteries with low amp. hour ratings, but when that was corrected the system worked flawlessly. Something to consider for future projects in a remote area is the possibility of providing each house (or tent) with a solar panel, battery (12 volt heavy duty - high amp. hour) and one or two 12 volt, 13 watt flourescent lamp units as this may be much cheaper in the long run for providing reading light than a generator, transmission lines and fuel to run a generator at night.

"BLUEPRINT" MAKING BY THE DIAZO PROCESS:

Description/Use: The project was constructing a number of buildings designed by the HIID staff. As the architectural drawings of these structures were done in Abyei, there was a need for reproduction of these prints for use by the building trades. To accomplish this the diazo dry process was used in conjunction with a locally made exposure frame and "printing tube". The process is based on the sensitivity to light of certain dyestuff intermediates that have the characteristic of decomposing into a colorless substance if exposed to ultraviolet light and of reacting to form an azo dyestuff upon exposure to ammonia vapors. It is a contact method of reproduction , and depends upon the transmission of light through the original (in our case an ink drawing on vellum) for the reproduction of positive prints. The exposure was made by exposing the drawing and the print paper to sunlight while they are held tightly together under a heavy glass pane (a simple printing frame was designed and built in the workshop for this purpose). The ultraviolet light of the sun brings about a photo chemical decomposition of the light-sensitive yellow coating of the paper except in those places where the surface is protected by the opaque lines of the original. The sun exposure varied from 3 to 12 seconds depending on time of day. The exposed print was then developed in a P.V.C. tube that contained ammonia vapors. The tube was 4 inches in diameter by 80 cm. in length (tube length is dependent on size of drawings required). The ends of the P.V.C. tube were fitted with end caps. To develop the paper a small cup containing ordinary household ammonia was placed in one end cap. The tube was then placed vertically onto the end cap. The exposed diazo-print paper was then rolled up

and placed inside the tube and the other end cap, which had a one inch slot cut into it for ventilation, was put on. The paper was exposed to the ammonia fumes for between 5 to 10 minutes. Upon removal, the paper is dry and ready for use and sunlight can make no further changes on the paper.

Results: The quality of the finished prints was satisfactory. This process is ideal for anyone who has a need to produce only a small number of prints.

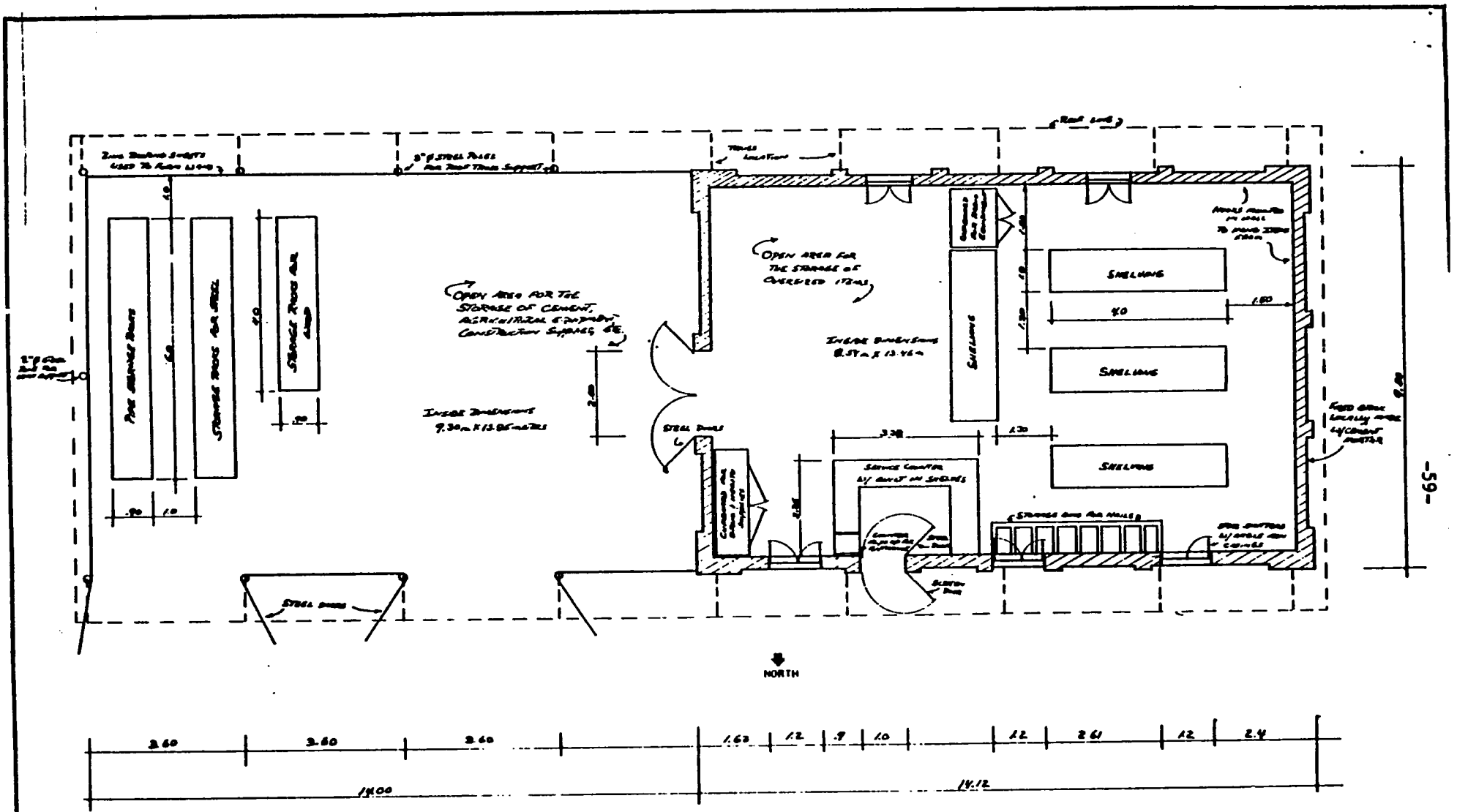
RECOMMENDATIONS CONCERNING APPROPRIATE THECHNOLOGY RESEARCH:

