DOCUMENTATION OF INTERNSHIP
AT
DRILCO, INC., HOUSTON, TEXAS
AND
FLUOR ENGINEERS & CONSTRUCTORS, HOUSTON, TEXAS

An Internship Report
by
John Michael Konopacki

Submitted to the College of Engineering of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF ENGINEERING

November 1977

Major Subject:

Interdisciplinary Engineering

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ABSTRACT

In fulfilling one of the requirements of the Doctor of Engineering program, an internship was conducted from June 1, 1976 to May 31, 1977 at two different Houston firms.

The first internship was conducted at the firm of Drilco, Inc. The primary engineering objective of the internship was to conduct a metrication impact study for the firm; this study was the basis for a report detailing the future metrication activites expected in the oil industry and how the firm can best meet these situations. Non-engineering objectives for this internship were also established. Investigations were conducted to determine the methods employed in the labor relations programs of the firm, methods used to conduct public relations campaigns, and how OSHA and EPA had impacted the firm. Additionally, arrangements were made to monitor a major management meeting.

The second internship was conducted at Fluor Engineers and Constructors, Inc., where three major engineering problems and one major non-engineering problem were addressed. Successful studies were conducted in updating two instrumentation standards, in designing an Emergency Shutdown System for a unique gas compressor, and in establishing the power requirements for the instrumentation at a gas processing plant. As a non-engineering assignment, all purchase orders and requisitions dealing with instruments for an Aramco gas plant were monitored to insure that the needed material would arrive at the jobsite when needed.

As a result of the lessons learned and the many experiences encountered during the internship, it is recommended that additional emphasis be placed on the use of vnedor data and vendor information sheets as instructional aids in basic and design courses. It is also recommended that additional course requirements be established in the fields of accounting and management, and that multiple internships of less than 6 months duration be encouraged.

ACKNOWLEDGEMENTS

Grateful acknowledgements are given to Dr. Charles Rodenberger without whose encouragement and understanding this entire endeavor would never have been possible. Also, thanks go to Dr. Ed Bailey and Mr. Dave Laura for their efforts and patience in guiding me through my work at Drilco and Fluor. Thanks also go to my Academic Committee members for their time.

A special note of appreciation goes to my wife for her love, devotion, and patience during the last 3½ years while I was working on this degree.

Dedicated to
And in Honor of

HUBERT JOHN KONOPACKI
Lieutenant Colonel
USAF
Deceased

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FORWARDING REMARKS

INTRODUCTION

This report is in partial fullfillment of the requirements of the Doctor of Engineering Program and its associated Internship Program. It covers the author's work in two firms during the period 1 June 1976 to 31 May 1977 and details the purpose, scope, and methods employed to perform the related engineering assignments. During the period covered, the intern performed duties in the Product Engineering Department of Drilco, Inc., a division of Smith International, Inc., from 1 June to 31 January and in the Control Systems Engineering Department of Fluor Engineers and Constructors from 1 February to 31 May. Through an unusual happenstance, the intern was offered the opportunity to receive indepth knowledge and training in two diverse industries which has proved to be of extreme value. This experience has greatly enhanced the worth of the internship to the extent that it has provided a broadened base for comparison and understanding of human and financial considerations. The final impact of the internship has yet to be felt in its entirety, but the experiences gained have been very useful both specificly and generally.

PURPOSE AND SCOPE

As with any internship, the ultimate purpose of the exercise was to gain practical knowledge in those areas related to the academic field being pursued by the student plus tempering his formal education with "real world" experiences.

To satisfy the technical aspects of the internship, two distinctly different systems were studied. At the Drilco plant the problems of the pending or projected metrication of the U.S., its industries, and the petroleum industry, in particular, were addressed, and a study was conducted to determine when, why, and how the oil tool manufacturing industry would convert to the metric system. At Fluor E&C a Saudia Arabian Natural Gas Liquification Plant (an NGL plant) was examined and specific, non-related systems problems were analyzed in detail.

Along with the engineering experiences offered by the program, non-technical, management related objectives were included to develop those skills needed by the modern engineer. These non-engineering objectives were established with knowledge of the intern's deficiencies with the hope that practical work might help him overcome his shortcomings. Specifically, as outlined in Appendix A, the purposes of the internship, aside from the purely technical aspects, were to:

(1) Allow the intern to work in a business environment, to deal directly with people of varying background and educational ability, and to gain experience in successfully managing a project of appropriate size.

