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R E P O R T

SUMMARY OF ACTIVITIES RELATED TO THE START-UP OF THE INSTA-PRO AND WENGER EXTRUDERS AND TRAINING OF PERSONNEL

ICAR/CIAE - Bhopal, India

March 9-31, 1990

Consultant Report by

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CONSULTANCY REPORT

ON

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SOYBEAN PROCESSING AND UTILIZATION (SPU) PROJECT

ICAR/CIAE - BHOPAL, INDIA

Submitted by

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EXECUTIVE SUMMARY

The Central Institute of Agricultural Engineering (CIAE), Bhopal, recently completed the installation of extrusion processing equipment in their pilot plant. Extruders installed in the plant included an Insta-Pro Model 600 and Wenger Model X-5. To ensure proper operation of the extruders and suitable direction of research with these machines, assistance was provided with objectives to train personnel om how to operate the extruders and to select appropriate machine configurations to make different products. Demonstration of capabilities and limitations of each extruder, definitions of test protocols and procedures to understand extruder operations, and methodologies for developing new products were also provided during the assistance period.

Training programs and trial runs provided during the assistance period were useful in helping personnel at the CIAE to have the necessary knowledge and skills to conduct research and develop products using the extruders without additional training and technical inputs. Specific test protocols were provided to further develop knowledge and skills with each extruder. By following the test protocols personnel will effectively train themselves in use of the extruders and gain the necessary experience required to use the equipment to its potential.

It was recommeded that a test program be conducted on the extruders before attempting any product development activity to insure a satisfactory working knowledge of each extruder. Additional recommendations were made to improve operations at the pilot plant such as acquiring a set of tools, improving the water delivery system, and having the electrical installation checked to insure that it meets codes.

Discussions were held at both the CIAE, Bhopal and at GBPUAT, Pantnagar on programs and research being conducted under the Soybean Processing and Utilization Project. Both programs are conducting research to determine how to utilize soybean and processed soybean products in India. Currently, efforts are being made to improve the extractability of oil from soybean through mechanical and biological methods. Development of flour extenders for baked products, fermented soybean products, drinks, etc, are also being considered. The research initiated at these facilities is primarily in initial stages and results should be available prior to the end of the project.

Coordination of research between the GBPUAT and CIAE needs to be improved to avoid any duplication of effort. In addition, cooperation between the two groups should be increased to make better use of existing knowledge and equipment at each institution. Links between the two groups and the food industry

or groups that are associated with food processing, grains, etc. would be useful in establishing and promoting capabilities of each institution as a source of expertise in extrusion processing.

Utilization of the existing extrusion equipment needs to be increased to bolster the research output at both institutions. Through this effort, a basis for seeking and obtaining additional funding to sustain operations at each location will exist. The added experience will also build upon the ability of the groups to respond to requests and to be considered as a source of expertise when extrusion problems arise in India.

1.0 Introduction

The Indian Council of Agricultural Research (ICAR) and the United States Agency for International Development (USAID) have jointly supported development and utilization of soybean as a food source to improve nutrition in India. As part of this effort, both groups have funded a project entitled "Soybean Processing and Utilization" (SPU). The SPU project has as an overriding objective to improve and increase the utlization of soybean in the home and at village levels by developing processes, equipment, and training programs for the following areas:

1. Full Fat Soybean Flour (FFSF)
2. Low Fat Soybean Flour (LFSF)
3. Soybean Dhal
4. Extruded Soybased Food Products
5. Soyflour supplemented baked foods
6. Handling, packaging and storage systems of soybased foods
7. Fermented soybean foods
8. Oilseed Processing and Utilization

The SPU project had funds to create two separate research centers in India. The first center, located at the Central Institute of Agricultural Engineering (CIAE), Bhopal, has been given responsibility for development and promotion of processes and equipment for the areas listed above. The second center, located at GB Pant University of Agriculture & Technology (GBPUAT) in Pantnagar, has been given responsibility to impart training in Food Process Engineering and Food Technology leading to Masters of Science and Ph.D degrees in the same areas.

To develop these centers, staff at each of these locations have been appointed and sent to various institutions in the United States for training. In addition, funding has been earmarked for consultants to help with various problems and/or assist in start-up of equipment, testing, and providing additional training if necessary at each center.

The CIAE Pilot Plant facility was built approximately two years ago in which processing equipment including extruders and necessary ancillary equipment have been installed. In an effort to get the extrusion processing element of the project started, assistance was provided on the operation and start-up of these extruders. This report summarizes activities during the assistance period and provides other observations on the projeot work.

2.0 Background

A building having 1000M2 of floor space was erected on the CIAE Campus for purposes of housing laboratories and pilot equipment for post harvest processing of soybean. While space crowding within the building is a current problem, additional space is being added to the existing building to house scientists in separate offices. Chemical and microbiological laboratories are being developed and equipped to enable full scale analysis of products made in the plant.

A portion of this building has been reserved for installation of pilot equipment including:

1. Cleaning, grading and dehulling equipment.
2. Drying equipment.
3. Milling equipment.
4. Oil expellers.
5. Wet processing equipment for fermented soyproducts.

In addition adequate space has been provided for the installation of extruders and ancillary equipment. This equipment includes the following items:

1. Wenger X-5 MZI Extruder
2. Ancillary equipment for Wenger such as a steam generator, air compressor, etc.
3. Insta-Pro Model 600 Extruder Plus ancillaries including:

    A. Feeder
    B. Water application
    C. Particalizer
    D. Cooler
    E. Face plate die and cutter
    F. Face plate roller assembly
    G. Spares to effect different extruder configurations.

The pilot facility is suitably equipped to enable extrusion processing of various formulations on a batch basis.

Work prior to the dates of this report using the extrusion equipment has been limited. Outside of a few test trials of the Insta-Pro using soybean, no other activity with the extruder had been undertaken. Because the pilot plant equipment related to extrusion was not installed early in the project, scientists from the lab were sent to receive training at foreign institutions. It was during these trainings that a number of the reported research efforts were completed on extrusion.

Objectives of the SPU project for use of the extruders are twofold. The first is to improve utilization of soybean by local people at village level and the second to develop new products which would help to achieve the first ofjective. The CIAE has a number of products that they wish to develop using extrusion technology and requested assistance to help identify the process conditions necessary to make these products.

3.0 Objectives of Assistance

Several objectives were provided for this consultancy and are given in Appendix I. After review of the CIAE projects, pilot plant and discussions with personnel, several specific objectives were added which would permit addressing critical needs. These included:

1. To demonstrate the capabilities and limitations of the Insta-Pro and Wenger Extruders.
2. To demonstrate procedures for testing extruder equipment and products.
3. To define example test protocols for developing a basic understanding of extruder capabilities and limitations.
4. To define example test protocols for product development using extruders.
5. To insure a clear understanding of the extruder operation by personnel at the plant.

4.0 Lectures & Discussions

As a way of introduction and familiarization with the SPU project and scientists, time was spent talking to various administrative personnel and to each scientist individually. This helped to understand the research work being undertaken at CIAE and to become familiar with personnel at the facility.

In addition, one-half day was devoted to a lecture discussion period during which the following topics were addressed.

1. How extruders work.
2. Types of extruders.
3. Autogenous extruders and their characteristics.
4. LEC Extruders.
5. LEC equipment definition.
6. Recent uses of LEC for food production.
7. Question and answer period.

The lecture was attended by all scientists and was found to be helpful in understanding extruders, how they work, and products which can be made.