As of April 1981 the Abyei Development project had established a very excellent workshop complex-warehouse infrastructure. This infrastructure with its talented workshop crew was capable of fabricating a wide assortment of articles such as items for the well program, large fuel and water storage tanks, furniture (both metal and wood) and an assortment of appropriate tech items mentioned above.

Using the facilities in Abyei a greater effort could be made to establish some form of an appropriate technology research center there that would focus on identifying alternative solutions to the many problems experienced by the local community. As stated in the introduction to this section on appropriate tech devices, a center of this type could construct, test and modify new devices. And if these solutions were accepted by the local community, it could then provide to the individual the necessary training, facilities, tools and the basic materials to construct the item at the center. The outcome of this type of concept would be the ability to reach more individuals, promote self-help, teach new skills, and provide the individual with devices that will be easy to maintain which they had constructed themselves. In this way one would be encouraging people to develop and use their human resources and inventiveness via such a research center to solve their communal problems, instead of relying on remotely designed technologies that are imported and that may be most inappropriate for their local needs.

Some of the new technologies that could be explored could be as simple as a low maintenance-durable school bench, charcoal cookers, timber preservation for termite control, or simply manufactured cooking utensils. Higher technology research could incorporate techniques for drilling and installing wells, manufacturing hand pumps (both of these items have been experimented with already in Abyei) or designing and building new agricultural items that are suitable for the area.

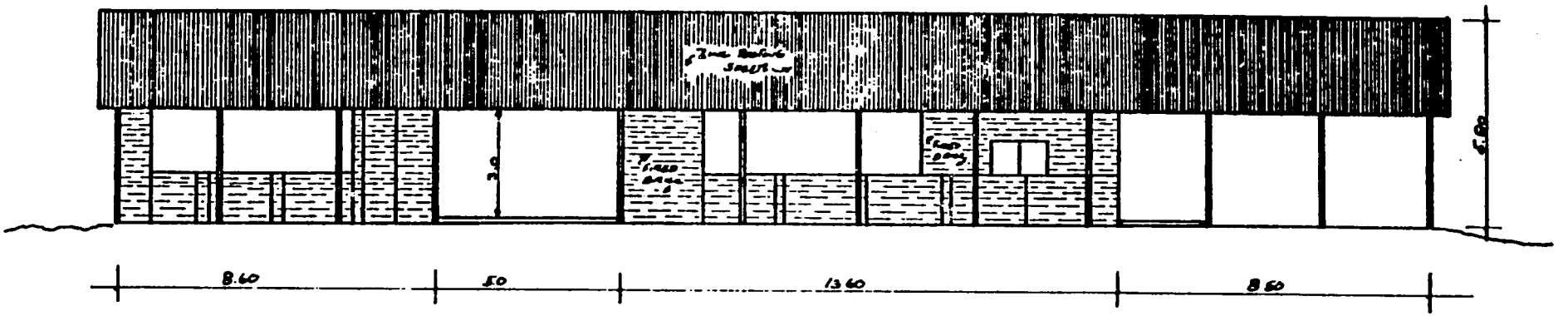
It would be important though to avoid creating new technologies that are dependent upon technical specialists, and therefore beyond the grasp of the people. The kind of technologies that are needed are those that match the local people's ability to understand, use and maintain them. It's important to foster local research capabilities and innovativeness and cease perpetuating dependent relationships on foreign technology.