(2) Develop an appreciation of the variety of problems/ situations found at varying levels of organization within a firm.

(3) Gain experience and exposure in dealing with multi-

level management structures and their associated problems.

It was felt by the author that all the stated and non-stated objectives of the internship were met, and that the experiences were of such a nature that the purposes of the internship were satisfied. Additionally, because of the unique position of the author (i.e., he was with the firm as an intern as opposed to the normal employee) he was able to: a) acquire a variety of different tasks which normally would not be delegated to a single person, b) make observations and be present during conversations not normally open to employees at his level, and c) interact easily with employees at several levels within the two firms.

This report will attempt to relate the significant aspects of the internship starting with the Drilco phase. In each case a brief history of the firm and its economic posture will be described so that the reader can better understand the circumstances of each internship. A technical discussion will be given covering the major areas of engineering training as well as a brief examination of "lessons learned" from each firm.

THE DRILCO INTERNSHIP

THE DRILCO INTERNSHIP

The first portion of the year long internship was conducted at the Drilco, Inc., plant located in Houston, Texas with the author working in the Product Engineering Department under the supervision of Dr. Ed Bailey (formerly of Texas A&M University). The major emphasis of this phase of the program was directed toward a metrication impact study; the study was to determine when the oil industry, and, hence, the oil tool manufacturing industry, would be converting to the metric system of weights and measures, and how such a conversion would be best implemented at Drilco. The study was initiated and completed in 7 months and was presented to the Drilco management at their September Manager's Meeting. (A copy of the report is given in Appendix B.)

In addition to the metrication report, a brief study was conducted on the feasibility of instituting geometric dimensioning along with the creation of a company-wide drafting standard. This study covered an indepth review of existing drawing practices at the plant plus a study of the impact of a plant wide training program of drafters, engineers, and machinists which would be required for both standardization of drafting techniques and for instruction related to the utilization of geometric dimensioning. This program was aided by the fact that a complete drawing review was required both for standardization and for estimating drawing conversion time for the metrication study. The study that was conducted was fashioned in such a manner that it served both purposes.

Prior to a discussion of the actual internship activities a brief history of the firm might prove to be helpful in evaluating the report.

HISTORY OF DRILCO

Drilco, Inc., was formed in the early 1950's as a Father/ Son(s) type service and inspection company located in west Texas. In its inspection capacity, the firm early recognized that many of the problems drillers were experiencing in the area were directly related to the poor quality of the drilling tools and their associated rotary shoulder connections. Viewing this as a golden opportunity, Drilco aquired a machine shop and began servicing damaged and worn tools, placing quality of workmanship as the prime advantage to their service. By the late 50's the emphasis within the company had shifted from the inspection phase to the machining phase of the firm's operation. This lead directly into the production of quality down-hole drilling tools. By the late 60's the firm had expanded to the limits of its available capital; needing additional finances with which to continue expantion, Drilco merged with a west coast drilling bit manufacturer, Smith Tools, from which emerged Smith International. In the early 1970's the Drilco operation had diversified to such an extent that reorganization of the firm into two separate companies was required. Thus, Drilco Industrial, Inc., of Midland, Texas, and Drilco, Inc.

of Houston were formed, splitting apart those operations associated with the mining industry and those associated with the oil tool industry. The tool manufacturing operation moved to a previous service center for Drilco located in south Houston and waited for the construction of a new plant. In 1974 the facilities were moved to north Houston into a fully air-conditioned building with operating room that was more than sufficient for the operating force at that time. By late 1975, however, the plant had reached almost full capacity and additional space was planned for in the form of an additional building adjacent to the present structures. This building, which is currently under construction, will house the drill pipe operation of the firm, an operation and line which are new to the firm.