5.0 Insta-Pro Extruder

The pilot plant has available an Insta-Pro Model 600 extruder delivered with the standard configuration recommended by the manufacturer for cooking whole soybeans. In addition, a number of spare parts were available to enable reconfiguration of the extruder-screw for processing other food products which have cereal. The extruder was received with only the single die end plate which is satisfactory for processing soybean. This end plate arrangement is limiting when trying to make cereal products since output cannot be shaped satisfactorily for use as snacks or finger foods and secondly control of the extruder is difficult because of the directional flow changes of product as it moves from the screw into the void volume between the screw, die plate volume, and finally through the die orifice.

During the training period, a multiple die plate head and face cutter were received at the facility. This unit provided greater flexibility for the extruder and enabled shaping and size control of products. Since the die orifices are located differently in this arrangement, the directional flow changes associated with the single die plate are avoided making operation of the extruder with cereals as well as other products much easier. Time was spent using this unit in the test trials also.

Configured properly, the Insta-Pro can make satisfactory products and should allow the SPU project at CIAE to achieve some of their objectives. It must be noted that the Insta-Pro has inherent limitations because its operation is at low moisture. The need to utilize soybean in all formulations including snacks also inhibits the amount of expansion possible with the extruder. Caution should be taken in assuming and promoting a perfect snack product since achieving such a product is difficult. Considertion should be given to developing foods within the capabilities of the extruder such as making full-fat soybean flour, semi-shaped finger foods, blended precooked flours, etc. Sufficient developmental work needs to be done by CIAE to insure that the technology can be used and transfered satisfactorily in India.

5.1.0 Training

In order to insure that everyone in the pilot plant working with the extruder understood its operation, set-up and use, it was decided to provide a comprehensive training program. This training included both classroom and hands-on training. Topics covered during the training period included:

1. Principles of operation.
2. Key Design features of the Insta-Pro.
3. Configurations used in set-up of the extruder for

the screw and die.

4. Start-up procedures for the extruder.
5. Shut-down procedures.
6. Operating procedures during testing.
7. Assembly and dis-assembly of the extruder.

5.2.0 Trial Runs Using Insta-Pro

Raw materials consisting of whole soybean, whole flint corn, white sorghum, and wheat were available for testing and training. Each material was ground into a grit powder suitable for use in the extruder. The grit powder had a fraction of particles larger than normally used for cereal extrusion with the Insta Pro. These larger particles are typically difficult to extrude and result in products having partially cooked pieces in the expanded mass giving a gritty mouth feel. Due to milling limitations in the plant and time factors, tests were conducted using these grit powders. For future reference, optimum particle size for the Insta-Pro Extruder should be as follows:

	Min.	Max.
Percent retained on US # 20 MESH	0%	0%
Percent retained on US # 40 MESH	0%	10%
Percent retained on US # 60 MESH	40%	80%
Percent retained on US # 80 MESH	10%	30%
Percent passing US # 80 MESH	0%	5%

Test trail runs were conducted to demonstrate the capablities and limitations of the extruder. It was decided to concentrate most of the trails using formulations which could be considered suitable for snack foods since the CIAE considered development of snack foods as a high priority. Various formulations tested during this period included:

1. 80% corn/20% soybean
2. 80% sorghum/20% soybean
3. 80% wheat/20% soybean
4. 50% corn/50% soybean
5. 70% corn/30% soybean
6. 100% soybean

Runs were made using both types of extruder die plates and each type of material. Problems with stabilizing the extruder were experienced when the single orifice die was used and processing cereal/soybean combinations. A suitable screw configuration could not be identified that would permit extruding consistent and homogenous product using this die. Despite this problem, it was possible to produce a high quality cooked soybean product with this head when trials were made.

When the multiple die plate with cutter head was received at the facility, it was installed and tested using similar cereal/soybean combinations as those used for the single die. Trial runs were more satisfactory than were the previous runs with the single die plate. Shaped products could be made but more expansion was desired for purposes of a snack food product over what was demonstrated. Greater expansion and better product quality can be achieved by further refining the screw configurations and operations of the extruder.

The use of this new head enabled two other problems to show up. The first dealt with the ability to consistently add water to the extruder during operation. This was due to a lack of consistent pressure and a lack of equipment to measure the flow while running. The second problem was related to the electrical system connected to the drive motor for the extruder. While operating under no load or light load conditions, typical motor noise was present, however, when the extruder would put higher load demand on the motor, a rapid increase in amperage would be seen and excessive high frequency vibrations could be heard and felt on the machine. Because of this problem it was not possible to determine when full load was reached making selection of processing conditions, configurations and other operating parameters difficult to identify.

The need for consistent power and moisture addition is critical to operation and control of the extruder. Therefore, consideration should be given to installing a better water pressure system with suitable flow measuring devices and that the electrical control system for the motor be checked by someone with experience in power distribution and motor control systems.

A number of problems were encountered during the trails that were unexpected, but at the same time provided a learning experience for the staff at CIAE. While it was not possible to fully develop expanded snack food products, the experience gained during these trails can be considered useful. Staff of CIAE have been trained adequately to continue with testing of the Insta-Pro as outlined in the next two report sections.

5.3.0 Immediate Experimental Work

The limited runs made during the test trails should not be considered adequate to fully understand and be familiar with the extruder. Instead, the test trails should be considered as only a demonstration of the extruder and additional trails using configurations used in the demonstration should be repeated for collection of more definitive information.. The ability to develop products and to operate the extruder depends on how familiar one is with the machine and its capabilities and limitations. It is, therefore, highly recommended that a

familiarization testing program be conducted with the Insta-Pro to enable understanding the effects of extruder configuration changes on machine operation and product characteristics. A recommended experimental plan is given below:

A. Experimental Objective -To understand how the Insta-Pro extruder configuration changes affect the ability to make satisfactory food products and the ability to control and operate the extruder.

B. Equipment - Insta-Pro 600 Extruder
Cooler
Product Test Equipment

C. Materials - Raw materials of 70% corn/30% soybean ground into grit powder and/or other blends as desired.

D. Methods - Extruder screw configurations will be changed by changing the sequence of steamlock sizes and die size.

- Determination of the effects due to a screw configuration change will be measured by recording operational conditions and measuring functional or physical attributes of the products.

E. Recorded Data

Extruder Operation
- Screw configuration
- Die size and type
- Feeder setting
- Water added
- Power
- Moisture content of input grain
- Moisture content of extrudate
- Temperature of processing by zones
- Product throughput

Product Evaluation
- Extrudate diameter
- Consistency test
- Bulk density
- Incorporation
- Flavour
- Colour
- Extrudate strength
- Others as required

F. Expected Results

1. Product characteristics as a function of moisture, processing temperature, screw configuration and die size.
2. Power requirements as a function of screw configuration, die size and material used.
3. Familiarization with operation and control of the extruder as a function of machine configuration changes.
4. Better understanding of the operation of the extruder.

5.3.1 Example Test Conditions

Table 1 gives a basic test protocol which if followed, would give a fairly clear picture of extruder performance when different screw configurations and a 70% corn/30% soybean mixture are used. It should be noted that it may not be possible to achieve certain designed test conditions. When this happens, it should be noted, to help define limitations of the process. It should also be noted that as test numbers get larger; a slight change in configuration is made resulting in more difficult extruder operations and more severe processing conditions. It may be necessary to modify the test matrix conditions to be more appropriate for the materials tested or product(s) desired.

One change to test conditions which might occur is if the multiple die plate is used with the face plate cutter. In this instance, it is necessary to consider several points.