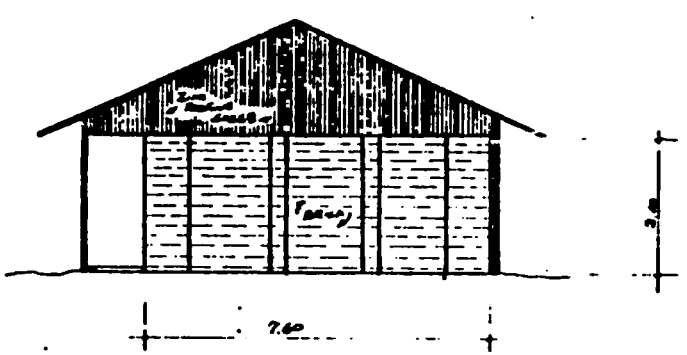
FLOOR PLAN

ALL MEASUREMENTS IN METERS

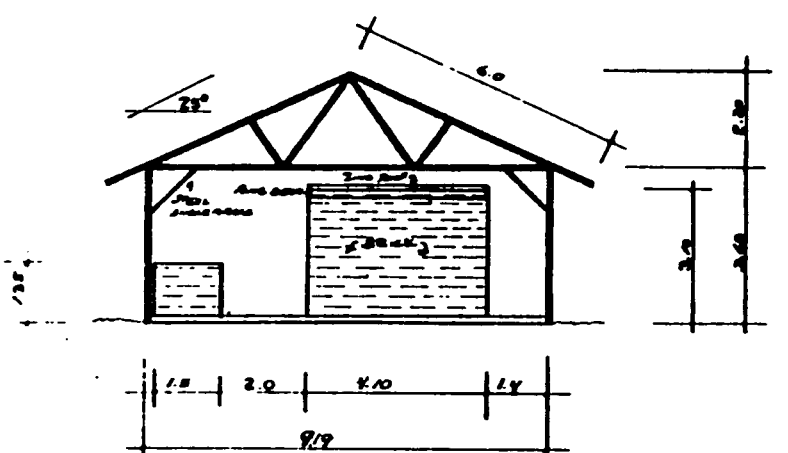
WAREHOUSE		
HIID-ABYEI DEVELOPMENT PROJECT SUDAN		
DATE: MARCH 1980	SITE: DUOP	SHEET 1/7
SCALE 1:50	DRAWN BY: W DONOVAN	
DESIGNED BY: DONOVAN, SHARP		