PHILOSOPHY OF MANUFACTURING AT DRILCO

The current operational capacity of Drilco gives the firm much needed latitude in producing the high quality drilling tool it is noted for. To maintain this latitude Drilco has extended its manufacturing scope, and unlike most tool manufacturers, the firm maintains full production capabilities, subcontracting only those items where outside vendors can provide distinctly better quality at substantial savings. Organic to the Drilco manufacturing plant are two heat treating plants and a trepanning section, operations normally subcontracted to a firm specializing in these operations. Coupled with its large machining capabilities, the plant can exercise extended control over its operations and is free from constraints normally found in smaller operations which must rely on subcontracting to complete specialized manufacturing processes. Because of this "beginning to end" control over its production, the firm is in a much better position to maintain its desired quality in its tool production.*

ORGANIZATIONAL STRUCTURE OF DRILCO

There are two major personnel structures within the firm: administration and plant personnel. A significant portion of the total labor force for the firm can be found in one of these two areas. Sandwiched between these two groups can be found the two engineering departments. Both Product and Process Engineering have responsibilities which bind them to both major groups. To obtain an accurate picture of the firm's structure, it would be instructive to follow the processing of an order from receipt to shipping.

All orders at the plant are routinely processed through the sales department. From sales the order is passed to

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* However, such a diverse operation for the support of a relatively limited class of products does have its drawbacks. This type of plant configuration requires a significantly larger and diverse cross section of trained personnel to operate the different facets of the production line. Also, these additional production sections increase the requirements and problems associated with production and inventory control. Accountability of the product and the production line, processing, and personnel is a major subdivision of the administration of the firm.

Additionally, the advantages sought in maintaining the extended capabilities must be borne during slack periods, and during times of low sales, either production capacity must be carried on over head or a significant reduction in the labor force must be taken. This happened to Drilco in 1977 when 30% of the plant personnel were layed off.

Order Entry where the necessary administrative and accounting documents are prepared. Order entry serves the purpose of data dissemination and is a focal point in the order handling process. Upon leaving Order entry, the documents are sent to scheduling, engineering, and finally to the shop. Peripheral operations to those above include the data processing department which handles all computer related tasks, generating the necessary documents for the securing of and processing of the raw material for the order prior to the actual machining operations.

Before the order is released to the plant personnel, the two engineering disciplines enter the picture. Product Engineering has the responsibility to review the order and certify that the requested features of the tool will not cause premature failure or degradation of the product. Additionally, the department will provide all necessary engineering data regarding the physical dimensions and properties of the tool. Process Engineering is responsible for defining the required tools for producing the item and insuring that these tools are available at the necessary time.

Raw material is stored in an area between the main machining plant and the heat treating facilities. In the heat treating area two continuous feeding ovens move the raw, rolling stock through opened, natural gas fired heating processes which are use to temper the stock. Reamer bodies and steel forgings which are not obtained from standard rolling stock are processed in batch type ovens prior to release to the plant. (See Appendix C)

Heat treated steel normally enters the plant at the trepanning department where the piece is bored to a specific inside diameter. The Drilco plant has the largest number of trepanners in the nation dedicated to the production of oil tools. Depending on the final application of the steel, the newly trepanned stock is then placed on the appropriate production line where it is processed into the needed tool. The firm has made extensive use of numerically controlled and computer numerically controlled lathes and mills to reduce human error and reduce production time. The use of modern machinery has added greatly to the versatility of the machining operations.

Once the appropriate machining is completed and the new tool receives the blessings of the Quality Assurance Department, it is painted and processed through shipping where company owned trucks are used to transport a tool to its ultimate destination.

As implied by its name, Administrative Services, the second major group within the firm, maintains and administers those activities which support the plant and its manufacturing processes. Besides their traditional roles associated with personnel administration and normal paperwork processing, this division has been given the added responsibility of detailed accounting of plant operations. This is used to maintain a high degree of control over the plant operations while giving management detailed information relating to daily production rates and possible production slack or short-fall. The extensive reliance on accounting type procedures results in very accurate data but at the expense of requiring a large manning force.

Finally, to support world wide sales and services, the firm maintains repair shops and rework centers across the nation and the world. These strategically located shops have limited manufacturing capabilities, but they are designed mainly to administer to the needs of field rework of oil tools and rotary shoulder connections. They also provide inspection facilities and serve as bases for the Drilco sales force.