1. The number of dies.
2. The size of each die.
3. The diameter of the product desired.

For this die arrangement, one might start by using only one die orifice (insert) and follow the pattern of Table 1. Alternatively, one could opt for more than one die insert. In otherwords, product would come out of two or more openings. The critical point to remember for using more than one die orifice is the total cross-sectional areas. For example, if the 1/2" single die were used, a cross/sectional area of 0.19635 inches squared is open at the end of the extruder. To determine the similar open area for more than one die opening, divide the area by the number of openings and calculate the diameters of each. Suppose two die openings were desired. The opening of each would be an area of 0.09818 inches squared, therefore, the diameter of each die would be 0.3536 inches. This diameter is not available as a

standard diameter. Instead, selecteion of the die would be made using the closest available standard die and in this case a die diameter of 0.375 incles would be used. A similar calculation could be done for other combinations or sizes. A column is provided in Table 1 which defines possible combinations of die openings.

Caution should be taken in sizing dies since the smaller the die opening, the more the pressure rise across the die. Pressure rise across the die is proportional to the cross-sectional area, diameter and physical dimensions of the die. Higher pressures can result in excessive expansion or plugging of the extruder, therefore, prudent selection should be made of die configurations used with this type of die plate. Proper selection will become easier with experience. As the die diameter decreases, the ratio of the die diameter to the largest particle size in the raw material decreases and because of this factor, starting of the extruder is also more difficult.

Each one of the test conditions outlined will require sample analysis. Running the tests without recording definitive information on the physical attributes of the product and functional characteristics gives little information. Tests recommended were listed earlier and are defined below:

1. Extrudate Diameter - Quantifies the amount of expansion and usually expressed as the ratio of the extrudate diameter to die diameter squared.

2. Consistency Test - Gives a method of quantifying the degree of cook. The test is performed by combining 100 grams of product in 400 grams water, then filling a cylinder with the mixture followed by lifting the cylinder allowing the mixture to flow out on a glass plate. The resulting flow diameter is measured after one minute. For cereal products, the smaller the diameter, the higher the degree of cook and usually the higher the processing temperature.

3. Bulk Density - Another method of evaluating expansion.

4. Incorporation - Test done to evaluate how well product goes into solution. A good test for food products which are intended to be instantized and rehydrated before use. This test is done by mixing 15 grams of ground product with 100 grams water. The 15 grams flour is placed in the water and mixed. The mixture is evaluated for the following:

Lumping - a scale from 0-10 is used, with 0 being free from lumps and 10 being very lumpy.

Smoothness - a scale from 0-10 is used, with 0 being grainy and 10 being soft and smooth.

Settling - a scale from 0-10 is used with 0 being no settling and 10 equal to large amounts of settling.

5. Flavor-color - subjective tests comparing one sample to another and ranking in order.

6. Extrudate Strength - Shear test on extrudate pieces done in shear to quantify the strength of the expanded extrudate piece and give insight into textural changes caused by extrusion.

The above experimental plan might be repeated for other combinations of the same ingredients. For example if the same series of tests were to be run on 50/50 and 80/20 combinations, a significant amount of knowledge on the extruder operation could be generated. In addition, consideration might be given to running similar tests for other cereal/soy formulations or, at a minimum, running these formulations at selected extruder configurations for comparison and expanding the knowledge base. Upon completion and analysis of the test phase, it is then possible to consider product development.

5.4.0 Product Development Tests

Tests to develop products carry a different objective from those discussed in section 5.3. Here the objective is to attain a certain product form or functionality which requires adjusting the process to achieve this goal. Therefore, a working knowledge of the process obtained by conducting familiarization experiments is essential. A case example is presented below to show the technique required to develop a product.

Objective To develop a corn/soybean product suitable for a snack food with good textural and mouth feel.

Formulation- 80% corn/20% soybean.

Procedures - Examine and consider potential configurations and process conditions which produce satisfactorily expanded pieces (Reliance on the work of section 5.3 is required). Extrude product using these conditions.

- Evaluate the products made against each other and select one but not more than two products with satisfactory qualities.

Suppose that during comparison it was found that the best sample came from a run made with a screw configuration of S-S-10P-S-10-S-8-S-8 with a 1/4" die and at a temperature of 130°C. The next steps to take are the following.

- Configure extruder as noted above and extrude the sample again to insure repeatability. Also run conditions around the selected point. For example, runs at 120, 125, 130, 135, 140°C might be made to insure that proces conditions are optimum.

- Evaluate Products made and compare samples. Finalize processing conditions and equipment configurations.

- Make at least two additional processing runs to insure repeatability of the process.

Note that the evaluation mentioned involves the use of data collected from both the processing tests and quality checks. Once all of the above conditions are satisfied, then the product is ready for acceptability tests by consumers. If results from consumer tests are positive, then a product has been developed.

5.5 Summary of Work with Insta-Pro

With the training and test trials it has been possible to demonstrate some of the capabilities and limitations of the Insta-Pro. Only with additional tests is it possible to develop a suitable knowledge of the equipment to enable development of good food products. The necessary "seed" knowledge has been given and equipment is available at the pilot plant to continue testing and eventually develop products. Progress is dependent on how aggressive the staff are in learning and using the equipment.

6.0 Wenger X-5

The pilot plant also has available a Wenger X-5 extruder for testing. This small unit is suitable for testing on a laboratory basis but does not lend itself well to making products which can be duplicated on pilot scale or production scale machines. Since the extruder is small, capacity is low which might allow it to be used for preliminary screening tests of raw materials. By testing on this extruder first, it can be estabished with little cost whether a material can be extruded. If so, then a similar product can be made using larger scale machines, keeping in mind that product functionalities and physical characteristics might be considerably different between the two extruders.

The other instance for which this extruder can be used is for undertanding theoretical principles of flow, heat transfer, and kinetic reactions during extrusion. While these tests do not result in tangible products, they do contribute to basic knowledge of the extrusion process. CIAE staff will have to decide which of these functions or maybe both that the unit will serve.

Within the pilot plant, sufficient ancillary equipment is available to support this extruder. Configurations are limited given the amount of spare parts available, therefore, consideration might be given to ordering additional screws and barrels to increase the flexibility of testing.

6.1.0 Training

In order to insure that everyone working with the extruder had a basic understanding of its operation, set-up and use, a brief training discussion was held. Topics covered during the training included:

1. Principles of operation
2. Key design features of the Wenger X-5
3. Set-up of the extruder
4. Start-up procedures
5. Shut down procedures
6. Operating procedures
7. Assembly and disassembly of the extruder

6.2.0 Trial Runs using the Wenger X-5

Materials similar to those listed for the Insta-Pro were made available for testing. Due to the scale of the extruder, all raw materials were ground to as fine a flour as possible with the milling equipment available.

Test trails again were set-up to demonstrate the capabilities and limitation of the extruder. Materials tested included:

1. 80% corn/20% soybean
2. 80% sorghum/20% soybean
3. 80% wheat/20% soybean
4. 100% soybean

Trails using the Wenger extruder and recommended procedures by Wenger as outlined in their operators' manual were not satisfactory. Mostly, problems arose due to the water system and inability to continuously inject water into the extruder during operation. Typically, a run consisted of start-up, a period of transition, failure to inject water, then a plug. Attempts were made to inject the water under high pressure using compressed air, however, extended runs were still not consistent and plugging occured. The operation of the Wenger using the compressed air/water injection system may work when using other specific products and extruder configurations than those available and used at CIAE. If the extruder were to be operated consistently under the author's supervision, reliance on the water injection system would be avoided.

In order to overcome the water injection problem and get the extruder to work consistently, operations should be done independent of the water application system. Therefore, consideration should be given to tempering raw materials to the desired moisture levels and feeding these materials for testing. The water application system would then be used only for start-up and shut down. All other tests should be run with uniformly distributed pre-moistened materials having different moisture contents.