NORTH ELEVATION



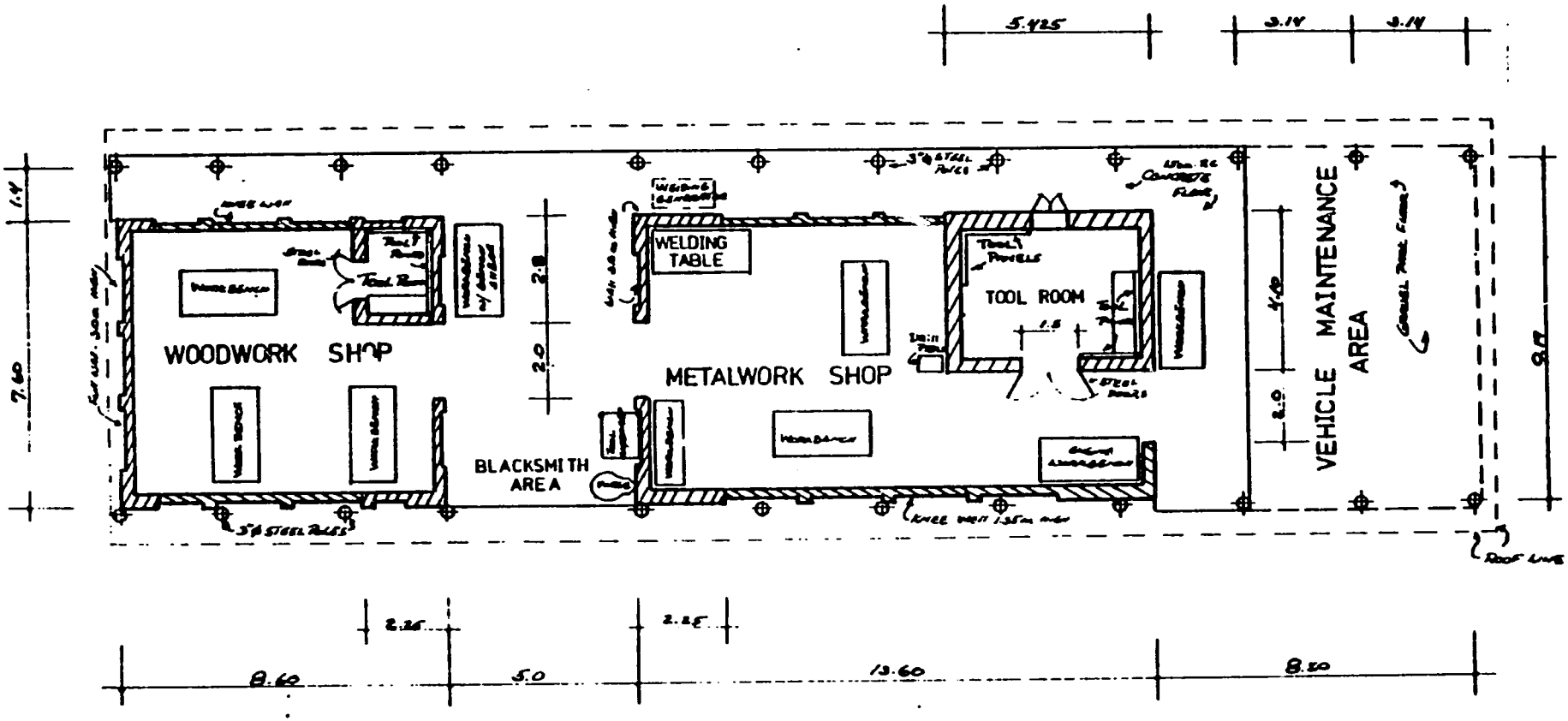
EAST ELEVATION



WEST ELEVATION

ALL MEASUREMENTS IN METERS

WORKSHOP COMPLEX		
HIID - ABYEI DEVELOPMENT PROJECT - SUDAN		
DATE - JANUARY 1980	SITE DUOP	SHEET no. 2/6
SCALE: 1:100		
DESIGNED BY: DONOVAN, SHARP		



FLOOR PLAN

NORTH

ALL MEASUREMENTS IN METERS

WORKSHOP COMPLEX

HIID-ABYEI DEVELOPMENT PROJECT SUDAN

DATE: JANUARY 1980	SITE: DUOP	SHEET no. 1/6
SCALE 1:100		
DESIGNED BY: DONOVAN, SHARP		

BRICKMAKING

Background

One purpose of the Abyei Development Project was to develop new and improved construction materials and techniques that would be appropriate for the area. Traditional structures in the Abyei area are made from vertical log walls covered with mud and a conical roof of logs covered with thatch. These structures are short-lived (i.e., 4-5 years duration); the walls crumble in the rainy season and the roofs are easy prey for termites; they are also poorly ventilated. Their main advantage is that they can be totally constructed out of readily available local materials at a cost of about £S 100.

In 1977, Dr. Mohammed El Mustafa Awad, staff member of the Buildings Research Institute at the University of Khartoum, was sent to Abyei to investigate the locally available construction materials and techniques. On the basis of both economic and technical analysis, choices of the most appropriate material or materials would be made and used for the project's construction program. Based on his report, "Building Materials and Construction at Abyei", the project decided to go ahead and manufacture locally burnt-clay bricks.

Dr. Awad had done tests on some bricks recently made (1977) in Abyei and found that these bricks do meet the requirements of the Sudanese Standard for Common Burnt Clay Building Bricks. However, he found, when comparing their strength with bricks once made in the area, the present production (1977) had a strength only half that of the old bricks and suggests that current quality is a result of deterioration in technical controls. Therefore new production of bricks would require that a careful follow-up of the technology of burnt-clay brick production be instituted.

Having hired a number of Sudanese with brickmaking experience, the project set about to manufacture its own bricks. By early 1979 brick production was well under way. By May of that year two kilns with 60,000 bricks each had been fired and this was sufficient for the spring construction program. A third kiln of 50,000 bricks was assembled and fired. However there was not sufficient amount of timber to sustain the firing and as a result the kiln was underfired resulting in very poor brick. This under-firing was to occur again for three different kilns over a year's period, with a loss of over 100,000 bricks (further discussion of this problem follows later).

It should be pointed out that brickmaking occurs in Abyei from November/ December through March. It ends in March due to lack of water as the seasonal river dries up during the dry season. Brickmaking stops during the rainy season, May through October, as the rains destroy unfired bricks left out in the open. (Additionally, even with covered drying areas, the high humidity impedes the essential drying stage and makes it difficult to stockpile sufficient amounts of dry timber for the firing process.)

The first kilns produced low quality brick with low tensile strength. Some of the problems appeared to have been a result of high sand content and improper mixing. Although brickmaking is relatively straight forward, there are a number of variables that must be controlled if quality bricks are to be produced.

In the 1980 and 1981 brickmaking season a number of these variables were researched and improvements attempted. One of the most frustrating problems confronting the project in the beginning was trying to prevent the cracking of over 60% of the green brick during the drying process. Clay preparation, additives, molding procedures and controlled drying techniques were explored in an attempt to control the problem. Some of the solutions affected the quality of the final brick and not necessarily for the better.

In early 1980 two small brick kilns (4,000 brick capacity) were built to test the newly researched brick formulas. One kiln was underfired negating the test. The second kiln was fired correctly and the resulting brick samples showed that, although more research was required, the tensile strength was improved over recently made local brick.