THE METRICATION IMPACT STUDY

The metrication impact study conducted for the management of Drilco had two main objectives: 1) to determine the present status of metric conversion in the oil industry and when and in what manner this segment of the nation would convert to the metric system, and 2) give the firm guidence as to what method would best be employed to implement such a system as could be determined in the foreseeable future. Efforts of the study were first directed toward the position of the American petroleum industries under the assumption that the presence of a metric conversion force in this group would be of significant importance. Absence of any metric forces would indicate but not firmly establish, that the industry was protected in some fashion from metrication forces, and such protection would require identification. Any activity within the industry would give the first indication as to the scope and importance of the metrication movement.

The study on the implementation of the metric system by the firm was needed to gain some appreciation as to the overall impact of the conversion and to reduce any unnecessary and costly mistakes which might be committed by the firm during a metrication program. The entire scope of the project was strategic in nature rather than tactical, and final conversion methodology was assumed to be tentative and subject to modification as final conversion activities approached.

Several factors were prominent throughout the study; the most significant motivational forces for metrication within the firm were its perception of the Metrication Act of 1975 and its heavy reliance on foreign orders. Also, fears associated with Common Market activities and the desire to "beat" the competition were present (the firm was quite concerned with increasing its share of the oil tool market).

The Metrication Act of 1975 fell short of actually committing the U.S. to a conversion date, but it did do much to encourage the use of metric units and bolstered the position of the units in America by confirming that it was national policy to eventually adopt the metric system.

This rather soft commitment by the federal government was an important enough shift in attitude that it warranted closer examination. Should the full power and weight of the federal bureaucracy be placed behind a conversion, more than enough momentum would be generated to push the oil industry into the use of metrics. If such an impetus existed and if such a conversion would be of beneficial use for overseas or export orders, Drilco was eager to have the information and begin steps to implement the conversion. However, if the study showed that the conversion was going to be rather slow in starting and its impact would be felt only several years hence, the firm was willing to forego any insignificant benefits for emphasis on other areas of plant production.

At the beginning of the study there was too great a difficiency in information to adequately conduct the first phase of the study. For the sake of speed and efficiency it was decided that the study of the conversion of the plant should run concurrent with the study of the petroleum industry. This proved helpful in that problems and solutions in one area indicated problems and solutions for the other area.

In the beginning no clear course of action existed as to how the task should be approached. Therefore, to initiate the study a form of network analysis was employed to construct a schematic of how the industry and how the plant might convert. This form of analysis indicated a sequence of activities which could lead to or cause either the plant or the industry to adopt the metric system. The construction of the chart or schematic was based on the techniques used in network analysis and fault tree analysis. Appendix D gives an example of a branch of the analysis. The reason such a technique was used initially was that it indicated a logical progression of events/causes requiring the metrication of either of the two subjects. Once this chain of events was established, the problems associated with their conversion could be more easily identified and studied.

The first network analysis dealt with the metrication of the petroleum industry, and the conclusion was reached that only governmental action (foreign or domestic) could initiate a forced conversion. With this in mind, the political philosophy and atmosphere of the ISO (the international body governing the metric system), the Common Market, the middle east countries where most wells are found, and the Americas (U.S., Canada, and Mexico) were examined in detail. As information was derived from each source, the network was reviewed and updated to reflect any changes to its structure.

With regard to the network constructed to depict the conversion of the plant, several areas where immediate action could be taken were indicated to the author. The most immediate concern was in the area of machine and production line conversion. An analysis of production methods and utilization of machinery was conducted, plus all machines were identifed by model and serial number. Manufacturers were queried as to the availability of conversion kits and metric replacement parts for the lathes, mills, etc., and this information was compared with the production methods survey. This gave an indication as to the effects of a conversion on the replacement or utilization of present machine tools.

Studies were conducted to determine the attitudes of foreign drillers to the use of non-metric drilling tools, and data was gathered pertaining to the impact of the Common Market's directive effecting the importation of English sized goods after 1980. Despite increasingly militant metric activity abroad, virtually no coordinated metric activity was visible in America, and within the oil industry, it was increasingly evident that most firms perferred to move toward metrication very cautiously.