The tempering process can be achieved by calculating and adding to the flour the amount of water required for the appropriate moisture content, mixing adequately and allowing the mixture to equilibrate for 12-14 hours at 4° C (Minimizes Fermentation). The formula used to determine the water to be added follows:

$$X = \frac{Q\ (Y-M)}{1-Y}$$

Where: Q = Quantity of flour blend, kg
M = Moisture content of flour blend, decimal
Y = Final moisture content of flour blend, decimal
X = Quantity of water to add, kg

To test the operation of the extruder, several moisture levels could be prepared one day, stored in the 4 C refrigerator or air conditioned room and tested the next day. As a starting condition for the extruder, preparation and extrusion of materials tempered to a wet basis moisture content of 18%, 22%, 26% might be attempted. These moistures are within a range over which normal expansion of corn flour without soybean occurs. With soybean added, some adjustment to moisture ranges may be necessary and can be determined through testing. Also, higher moisture tests can be attempted provided the extruder feeding device is capable of handling the product consistently. If high moistures in the range of 30-35% cannot be fed, then consideration of adding water with the injection system may be necessary, but when this much water is required, the injection system may be less likly to cause problems. Alternatively, the product or flour blend could be tempered to a moisture level of 20% (for example) then during extrusion, the additional required water added with the injection system to make up the difference in moisture.

6.3.0 Immediate Experimental Work

Similar to the Insta-Pro, it is essential that time be allocated to becoming familiar with the capabilities and limitations of the Wenger X-5. Because of the design and operational nature of this extruder, a number of operational variables can be changed including:

1. Process Temperature in eight different zones.
2. Screw speed
3. Feed rate
4. Moisture during processing
5. Screw configuration
6. Die diameter
7. Barrel configurations
8. Steam and water inputs along the length of the barrel.

Because of the extensive number of variables it is important to test as few variables as possible at a time to minimize the effects due to variable dependency. The most expeditious way of approaching an understanding of the extruder is to study the effects of changing one process condition at a time while holding other conditions fixed. For example, the following tests might be conducted:

A.	Experimental Objective	:	To understand the changes in product extruded and measurable extruder criteria when changing screw speed, moisture and temperature.
B.	Equipment	:	Wenger X-5 Product evaluation equipment
C.	Materials	:	Any cereal/soybean combination in flour form. Note: This test might be run with several combinations and/or materials.
D.	Methods	:	Three levels of screw speed, moisture and temperature should be selected which produce noticeable changes n the extrudate. This will form a 3x3x3 matrix of 27 test points. Feed rate, screw configuration, die diameter and barrel configuration would remain constant. Note:To study the effects of variables other than screw speed, moisture and temperature, the 3x3x3 matrix could be run at different variable levels such as different feed rates, die diameters, etc. Thus giving more levels to the test matrix.

All tests should be run, samples collected and measured for product quality.

E. Recorded Data

Extruder Operation
- Screw configuration
- Die size
- Feeder setting
- Water added
- Power
- Moisture content of input material
- Moisture content of extrudate
- Processing temperature at die and where desired along barrel
- Output from extruder
- Input of steam and water along barrel
- Screw speed

Product Evaluation
- Extrudate diameter
- Extrudate strength
- WSI
- WAI
- Others as required

F. Expected Results

1. Product characteristics as a function of each controlable variable.
2. Power requirements as a function of each controlable variable.
3. Familiarization with operation and control of the extruder as a function of changes in extruder conditions and configurations.
4. A better understanding on how each variable influences product quality and extruder performance.

6.4.0 Summary of Work with Wenger X-5

Only a small portion of the possible text combinations were attempted in trials. The intent was only to initiate work with the extruder and efforts were satisfactory in accomplishing this goal. Further testing of the machine is necessary to provide a better understanding of the extruder and extrusion variables. While the machine has limited application, it is a suitable research tool for understanding extrusion priciples.

7.0. General Observations of the Facilities at CIAE

The pilot plant area while adequate does require additional items and in some cases corrective measures to make the facility a functional and safe environment to work in. The following summarizes observations:

7.1.0 Electrical Wiring - It is important to insure both the safety of personnel and assurance of consistent and appropriate power controls and distribution. It would be in the best interest of CIAE to seek assistance to examine the current adequancy of the wiring, motor controls, safety device, etc. in the pilot plant, to minimize the chances of frequent electrical failures and the possiblity of any health hazard. Resources such as the State Electrical Board, commercial companies that specialize in motor controls, and others might be asked to evoluate the needs in the plant

7.2.0 Tools - Extruders require a minimum amount of support equipment. It is important to have a set of tools dedicated only to the extruders. It is recommended that a set of tools consisting of the following be purchased, labeled, and used solely for the extruders:

1- Socket and drive set with socket sizes 1/8" - 1 1/2" by 1/16" increments. (American standard, not metric)

2- One set of open end and box end wrenches spaning the range of the socket sizes. (again American standard)

3- One machine hammer (250 gram)
4- One machine hammer (1000 gram)

5- Set of flat blade and phillips screw drivers

6- Set of adjustable wrenches size 20 cm, 30cm or equivalent

7- Set of punches and chizels

8- 1 set of taps and dies for American thread

9- Miscellaneous pliers, pipe wrenches, etc., to accommodate service of equipment.

10-Then above tools should be kept in the plant in a designated area, such as a tool room, in a way so as to be easily accessible when needed.

7.3.0 Specific changes or additions for Insta-Pro Extruder.

A. Add Water rotameter to enable measurement of water flow into the extruder. Specifications for such equipment are given in Appendix IV.

B. Relocate controls for extruder so that they are within an arms length of the extruder.

C. Installation of a conveyor to move product from extruder outlet to cooler inlet.

7.4.0 Water System

A water system had been installed that used gravity to provide necessary pressure for water to the extruders. In addition, a pressure booster pump was installed to help generate pressure. To conserve water, a return line to the tank should be installed to close the system and improve water conservation practices. Alternatively, a pressure system consisting of a

bladder tank and jet pump would be far supperior for the plant and would replace the existing system providing the necessary water volume and pressure requirements for the extruders.

7.5.0 Sanitation Practices

Since this lab is to be a food lab, the appearance and cleanliness sould reflect this fact. Currently, the building and equipment need to be cleaned and reorganized. Some helpful suggestions include:

- Organize specific locations for each piece of pilot equipment and not use the area for any other storage of materials other than those that are needed for the equipment.
- Remove unwanted debris and unnecessary junk from the facility.
- Scrub floors with soap and water regularly. Wash or wipe off equipment regularly. Sealing the concrete with an appropriate sealing compound would improve floor maintenance.
- Keep the facility painted.
- Install screens on windows and doors to reduce fly and insect contamination.
- Make sanitation a priority.
- Operators of the plant should wear white overalls and cap while working in the pilot plant.

7.6.0 Provision for Separate and Accessible Spare Parts

While setting up or operating extrusion equipment, it is essential to have access to necessary tools and parts. The current practice in the pilot plant is to lock all tools and parts in a cabinet for which there exists only one key. It is the experience of the author that the practice of issuing only one key can at times cause unnecessary delay in operations since the person responsible for the key can be off doing other assigned work. Therefore, it is recommended that a separate cabinet for extruder parts be made available with the key remaining in the pilot plant. Alternatively, two keys could be issued for the existing cabinet, one key would be given to the

currently responsible person for all the keys and one additional key would remain with one of the scientists in the building.

8.0 GBPUAT, Pantnagar Visits

A visit of two days was made to G.B. Pant University of Agriculture and Technology in Pantnagar. Both the College of Technology and Department of Food Science and Technology were visited and dicussions held on current activities in the area of soybean utilization. The University provides a forum which permits detailed studies of various aspects of food processing not available at the Bhopal facility.

Activities currently undertaken in suport of the SPU by the College of Technology include:

1. Recovery of oil from extruded soybean - studies have been undertaken to define the extractability and extraction rates from flaked and extruded soybean to enable quantifying the advantages of the various soybean conditioning processes.