With the construction program requiring bricks and the brickmaking season so short, it was decided that the same formula used in the test bricks would be used to produce a large 60,000 brick kiln. Although this was a gamble, the brick produced from this kiln, although still lower in tensile strength than was desired, was far superior to any brick found around Abyei.

The 1981 brick season started off in the same manner as the other two seasons - that is, poorly. Even though the project improved brick quality, testing procedures and production methods the brickmakers regressed back at the beginning of the season to the time honored way of making brick. This "loss of memory" for new techniques occured at the beginning of each new season. As a result, time was lost re-training and re-explaining to the workers how to produce bricks of the necessary quality.

The first kiln of the 1981 season produced bricks that were rather porous and crumbly; the results of poor mixing and inaccurate proportions of additives to the clay. The product from the second kiln was better due to the increased supervision at the brick yard by senior project staff members. Close supervision of the brickmaking process (digging, mixing, molding, drying and firing) was a key element for assuring quality bricks.

The project produced more than 350,000 bricks over a three season period. The peak production rate was 2,500 bricks per day with the project employing 24 persons to accomplish this.

The problems the project had to contend with in attempting to produce quality brick were often overwhelming; the low humidity (16%); daily temperatures of 100° F or more; the need to haul sand over five miles to add to the brick; the drying winds; lack of water; having to acquire large amounts of timber to fire the kilns; the shortness of the brickmaking season; the need for constant supervision over all phases of the brickmaking process.

What follows is a description of how bricks were made locally in Abyei by the project; the problems encountered, the solutions, and the results are listed here.

Site Selection and Preparation

Water is a critical element in the brickmaking process and as a result influenced site selection. Traditionally brick sites were located along the Nyamora river as there was sufficient water until about February/March when the river and suitable clays for brickmaking dry up.

Once the site was selected, the top five to six inches of soil was skimmed off before collecting the mixing clay. This had to be done as the top layer of soil usually contains a high percentage of silt and sand plus vegetation and rubbish that would interfere with producing quality brick.

The site where the bricks would dry had to be cleared, smoothed and leveled. Sand was spread about to help fill in the cracks and level the surface.

For the 1981 season, in an attempt to extend the brickmaking season, former clay pits, 1 meter deep and 3 meters square, were filled with water by a diesel pump from the Nyamora and used as reservoirs.

Clay Preparation

Brickmakers in Southern Sudan normally choose the sandier clay deposits because of the material's ease of molding and lower tendency to crack with rapid drying. Abyei brickmakers tend to do the same, however, the clay that is used appears to be rich in the mineral montmorillonite. This mineral expands when exposed to water, only to resume its original volume when redried. Bricks made from these clays have a tendency to result in excessive cracking even under the best of controlled mixing and drying conditions. As there was no other better suited clay beds to be found within a realistic distance of the Abyei area (the economics of transporting both water and the finished product were the considerations) the decision was made to go ahead and attempt to work with these clays. It was found that such exaggerated expansion and contraction of the clay, could only be offset by the addition of coarse sand (salt size granular consistency) until the sand proportion reduces cracking of the drying brick to an acceptable level (10% or less of the day's production run). Analysis of the dug clay revealed that 90% was clay and 10% sand. Experimenting with different proportions of clay to sand under controlled conditions, it was found that a proportion of 60% to 40% (clay to sand) was required to reduce cracking while the bricks were drying. However this excessive amount of sand additive reduced the over all strength of the brick. Therefore, the project was faced with a dilemma: a higher sand percentage resulted in a higher production rate in the brick yards (less cracking) but a reduction in the strength of the fired brick; a lower sand percentage resulted in a very low and unacceptable production rate (loss of brick due to cracking) but a higher tensile strength fired brick. The project's decision was to manufacture bricks with the higher sand percentage and compensate for the lower tensile strength brick by using building construction techniques that took this into account (read the report on construction activities by J. Sharp for what was done).

Once the brick site was established, pits were dug. Water was added along with the dug clay. This clay mixture is allowed to soak for a week or more which helps to weather it and break down the larger clay particles into an even plastic body. To ensure an even mixture the workers tread through it with their bare feet. When this mixture is ready, a measured amount of soaked

clay, sufficient for the next day's production run, is dug from the pit and mixed with the correct proportion of sand. Measuring out the proportions was accomplished by counting shovels of sand and clay. The workers tread through this mixture with their bare feet (to ensure even mixing) then cover it with a damp sack and allow it to sit overnight. A sample is tested each time to insure correct proportions. The following day the mixture is used.