Work on the plant conversion program progressed a faster rate. Surveys of drawings, machine tools, measuring instruments, and publications were completed, and along with historical data, estimations of the cost, time needed to convert under different conditions, and the extent of conversion needed were developed. The drawing survey was rather interesting because several test samples relected quite accurately the final analysis results.

The metrication study was formally presented to Drilco as a report (See Appendix B) detailing the several forces which are directing the metric conversion of the U.S. It covered the impact of trade restrictions by the Common Market, the impact of the Metrication Act of 1975, and the impact of metric standardization of oil tools which was being fostered by the ISO. The report also detailed a plan for the conversion of the plant beginning in 1977 with the adoption of dual measurements on external reporting and continuing to 1985 with the complete conversion of all drawings. Cost for the conversion was estimated to be less than $200,000 if instituted with sufficient lead time.

PROBLEMS ASSOCIATED WITH THE STUDY AND LESSONS LEARNED

Of course the metrication study did experience some problems and the author had several interesting learning experiences. The most notable problems were in the area of employee perception (understanding the problem) and absenc of adequate historical information. The problems associated with human interpretation of the intent of the project and its ramifications were initially anticipated, but the scope of their impact and the effects on the workers was not expected. And, even more surprising at the time, but not in retrospect, was the lack of historical data needed for completion of the project.

The author gained valuable experience in dealing with people under less than ideal conditions while conducting the in-house surveys. It was evident that from past experience and from published data, the average American worker was extremely suspicious of the metric system and had several misconceptions concerning the adoption of these units by American industry. However, the author was not prepared for the level of suspicion experienced during the first portions of the project. This was compounded by the fact that the author was new to most of the plant personnel and not a well known confidant of the plant. The general attitude of the average plant and shop worker was that the U.S. should continue the use of non-metric units. This attitude was mainly prevelent with the line machinists and Quality Assurance inspectors who had little understanding of the basic metric system. When questioned on metrics these individuals were visibly restrained in their comments and even suspicious of the author's motives. Responses were either very guarded or openly evasive. On the other hand, some workers were well versed in the metric system and metric units, and this group was much more receptive when questioned on metrics.

The whole situation was a classic example of the fear of the unknown, but its impact was not truely appreciated by the author until after the initial surveys were completed. Subsequently, most in-house surveys and studies were conducted in such a way that no mention of metric units or the metric system was made if appropriate information could be obtained without broaching the topic. The receptiveness of an individual is quite important when conducting a personal interview, and this situation was quite illuminating in regard to proper planning of surveys and the interpretation of their findings.

Another major stumbling block at the beginning of the study was the lack of historical data which was needed to evaluate possible courses of action. In most cases the data was available but either its location was unknown by the author or his contacts, or it was in such a form that it required extensive revision (and legwork) to mold it into a usable form. One example was the lack of data as to the productivity of certain pieces of machinery; data would have probably shown that certain milling machines were slower in many operations because of the worn parts (feed screws, etc.) requiring much closer attention by the operators to maintian close tolerances. In order to improve the handling of historical data requirements, closer examination of possible sources was required as well as extending the time allocated to derive the information from available sources. Also, back-up methods for obtaining data were initiated; these may not have directly indicated the actual data needed, but "ballpark" figures could be obtained.

Under the topic of lessons learned, the most significant impression made on the author occurred during the Monthly Managers Meeting when he made the presentation of the findings of his study to the senior members of the firm. At this time Drilco (as well as most of the oil tool manufactures) was experiencing a significant reduction in sales which was adversely effecting its profit structure. For some two hours, the firm's president, vice-presidents, and the middle managers examined and reviewed the accounting data which depicted the posture of the firm. The session was very frank, at times heated, and quite informative, and the impact of the financial situation was heightened by the fact that the firm was losing money at the time (i.e., loses had to be trimmed). No formal education, role playing, or case study would have had more of an impact than observing such a situation develop. And, the author was impressed with the fact that the business/management/accounting classes of the D.E. program had prepared him in such a manner that he was able to understand and follow the developing situations. Appreication of the business aspects of the program was greatly increased.