2. Recovery of oil from enzyme treated soybean - studies are being completed in which enzymes are being used to break down the oil containing cell walls in soybean as a means of freeing the oil for extraction either by expelling or solvent extraction.

3. Definition of extruded soybean products - rather than specifying the processing conditions, studies are being made into how best to measure quality of processed soybean for oil extraction making the process independent of extruder type.

4. Development of a five year plan on extrusion which has goals of developing ultra-low cost extrusion processes for rural operations, to develop a resource base on extrusion, to advance the frontier of knowledge in extrusion and to provide facilities and faculty support for educating graduates of the college.

In the College of Food Science and Technology activities are also being undertaken to develop utilization of soybean. Emphasis has been placed on utilizing defatted soybean meal as a flour extender to make chappaties, cookies and other baked products. Other uses being studied include utilizing defatted soy flour for making soymilk, paneer and a pressed and fried noodle.

8.1.0 Facilities

Both the College of Technology and Department of Food Science & Technology have well equiped laboratories for developing processes to make foods having soybean as a base. One emphasis of both groups is the development of extrusion processing and excellence. Extrusion equipment is available at the University including the following:

1. Brabender Co-Extruder - Housed in the College of Technology.

2. Wenger X-5 - Housed in a pilot plant managed by Food Science and Technology.

Both extruders are currently in a state of disrepair. There was no clear evidence to support activities to repair these units other than faculty indicated they were arranging for repairs. The Brabender has a defective feed drive which could be repaired or replaced. The Wenger X-5 has a more serious problem and requires parts to rebuild the central bearing and screw-shaft holding device.

The ability to use the extruders and produce research is a critical factor in establishing a center for excellence. It is recommended that the extruders be repaired and new research in extrusion begin to enable development and progress towards such a center.

8.2.0 General Observations

There appears to be a need for greater coordination of soybean processing research being conducted at GBPUAT and the CIAE. An annual research agenda should be jointly developed and specific responsibilities assigned separately to each group to avoid duplication. There should be provision made for each group to participate and conduct research in the other group's laboratories and pilot facilities since each group has equipment not necessarily available at the other location. This would allow greater utilization of existing equipment, enhance research potential and build upon cooperation between the groups.

Colorado State University as well as other Universities in the United States have mandates which involve education, research, service and extension. The service and extension function is a form of outreach to improve community environment, living conditions or technology. It is apropriate to consider the same functions for GBPUAT, yet this element does not seem to

exist at any identifiable level. It is important for academia and industry to work close with each other to learn as well as help each other. Some proprietary factors would have to be considered under this arrangement, however, to develop soybean utilization fully, cooperation with industry should be considered by the groups at GBPUAT. Without this cooperation, directions of research can take different paths with little progress towards improving the well being or needs of the populace or industry.

8.3.0 Future Activities and Cooperation

The College of Technology has had requests for assistance to design plants for various purposes including extrusion operations. It was requested that CSU provide information on plant design to the College as a means of assistance. CSU is not in a poistion nor has specific information and manuals on plant design. Instead, it was recommeded that CSU send examples of planning documents for use by the group. In addition, it was discussed briefly that cooperation between the two Universities might be developed on training and implementing plant design. Individuals might come for training at CSU and/or CSU staff could provide specific plant design assistance to the College when a request and agreement for a design was made to the College.

9.0 Recommendations

9.1 It is recommended that studies continue with the extrusion equipment as outlined in the report to familiarize the staff with the extruders. The most difficult part of working with extruders is gaining basic experience. A systematic approach, as outlined in the report, to understanding how to operate and set-up the extruder would be of the greatest benefit to the CIAE initially. The time and expense required for these tests would net many more returns in the ability to produce new products than by making uneducated guesses on extruder configurations and processing conditions.

9.2 It is recommended that after the initial studies are completed, effort be devoted to developing new products using the extrusion equipment. Information and knowledge gained in the familiarization tests can be used effectively for this phase. Snacks, precooked cereal/soy products for drinks, soup or curry bases, full-fat soybean flour, low-fat soybean flour all might be possible products that can be developed.

9.3 It is recommended that additional equipment consisting of water flow measuring devices, tools, and storage facilities for spare parts be obtained locally for use with the extrusion equipment. When operating the Insta-Pro extruder some problems may have been avoided if proper water flow measuring devices were available. Specifications for the equipment to measure and control the water flow were provided. Tools, as outlined in the report, should be purchased and stored in an accessable location for use in the plant.

9.4 It is recommended that additional spare parts for the Insta-Pro extruder be purchased to insure a satisfactory, inventory for replacement as needed. Due to problems arising during the training period, some vital spares were depleted such as the injector for water, etc. Having one or more additional spares would minimize the amount of down time should the same item break in the future.

9.5 It is recommended that cooperation between SPU and Colorado State University continue. One area in which coperation might occur is in continued work with the extruder and product development. While it is the writers' opinion that work can continue using the extruders without additional technical assistance, occassionally, problems arise which can be solved with additional input. Some of these problems can be addressed through cable or mail while others may be serious enough to merit on site assistance. Colorado State is prepared to help in any way possible along these lines.

A second area of cooperation may come from a need to promote and disseminate the knowledge on extrusion throughout India. This effort could be carried out through workshops, demonstrations, etc. Again Colorado State University is willing to assist in these efforts in the future should it be required and requested.

9.6 It is recommended that the CIAE pilot plant electrical system be examined for its safety and adequacy in the plant. While all electrical wiring is functional, the methods used to wire the equipment are unsafe and measures should be taken to insure that the electrical connections are properly done as per electrical codes. Motor controls and circuits should be rechecked to insure that errors have not been made in the installation and that size and functionality of the equipment is adequate.

9.7 It is recommended that CIAE purchase a small mixer to prepare materials for extrusion. Given the potential need to pretemper raw materials before extrusion for which uniformity of mix is key to the operation of the extruder, a small mixer should be available. Raw materials were prepared by hand during the trials which gave mixes that were not consistent and uniform. Given the food machinery industry in India, it should be possible to locate a small paddle or ribbon mixer for purchase thus eliminating the need to import. Alternatively, consideration might be given to an electrically driven concrete mixer which serves well as a mixer.

9.8 It is recommended that the existing extrusion equipment at facilities in Bhopal and Pantnagar be developed to their full potential through testing and research. By developing and conducting research with these extruders each group can demonstrate the capabilities and capacity to conduct research using extrusion technology. A side benefit of developing and demonstrating suitable and sufficient research is an increased potential for acquiring additional funds to continue research from funding organizations with interests in the areas of research. Ultimately potential funding for additional extrusion equipment can also be a benefit of good research effort.

9.9 It is recommended that the spare parts for all equipment be evaluated carefully and a sufficient inventory be made available. Acquiring equipment is important to research but equally important is mantanence of the equipment to keep it operating. Funds should be allocated under the SPU project to purchase additional spares even at the expense of a reduction in funds to buy equipment. Priority should be placed on purchases of parts and misellaneous equipment that will keep the equipment functioning for long term operations. Second priority needs to be placed on purchasing capital equipment at this time.

Appendix-1

TERMS OF REFERENCE
MR. RONALD E. TRIBELHORN
SHORT-TERM CONSULTANT - SPU PROJECT

MARCH 12 - 30, 1990

During the three-week assignment in India, Mr. Tribelhorn will perform the following duties:

1. To hold discussion with the Project Director, SPU; and the Director CIAE-Bhopal, and to evaluate status and needs of the sub-project.

2. To adivse on the operation of Wenger X-5 Extruders.

3. To advise on the use of Insta-Pro Jr. 600 Screw configurations for preparation of various soybased food items.

4. To advise on the design and selection of extruder components for preparation of soybased food items on Wenger X-5 extruder.