Traditionally brickmakers in this area have added dung to the clay while in the soaking pits. The function of this is to provide a fuel additive. The dung provides a carbonaceous ingredient to the clay body which burns out of the brick once sufficient external temperature has been reached. This fuel additive can provide a significant amount of the heat requirement when firing the bricks thereby saving tremendous amounts of external fuel requirements. The project experimented with the dung additive in 1979 and found a number of problems when incorporating it. The most significant problem was obtaining consistent proportions in each mixture and insuring that it was a homogeneous one. (It should be pointed out that little is known as yet as to the ideal proportions as research papers available state anywhere from 5% to 25% dung additive.) If there happened to be dung particles larger than 3mm diameter, when these burnt out it would leave a pocket of high ash residue equivalent in size to that of the original fuel. These ash inclusions cause a lack of strength in the brick and are unsightly when protruding through the surface. In addition dung in the mix has on occasion led to extensive termite damage while the bricks were drying on the ground, as the termites would riddle the bricks while seeking out and consuming the fibrous dung. As a result of these problems the project decided to omit this fuel additive for the time being and concentrate more on solving the problems of cracking and low tensile strength of the brick.

Brick Molds and Brickmolding

For the first brickmaking season the project had borrowed a number of molds. However, there were three different brick sizes being molded and mixed indiscriminantly by the workers which later caused problems for the masons. In addition it was discovered that these mold sizes (24cm x 12cm x 6cm, 23cm x 11.5cm x 7cm) were not of a correct size ratio which in turn led to extravagant demands on cement-plaster to cover the uneven interior wall surfaces. This arose from failure to size the mold so bricks were of a width less than 1/2 the

length: e.g. they were 24cm long by 12cm wide... rather than the correct 24cm by 11cm. Used in a double-course wall, 2 rows of stretchers (longitudinal lay-up) and their intervening mortar bond should just equal the length of a header course (perpendicular lay-up), producing a smooth wall surface on both sides of the wall. By contrast, the 24 x 12 brick, with the center mortar bond in a stretcher course, protruded beyond the header course by at least the thickness of that center bond.

After that first season all molds were collected and sorted for future disposition and a 24 x 11 x 8cm size double mold was built from wood by the project's carpenters and put into use. This new size allowed a 2cm bond in a stretcher course before equaling the width of a wall's header course.

Prior to placing the prepared clay into the wooden molds, considerations have to be made as to how the finished brick will be demolded. To prevent the clay from sticking to the mold two different techniques can be used: slop-molding which uses excess water or sand-molding which uses sand.

Traditional brickmakers in the Abyei area use the slop-molding method. In slop-molding,a "loaf" of clay is made from a very soft, watery clay mixture. This loaf is thrown into a mold, which rests on a wooden pallet, (both the mold and the pallet have been wetted) and the excess mixture scraped off with a wooden striker. The mold and pallet are carried to the drying area, inverted onto the ground, the pallet removed and used as a striker removing any clay that may have flared out from under the mold, and the mold lifted allowing the wet clay to slide onto the ground.

There are a number of problems encountered when using the slop-molding method. As the wet clay slides out of the mold, often a bending process occurs as a result of the brick sticking in the corners of the mold. The brick therefore becomes distorted. If the mixture was too soft and wet the molded brick bottom will spread as a result of its own weight. In addition any irregularities of the ground will be transferred to the soft brick. Furthermore, there is greater shrinkage of the brick with this higher water content and the potential for it to become distorted and cracked during drying.

Recognizing the problems with slop-molding, the project attempted to introduce the concept and techniques of sand-molding to the brickmakers. With this method, moist clay (not the soft, watery type used for slop-molding) was shaped into a loaf and dusted with a coat of dry sand. The mold was also dusted having first been immersed in water so that the sand would stick to it.

The loaf was thrown into the mold and excess clay was cut off with a wire. This method of dusting the mold and clay loaf eliminated the adhesion of the clay to the mold resulting in easy release. As less water is used in the process, many of the problems with slop-molding are eliminated. However, it is slightly more time consuming as it is one extra material for the molder to handle.

Regardless of the observable benefits of the sand-molded process it was abandoned. The reason was simple: the brickmakers didn't like it for it involved more work on their part and lowered their daily production output. Quality was not their concern (unfortunately) - less work was. When the ex-patriate staff person was not there to supervise, the molders would go rapidly from sand to slop-molding.

Drying

The first stage of drying takes place with the newly formed bricks laying on the ground in the open. After a few hours the bricks can be lightly handled and are turned to facilitate drying on the underside. This turning process occurs again on the following day. Once the bricks are somewhat "green hard", they are removed from the drying area and stacked in long rectangular piles, for the second stage of further drying. The bricks are placed in a stacking pattern that allows air to pass over all sides of the brick. The bricks are then left in these stacks for at least two weeks when they are then ready to be fired.

The hot, strong sun, low humidity and drying winds has its greatest affect upon the brick during the first drying stage. These harsh drying conditions are the major contributors to the problems of bricks cracking. In seeking to lessen these affects a number of different approaches were attempted. A grass wall, two meters in height, was built around the drying site one season to help control the drying winds. Although it appeared to have some effect it was abandoned the following season as it was simply too expensive to erect and maintain such a fence. To help curb the effects of the strong sunshine, grass bundles were placed over the newly formed bricks. This covering proved to be quite beneficial, reducing the effects of a too rapid drying process.