CONCLUSION OF THE DRILCO INTERNSHIP

The sales posture of Drilco did not improve over the ensuing period, and in January it became apparant to the author that he would be included in the next layoff. "Across the board" layoffs were being instituted, and in order to retain the integrity of the Product Engineering Department (which was already in need of additional personnel) full time employees must be retained. Therefore, at the end of January the Drilco internship was terminated and the author moved to the Fluor Corporation. In retrospect, this change had many advantages because it allowed for a more diverse and varied internship than was anticipated;

much more was learned and experienced by the changing of the firms than would have been gained by continuing with Drilco. Although the situation was less than humorous at the time, the confidence it built and the experiences it brought forth were more than worth any detrimental aspects of the job change.

THE FLUOR INTERNSHIP

THE FLUOR INTERNSHIP

The remaining portion of internship was conducted at the firm of Fluor Engineering and Construction, located at Houston, in the Control Systems Department under the supervision of Mr. Dave Laura. The difference in the two organizations in management philosophy and engineering mission was as radical as the difference between a manufacturing plant and an engineering consulting firm. Although both firms were tied to the petroleum industry, factors which influenced the operation of each firm were markedly different. For example, when Drilco was experiencing a decrease in sales, Fluor was in the middle of an expansion/hiring period.

The area of Control Systems was chosen to complete the internship because it was the most interdisciplinary in nature of all the engineering departments of the Fluor Corporation. Additionally, all the proposed projects for the internship with Control Systems in some way related to previous course work or practical experiences of the intern. However, unlike the Drilco internship, no major study was to be conducted; instead, four smaller, more detailed studies were to be undertaken. The four projects were:

(1) Reexamination of engineering standards relating to instrument applications for an NGL plant.

(2) Development and analysis of the Emergency Shutdown Logic for a particular compressor unique to one NGL center.

(3) Analysis and evaluation of electrical power requirements of Control Systems instruments to be operated from the uninterruptible power system at one NGL plant.

(4) Monitor and evaluate the physical status of purchase orders originating from Control Systems and reduce factors which were adversely affecting their processing.

All these projects were related to a large contract on which Fluor was working at the time. The contract was related to the processing of natural gas in Saudia Arabia and will be covered in more detail in future sections.

As with the Drilco internship discussion, it might be wise to examine the history of the Fluor Corporation, although the impact of the corporate structure and management organization is not as important as with Drilco and has little impact on the work performed for the projects.

HISTORY OF FLUOR

The Fluor Corporation was started in the early 1900's by a Swiss immigrant and bears his name today. Sii Fluor, Sr., was initially connected with a construction firm in Wisconson which built facilities for logging companies. Viewing better job opportunities in southern California, Fluor moved his family and his business to the Los Angeles area where the firm was initially active in civil construction. In the late 1910's the firm won the bid for construction of some heat exchangers for a California oil refinery; this construction job eventually lead to the design of an improved heat exchanger for water cooled processes which was patented by Fluor. Construction of the heat exchangers brought rapid success to the firm and tied it to the petroleum industry. By the mid 1940's, Fluor E&C was an established consulting and construction firm in the oil industry, and in 1946 the firm built its first complete refinery (in Billings, Montana). The 1950's saw the firm diversifying its engineering and construction efforts, not only in the oil related fields, but again in civil construction; Fluor designed and built the Air Force Base at Dhahran, Saudia Arabia, for the U.S. This also signaled the beginning of close relationships between the middle east and the corporation. By the late 50's and throughout the 60's, Fluor concentrated on refineries, ammonia plants, and diversification. By the early 1970's Fluor had branched into several E&C companies with expertise in several different areas, ranging from mining operations (Fluor-Utah) to the design and construction of power generating stations (Fluor-Pioneer) to petroleum firms (Fluor-Houston).

Recent contracts with the Fluor-Houston operation have been, to a large part, connected with the Arabian-American Oil Company (Aramco), particulary in the areas relating to the processing of natural gas .