5. To hold discussion on development of quality evaluation techniques for extruded products.

6. To give lecture on details of extrusion cooking/operation and maintenance of various types of low cost extrusion cookers.

7. To hold discussion and give lecture on recent advances in extrusion-cooking technology and other related matters at the SPU Sub-Project Center in GBPUAT, Pantnagar.

8. To submit written report summarizing consultancy activities and recommendations to the Sub-Project.

9. To give an oral debriefing to ICAR/USAID and Winrock before departure from New Delhi.

Appendix II

ACKNOWLEDGEMENTS

The author wishes to acknowledge the help and assistance throughout the assignment of the following people:

1.	Ms Surbhi Bhat	-	Winrock/Washington DC for arranging and rearranging my travel schedule to accommodate me and for assistance in preparation of the trip.
2.	Dr. A. Colin McClung	-	Winrock/Delhi for his assistance and cooperation for helping complete my assignment.
3.	Mr. P.S. Srinivasan	-	For his coordination and planning of the authors schedule and for helping to complete the assignment.
4.	Mr. R.T. Patil	-	CIAE for his help and assistance on site, for arrangeing the timely transportation and for coordinating all activities of CIAE.
5.	Dr. Nawab Ali	-	For his support and help in the assignment.
6.	Staff of CIAE	-	All of the staff at CIAE for their hard work and help in all activities associated with this consultancy.
7.	Dr. B.P.N. Singh	-	For his help and direction during the visit at Pantnagar.
8.	Dr. Y.C. Agrawal	-	For his time in discussing programs and showing the facilities at Pantnagar.

9. Dr. B.K. Mital - For his time in discussing programs and showing the facilities at Pantnagar.

10. Dr. Surjan Singh - For accompanying the author to Pantnagar making the trip more pleasant and easier to complete.

11. Ms Lillian Cooke - For assistance in typing this report.

Appendix-III

Itinerary

March 12 - 31, 1990

March 12	-	Arrive Delhi 1:25 AM via PAN AM
March 12 (Mon)	-	11 A.M.: Met with Winrock Staff Persons contacted: Dr. A. Colin McClung, India Coordinator Mr. P.S. Srinivasan, Admin. Specialist
	-	12 (Noon) Met with USAID Staff Persons contacted: Mr. John A. Becker, Chief,USAID/AGRE Dr. Surjan Singh, Program Specialist
	-	3 P.M.: Met with ICAR Officials Persons contacted: Dr. T.P. Ojha, Dy.Director General Dr. Anwar Alam, Asstt. Director General
March 13 (Tue)	-	6 A.M. Depart for Bhopal
	-	8 A.M. Arrive Bhopal
	-	10 A.M. Met with CIAE Officials Persons contacted: Dr. N.S.L. Srivastava,Director Dr. Nawab Ali, Project Director General Dr. A.P. Gandhi, Sr. Scientist, SPU
	-	2 A.M. Met with CIAE Staff Persons contacted: Mr. R.T. Patil, Scientist Mr. Jaswant Singh Dr. A.P. Gandhi
March 14 (Wed)		9:30 A.M. Delivered lecture on extrusion processing and aplications
	-	2 P.M. Met with staff to plan extrusion trails and tests
March 15 (Thur)	-	Insta-Pro Extrusion trails
March 16 (Fri)	-	" " " "
March 17 (Sat)	-	" " " "

March 8 (Sun) -	REST DAY
March 19 (Mon) -	Insta-Pro Extrusion trials
March 20 (Tue) -	" " " "
March 21 (Wed) -	Wenger Extrusion Trials
March 22 (Thur)-	" " "
March 23 (Fri) -	Wenger & Insta-Pro Trials
March 24 (Sat) -	Wenger trails and wrap-up of activity

Persons Contacted and worked with:

Mr. R.T. Patel
Dr. Jaswant Singh
Mr. Y.K. Ojha
Dr. A.P. Gandhi
Mr. R.N. Tripathi
Mr. Patle
Mr. Suresh
Mr. Dubey
Mr. Lal
Mr. Mistry
Mr. Ramesh
Mr. Sanjay
Mr. Gupta

March 25 (Sun) -	Travel from Bhopal to Pantnagar
March 26 (Mon) -	Met with officials at GBPAUT, College of Technology and Department of Food Science & Technology

Persons Contacted:

Dr. B.P. Singh
Dr. Y.C. Agrawal
Dr. B.K. Mital

March 27 (Tue) -	Further meetings at Pantnagar. Visit laboratories. Returned to Delhi.
March 28-30 -	Final Report preparation and meetings with Winrock, USAID and ICAR Officials.

...

Variable area flowmeters

Get dependable flow measurement with these variable area flowmeters. They're ready for panel mounting in your industrial process control system, or bench mounting in a laboratory flow setup. Available with metal or Teflon® valves, with 65-mm or 150-mm flowtubes.

These versatile instruments measure flows with ±2% accuracy full scale—use the same flowtube for air, gas, and water. Repeatability is ±0.25%.

Ideal applications include metering carrier gases in chromatography, indicating and controlling gases in semiconductor manufacturing, and measuring liquids and gases in pilot plants and process flows.

Easy to read—a ceramic scale is fused onto the flowtube, and a special window magnifies the scale for easier reading. A vertical tangential locator line ensures hairline accuracy in reading float position. Universal millimeter scale lets you work with many different fluids at diverse pressure and temperature conditions. Simply refer to the calibration sheets (supplied) to interpret flow readings.

Easy to install. Each flowmeter comes with two panel-mount retaining nuts. See diagrams at right for details.

Accessories make your system more versatile (see below right). Order ⅛" pipe-to-tube adapters to simplify setup. For high pressure applications, use reinforced PVC tubing with tubing clamps. With the optional tripod base, you can monitor up to three flows using any combination of 65-mm and 150-mm flowmeters.

Two sizes to meet your applications:

The 65-mm models are the right size for monitoring and controlling flow from a centralized control panel in the plant. They also make an excellent backup system to electronic flow systems in the event of a power failure.

The 150-mm models offer better resolution by spreading the scale over a greater length. Like the 65-mm models, they contain a built-in needle valve for dependable flow control.

The 150-mm high resolution flowmeters contain a 16-turn high precision metering valve. Get greater flow rate control than with standard flowmeters—a feature especially useful when performing chromatography studies.

Good chemical compatibility. Fluid contacts aluminum fittings with Buna N O-rings and packings in the aluminum model or 316 stainless steel fittings with Viton O-rings and packings in the stainless-steel model. Borosilicate flowtubes and floats of black glass, stainless steel or carboloy are also wettable parts in both models. All housings are aluminum.

Maximum operating pressure is 200 psig; maximum fluid temperature is 250°F (121°C). Minimum flow rate is about 1/10 of maximum shown in tables on facing page. Inlet and outlet connections are ⅛" (F)NPT; outside threading for panel mounting nuts.

Shipped fully assembled. Order the exact combination of materials and flow rates to match your application (see facing page). Select the flow rate, flowtube length, then fitting material; specify that catalog number when ordering. Call our Flowmeter Service Department for more information at 1-800-323-4340.

Panel-mount installation

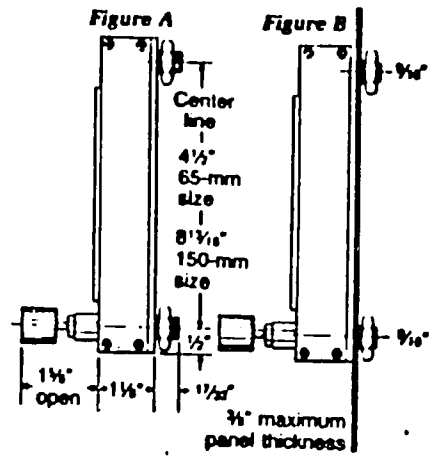


Figure A: Dimensions show flowmeter side view. Face width (not shown) is 1¼". Use the center line dimensions for drilling panel.