One difficulty that occurred often was that of getting the brickmakers to turn the brick at the appropriate times and frequently. Often those bricks made later in the day were never turned when they should have been as the workers would go home and leave them until the next day. As a result, distortion would sometimes occur or more commonly, the brick would crack due to unequal drying rates.

Firing

The kiln design used in Abyei was common throughout the region. It has a rectangular base 10 meters long by 4 meters wide and is built with a taper to a height of 4 meters. This size kiln has a capacity of about 50,000 brick. Incorporated in the design are eight arched firing tunnels of 75 cm width which run through the kiln perpendicular to the longest side. Once the bricks are set in place, the entire kiln is plastered with a thick sand and mud mixture to help insulate it. The top of the kiln is left unplastered and instead is covered with one layer of brick laid flat and close together to regulate air flow. In addition the fire tunnel openings on one side are temporarily sealed up with brick and mud plaster.

The fuel for the firing process was wood cut from the surrounding areas and brought in by tractor and trailer. Anywhere from 150 to 225 cubic meters of dried timber were required for each firing. This figure was based on the simple ratio of 2 cubic meters of wood for every 1000 brick. (Another ratio commonly stated is one ton of wood per 1000 brick.)

The length of time for firing a kiln ranged from six to eight days and this was dependent upon how dry the bricks and timber were, the size of the kiln, the cooling effect of winds and whether or not a carbonaceous ingredient has been included in the brick.

Firing is begun by igniting the timber in the tunnels from one end. After a few days those ends are closed up, with brick and mud plaster, and the other end is opened. Firing continues on this side until the top of the kiln is hot enough to instantly ignite straw that is thrown upon it. When that occurs the firing ends and the remaining tunnel openings are sealed off. It then takes the kiln seven to fourteen days to cool down.

There are a number of problems to be solved yet for both the kiln design and the firing process. As one example, the large openings of the fire tunnels, needed for tending the fire, allow cold air to enter thereby wasting fuel. Damping systems are therefore required. The project attempted to incorporate a simple system by using zinc sheets propped up at the openings that would allow limited cold air in. There were difficulties with this, however, as the sheets would become too hot to handle and therefore inconvenient when it came to stoking the fires.

Certainly the most frustrating problem that plagued the project was that of the "supervisor" starting to fire the kiln before sufficient wood had been gathered to sustain the burn. Whether it was the inability to judge cut timber volumes or a bit of anxiousness to start the firing is debatable. In either case four "supervised" kiln firings were underfired.

Transportation during the rainy season is extremely limited. In anticipation of this, kilns fired after the 1979 season were built next to the construction sites allowing easy access to the fired bricks without the need for transportation by the construction workers.

Brick Production Costs

Estimating the costs of producing brick by the project is difficult. Much research and development was carried on during the different seasons, costs of which are unknown. Transportation played an integral part - hauling of sand, brick, timber and men - for which there are no accurate figures available on fuel costs and vehicle maintenance. Underfirings of kilns resulted in loss of brick which added to the costs of brick production.

What can be provided though are sample labor costs incurred in producing brick, from clay preparation to firing the kiln. As these costs make-up a major portion of the capital outlay, a fairly good idea of what it costs to produce bricks in Abyei can be shown.

Description	Labor Costs
* Clay Preparation and Molding - - - - - - - - - - - - -	฿ 8.64 per 1000 brick
(24 men making 2,500 bricks/day at daily ave. wage of ฿ .90)	
* Kiln Construction - - - - - - - - - - - - - - - - - - -	฿ 2.25 per 1000 brick
(5 men - 25 days to build 50,000 brick kiln at ave. daily salary of ฿ .90)	
* Cutting Timber for Kiln - - - - - - - - - - - - - - - - -	฿ 3.60 per 1000 brick
(200 cubic meters of timber required. 1 cu. m. can be cut by one man each day at a day's wage of ฿ .90)	
* Kiln Firing -	฿ 1.92 per 1000 brick
(12 men/day for 8 days at ฿ 1.00/day)	
TOTAL LABOR COST:	฿ 16.41 per 1000 brick

Recommendations and References

From 1979 to 1981 the Abyei Development Project manufactured bricks in sufficient quantities to build much needed infrastructure. The establishment of a brickyard and the manufacturing of fired clay bricks was not unique to the area, for in former years this had been done by others. Although brickmaking technology is known, the actual application of it remains dormant until the need arises. However, the project, based on its own experience in using the local approach to the technology of brickmaking, realized that there was a need for improvement in both brick quality and production efficiency and spent two brickmaking seasons searching for solutions. It succeeded in some areas but improvements are still required in others.