Figure B: Drill two 9/16" holes to fit inlet and outlet. Maximum panel thickness is ⅜". Use the two retaining nuts (supplied with every unit) to secure flowmeter.

Tripod bases

Bench mount up to three flowmeters in the lab—any combination of 65-mm and 150-mm models. Three leveling screws and spirit level are built into acrylic base.

Cat. no.	No. of flowmeters	Price
J-3226-10	1	$30.00
J-3226-20	1 or 2	33.00
J-3226-30	1, 2, or 3	35.00

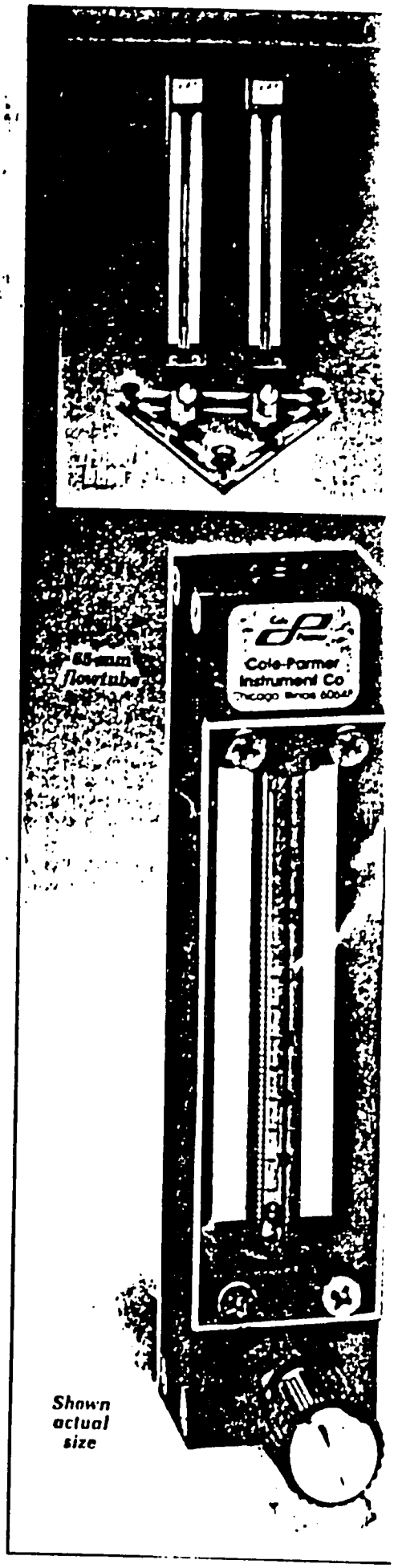
Pipe-to-tube adapters

Polyethylene straight adapters			
Cat. no.	MIPT	Tubing ID	Price/12
J-6450-10	⅛"	3/16"	$3.12
J-6450-11	⅛"	¼"	3.24
J-6450-12	⅛"	⅜"	3.36

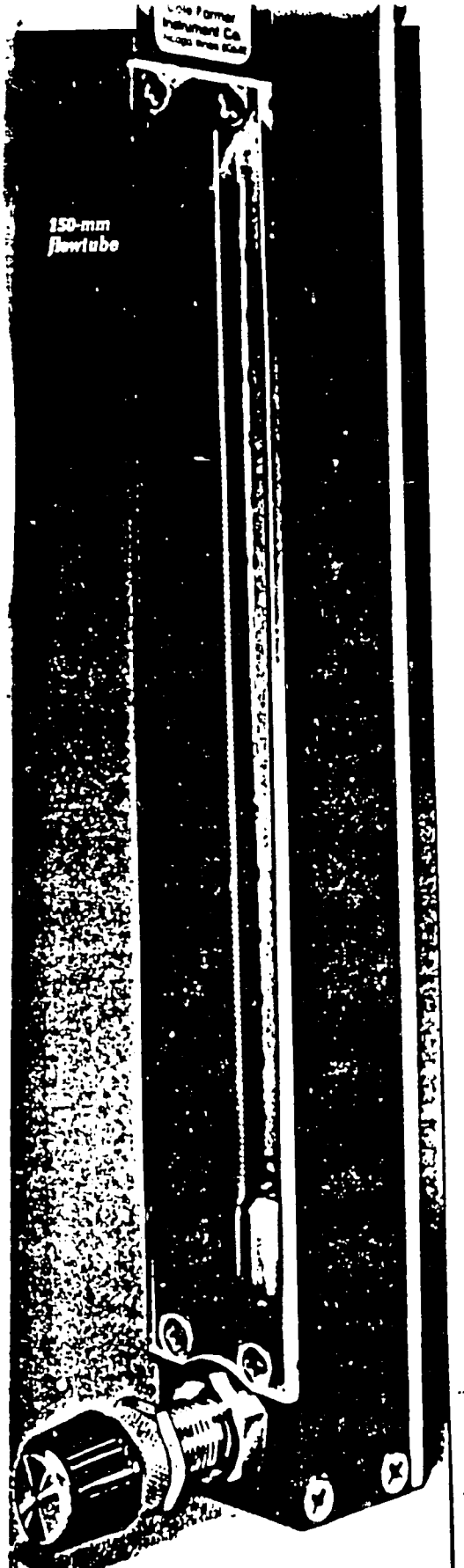
Reinforced PVC tubing

Cat. no.	Tubing ID	Price/ft
J-6401-00	3/16"	$0.27
J-6401-01	¼"	0.33
J-6401-02	⅜"	0.40

Teflon, Viton—Reg TM E.I. du Pont de Nemours & Co.
Kel-F—Reg TM 3M Co



Shown actual size



For outstanding chemical resistance, order a Teflon model (see page 267) with aluminum frame, sapphire float, valves of Teflon TFE, and Kel-F valve spindle and fittings. O-rings are Kalrez.

Flowmeters with 65-mm flowtubes						
Aluminum model		316 stainless steel model		Max flow rate*		Float material
Cat. no.	Price	Cat. no.	Price	Air (ml/min)	Water (ml/min)	
J-3216-00	$ 53.00	J-3218-01	$132.00	5.64	0.23	Glass
J-3216-02	53.00	J-3218-03	132.00	20.76	0.658	316 stainless steel
J-3216-04	53.00	J-3218-05	132.00	50	0.539	Glass
J-3216-06	53.00	J-3218-07	132.00	151.2	2.71	316 stainless steel
J-3216-08	53.00	J-3218-09	132.00	130	1.41	Glass
J-3216-10	53.00	J-3218-11	132.00	328.7	6.94	316 stainless steel
J-3216-12	53.00	J-3218-13	132.00	175	2.15	Glass
J-3216-14	53.00	J-3218-15	132.00	515	13.23	316 stainless steel
J-3216-16	53.00	J-3218-17	132.00	1350	26.97	Glass
J-3216-18	53.00	J-3218-19	132.00	2680	70.67	316 stainless steel
J-3216-20	53.00	J-3218-21	132.00	2205	53.91	Glass
J-3216-22	53.00	J-3218-23	132.00	3942	117.88	316 stainless steel
J-3216-24	53.00	J-3218-25	132.00	2606	54.1	Glass
J-3216-26	53.00	J-3218-27	132.00	5284	154.44	316 stainless steel
J-3216-28	53.00	J-3218-29	132.00	6432	136.36	Glass
J-3216-30	53.00	J-3218-31	132.00	11,816	**	316 stainless steel
J-3216-32	53.00	J-3218-33	132.00	13,153	266.67	Glass
J-3216-34	53.00	J-3218-35	132.00	23,883	**	316 stainless steel
J-3216-36	63.00	J-3218-37	142.00	22,575	522	Glass
J-3216-38	63.00	J-3218-39	142.00	42,763	1261	316 stainless steel
J-3216-40	63.00	J-3218-41	141.00	62,147	1866	Carboloy
Flowmeters with 150-mm flowtubes						
J-3217-00	90.00	J-3219-01	176.00	25.3	0.293	Glass
J-3217-02	90.00	J-3219-03	176.00	76.68	1.08	316 stainless steel
J-3217-04	90.00	J-3219-05	176.00	52.04	0.53	Glass
J-3217-06	90.00	J-3219-07	176.00	156.54	2.45	316 stainless steel
J-3217-08	90.00	J-3219-09	176.00	94	1.10	Glass
J-3217-10	90.00	J-3219-11	176.00	263	4.9	316 stainless steel
J-3217-12	90.00	J-3219-13	176.00	376	5.07	Glass
J-3217-14	90.00	J-3219-15	176.00	835	19.38	316 stainless steel
J-3217-16	90.00	J-3219-17	176.00	845	16.30	Glass
J-3217-18	90.00	J-3219-19	176.00	1694	44.74	316 stainless steel
J-3217-20	90.00	J-3219-21	176.00	2142	47.24	Glass
J-3217-22	90.00	J-3219-23	176.00	4077	118.8	316 stainless steel
J-3217-24	90.00	J-3219-25	176.00	4618	81.3	Glass
J-3217-26	90.00	J-3219-27	176.00	9049	215.8	316 stainless steel
J-3217-28	90.00	J-3219-29	176.00	9640	212	Glass
J-3217-30	90.00	J-3219-31	176.00	18,409	512	316 stainless steel
J-3217-32	100.00	J-3219-33	186.00	23,150	540	Glass
J-3217-34	100.00	J-3219-35	185.00	43,943	1286	316 stainless steel
J-3217-36	100.00	J-3219-37	185.00	64,109	1812	Carboloy
High resolution flowmeters with 150-mm flowtubes						
J-3227-00	134.00	J-3229-01	246.00	25.3	0.293	Glass
J-3227-02	134.00	J-3229-03	246.00	76.68	1.08	316 stainless steel
J-3227-04	134.00	J-3229-05	246.00	52.04	0.53	Glass
J-3227-06	134.00	J-3229-07	246.00	156.54	2.45	316 stainless steel
J-3227-08	134.00	J-3229-09	246.00	94	1.10	Glass
J-3227-10	134.00	J-3229-11	246.00	263	4.9	316 stainless steel
J-3227-12	134.00	J-3229-13	246.00	376	5.07	Glass
J-3227-14	134.00	J-3229-15	246.00	835	19.38	316 stainless steel
J-3227-16	134.00	J-3229-17	246.00	845	16.30	Glass
J-3227-18	134.00	J-3229-19	246.00	1694	44.74	316 stainless steel
J-3227-20	134.00	J-3229-21	246.00	2142	47.24	Glass
J-3227-22	134.00	J-3229-23	246.00	4077	118.81	316 stainless steel
J-3227-24	134.00	J-3229-25	246.00	4618	81.3	Glass
J-3227-26	134.00	J-3229-27	246.00	9049	215.8	316 stainless steel
J-3227-28	134.00	J-3229-29	246.00	9640	212	Glass
J-3227-30	134.00	J-3229-31	246.00	18,409	512	316 stainless steel
J-3227-32	144.00	J-3229-33	256.00	23,150	540	Glass
J-3227-34	144.00	J-3229-35	256.00	43,943	1286	316 stainless steel
J-3227-36	144.00	J-3229-37	256.00	64,109	1812	Carboloy

*Minimum flow rate is approximately 10% of the maximum figure. **Not recommended for use with water.

To determine which flowmeter to order for applications with gases other than air simply convert the maximum flow rate you wish to measure (F_q) to the equivalent flow rate capacity for air (F_{std}) using the formula below:

$$F_{std} = \sqrt{G} \times F_q$$

where G = specific gravity of the gas you wish to measure. Then find the maximum flow rate in the table above which would satisfy your calculated F_{std} value.

For example: You wish to use a 65-mm aluminum flowmeter to monitor the flow of propane in an application where the flow range has been defined as 200 to 2000 ml/min. Propane has a specific gravity of 1.562. so:

$$F_{std} = \sqrt{1.562} \times 2000 \text{ ml/min} = 2500 \text{ ml/min}$$

So to achieve maximum resolution with that type of meter, your best choice would be model 3216-18, with a flow range of 70.67 to 2680 ml/min.

Teflon, Viton, Kalrez—Reg TM E. I. du Pont de Nemours & Co. Kel-F—Reg TM 3M Co

TABLE 1. INSTA-PRO CONFIGURATION TEST PROTOCOL FOR 70% CORN/30% SOYBEAN COMBINATIONS

Test No.	Extruder Screw Configuration (1)	Single Die (2) Diameter	(3) Multiple Die Plate Possibilities: One die	Two dies	Three dies	Processing Temp. °C
1	S-S-10P-S-10P-S-10-S-08	1/2"	1/2"	3/8"	9/32"	110, 130, 150, 170
2	S-S-10P-S-10P-S-10-S-08	7/16"	7/16"	5/16"	1/4"	110, 130, 150, 170
3	S-S-10P-S-10P-S-10-S-08	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
4	S-S-10P-S-10P-S-08-S-08	1/2"	1/2"	3/8"	9/32"	110, 130, 150, 170
5	S-S-10P-S-10P-S-08-S-08	7/16"	7/16"	5/16"	1/4"	110, 130, 150, 170
6	S-S-10P-S-10P-S-08-S-08	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
7	S-S-10P-S-10-S-10-S-08	1/2"	1/2"	3/8"	9/32"	110, 130, 150, 170
8	S-S-10P-S-10-S-10-S-08	7/16"	7/16"	5/16"	1/4"	110, 130, 150, 170
9	S-S-10P-S-10-S-10-S-08	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
10	S-S-10P-S-10-S-08-S-08	1/2"	1/2"	3/8"	9/32"	110, 130, 150, 170
11	S-S-10P-S-10-S-08-S-08	7/16"	7/16"	5/16"	1/4"	110, 130, 150, 170
12	S-S-10P-S-10-S-08-S-08	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
13	S-S-10P-S-10-S-08-S-05	1/2"	1/2"	3/8"	9/32"	110, 130, 150, 170
14	S-S-10P-S-10-S-08-S-05	7/16"	7/16"	5/16"	1/4"	110, 130, 150, 170
15	S-S-10P-S-10-S-08-S-05	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
16	S-S-10-S-10-S-08-S-05	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
17	S-S-10-S-10-S-08-S-05	7/16"	7/16"	5/16"	1/4"	110, 130, 150, 170
18	S-S-10-S-10-S-08-S-05	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
19	S-S-10-S-08-S-08-S-05	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
20	S-S-10-S-08-S-08-S-05	3/8"	3/8"	5/16"	1/4"	110, 130, 150, 170
21	S-S-10-S-08-S-08-S-05	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
22	S-S-10-S-08-S-05-S-05	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170
23	S-S-10-S-08-S-05-S-05	7/16"	7/16"	5/16"	1/4"	110, 130, 150, 170
24	S-S-10-S-08-S-0-S-05	3/8"	3/8"	1/4"	7/32"	110, 130, 150, 170

1) Numbers represent steam locks
Letters represent screw segments

2) Single die and die plate

3) Multiple die plate with face cutter

4) Note: Some of the temperatures may not be possible for some configurations