What the project did learn and what further research is required is listed here:

- The brickmaking season is short due to the rainy season. Organization and supervision is required to insure that sites are cleared, timber is cut, that clay mixtures are of correct proportions and consistency, and kilns are fired correctly. Any delays or errors will result in lower outputs of bricks which may result in a slowdown of planned construction activities. Supervision is the key element. The project's experience with supervisors however has often been disappointing. Local brickmakers hired as supervisors tended to promote higher brick productions without concentrating on improving the quality of the finished product. New methods were often rejected if it resulted in lower production even if it was shown that it would improve quality.

- Explore the ways of storing water so as to extend the brickmaking season further into the dry season.

- Build a large roof over the molding and drying areas. This roof would provide shade to the workers and help to reduce cracking of the bricks during the drying process. Although initially expensive the actual benefits as the result of this may outweigh the cost.

- Test daily clay mixtures for correct proportions of clay, sand and silt. A simple procedure used by the project was that of filling a glass jar half way with a sample of the next day's mold mixture. Water is added to this until the jar is nearly full, and then, with a lid on, the jar shaken vigorously. This mixture, if allowed to stand overnight, will settle out into

layers with sand on the bottom, silt next and clay on top. By measuring the various levels a rough idea of the different proportions of clay and sand can be determined.

- Experimenting with various sand and clay mixtures, it was found that with a mixture of 55% clay and 45% sand a brick (unfired) could be produced that exhibited rather unique properties. In comparing these unfired clay bricks, it was found that the unfired bricks had a higher tensile and compression strength than the fired ones. The unfired brick breaks down however, when exposed to moisture. If research could be done to help find ways of stabilizing and protecting these bricks, green brick could possibly be used as a permanent building material. By abandoning the firing stage altogether costs of brick production would be lower and valuable timber would be saved.

- The dug clay mixture should be allowed to soak in water for at least a week to weather it and break down the larger clay particles into an even plastic body.

- The addition of dung as a fuel additive to the clay mixture should only be done if adequate means of breaking down particle size and determining correct proportions are researched first.

- Water is typically used in the clay mixture to allow the brick to slide easily out of the mold (slop molding). However this excessive amount of water contributes to the problem of cracking and defects during the dry process. As sand is available, possibly the introduction of the sand-lubricated method of molding could be attempted again.

- In an article by R.G. Smith, "Improved Moulding Devices for Handmade Bricks", there is a description of an experimental mold device which can be constructed from timber. A two man team using this apparatus can produce about 1,200 bricks per day. Based on the sand-molding techniques it produces a stiff, well-shaped brick. Possible testing of this apparatus could be done in Abyei.

- Investigations should be made on developing an efficient hearth and grate for the firing tunnels that would allow only the minimum amount of air to enter to sustain the firing. The present methods allow vast amounts of cold air to enter the kiln, which has a cooling affect on the kiln and therefore wastes fuel.

Brickmaking:

Further information on brickmaking can be found through these sources:

Dancy, Harold K., A Manual of Building Construction. Intermediate Technology Publications Ltd., 9 King Street, London WCZE 8HN, U.K., 1948, reprinted 1975.

Contains a chapter on brickmaking and includes drawings for making molds for special shaped bricks.

Parry, J., "Better Brickmaking for Developing Countries." Appropriate Technology, Vol. 5, No. 1, pps. 7-9, 1978.

This article provides a summary of Parry's booklet on handmade brickmaking. For the detailed illustrated instruction booklet titled "Better Brickmaking for Developing Countries", write to John Parry, IT Building Materials Workshop, 45 George Road, Edgbaston Birmingham, B15 1PP, U.K.

Parry, J., "Brickmaking in Developing Countries." Overseas Division, Building Research Establishment, Garston, Watford WD2 7JR, U.K., 1979.

A comprehensive review of brickmaking in nearly 40 different countries, plus recommendations for research to improve existing technologies. A comparison of Northern and Southern Sudan brickmaking methods is provided.

Smith, R.G., "Improved Moulding Devices for Handmade Bricks." Appropriate Technology, Vol. 7, No. 4, pps. 9-11, March 1981.

A simple review of traditional hand-making methods with a description of two new designs in brick molds.

Thomas, D.W., "Small Scale Manufacturing of Burned Building Brick." Stock #10E, VITA Publication, 3706 Rhode Island Ave., Mt. Rainier, Maryland U.S.A. 20822, 1968.

Molding, drying and firing clay bricks with directions for building a small kiln with permanent walls.

The following bulletins can be obtained from the Department of Transport, Works and Supply (Technical Bulletins), P.O. Box 1108, Boroko, Papua, New Guinea:

"Selection of Materials for Burnt Clay Brick Manufacture." (Technical Bulletin #7) by Papua New Guinea's Building Research Station, 1970. This bulletin provides instruction on the preliminary identification of suitable materials for burnt clay products.

"1000 to 3000 Capacity Brick Kiln," by PNG Building Research Station, 1973, leaflet 18 pages. This leaflet provides a design for building a permanent brick kiln.