THE SAUDIA ARABIAN GAS PROGRAM AND THE INTERNSHIP PROJECTS

The author's internship activities were related to one of the Aramco projects currently being designed by the

Houston office, and located at Shedgum, Saudia Arabia. This plant and a sister NGL (Natural Gas Liquids) plant are part of an overall program established by Aramco to recover and market gas which is normally flared. Currently, gas produced as a by-product of oil production is flared to the atmosphere (in the U.S. this gas is piped into the interstate gas lines), but under the Saudia Arabian Gas Program (SAGP) this gas would be processed and shipped to European and U.S. consumers as natural gas liquids (with the purified methane remaining in-country). The entire project covers the construction of Gas-Oil Separating Plants (GOSPs) to process the gas coming directly from the wells and pump it to two NGL centers where it would be treated to remove the high sulfur content and liquids stripped for piping to fractionation facilities. The NGL centers are designed to accept the incomming gas, remove any particulate matter or liquids, treat the gas with DGA for the removal of its high conventration of H_2S, compress the sweet gas, strip it of liquids, and then pump it to a fractionation center. NGL tankers, currently under construction in Japan, would take the liquids by water to an appropriate off-loading point.

Both the Shedgum NGL Center and its sister plant the Uthmanyiah NGL Center are being designed and constructed using a modular concept in order to reduce engineering and construction costs while providing for flexibility and ease of future expansion. Appendix E shows the plot plan of the Shedgum plnat and graphically displays the modularity of the project. Design of the plant is such that major modules and major subdivisions of the common modules can be shut down without causing a major degradation or complete shutdown of plant outputs.

SAGP-J-7000.1 AND 7000.2 REVIEW AND UPDATE

The first major project assigned to the intern was a review of the SAGP-J-7000.1 and 7000.2 standards. These two documents covered the application of instruments for the NGL centers and motor protection equipment for the plant's compressors and pumps. The guides were the document used by Control Systems engineers when specifying field or vessel mounted instruments plus any machine protection devices on a variety of machinery. 7000.1 covered temperature, pressure, flow, and level instruments, control valves, relief valves, traps, and drainers, and annunciators, switches, and all electrical hardware purchased by Control Systems including analyzers, control panels, and instrument systems. Appendix F gives examples extracted from this standard. 7000.2 covered motor protection devices to be installed on compressors, pumps, and most rotating machinery such as vibration monitors and temperature monitors associated with the main bearings and shafts, plus monitoring devices associated with oil levels and temperature. This standard required only minor revisions.

The review of these documents was required to insure that individual items and whole systems purchased by the Control Systems groups were in accordance with established Aramco standards. The intern was required to familiarize himself with all related Aramco material and the procedures that were being employed at the time for design of the instrument systems. Applying this information, he was responsible for noting and resolving conflicts in application philosophy and acceptable engineering practices. Since both guides were to be published as offical Aramco documents, interaction with in-house client (Aramco) personnel was required.

The purpose of this first assignment, besides the obvious need for updating the two SAGP standards, was to familiarize the author with the application of instruments as applied to the SAGP program and in petrochemical plants, in general. This required extensive studies of vendor data sheets, piping and instrumentation diagrams (P&IDs), and Fluor originated application specifications, plus actively seeking the help of several experienced instrumentation engineers. This was the basis for the initial (and continuing) education of the intern in the field of control systems engineering.

EMERGENCY SHUT DOWN (ESD) SYSTEM FOR THE LPPT COMPRESSOR

The second project given to the author was related to the design of an ESD system for a one-of-a-kind motor and compressor located just off the plant site of the Uthmaniyah

NGL site. A Gas-Oil Seperation Plant (GOSP) was located just off site, and because of the very short distance between the GOSP and the Slug Catching Module, high pressure compressors used at other GOSPs were not needed. Instead, as a substitution, a low pressure production trap compressor was employed to move the gas from tne GOSP to NGL center. To comply with the motor protection program required by the client, the compressor and its motor had to have monitoring equipment mounted internally to initiate shutdown should appropriate conditions occur which could cause irreparable harm to the equipment or the system. It was the author's job to identify those processes/conditions which would be detrimental to the operation of the equipment and to prescribe the necessary logic to protect the system. The actual ESD system would be purchased and installed by Honeywell, but the shutdown logic design had to be specified by engineering. Critera for the design of this system included compliance with Aramco specifications regarding fail-safe protection plus maintaining a minimum number of logic gates in the system (reducing cost).

The project was first approached by examining previous ESD logic packages and identifying those areas commonly requiring protection. The system studied showed four different areas that fell into this classification: motor protection during start-up, compressor protection during start-up, protection of both during routine maintenance, and protection for both during an emergency shutdown. After a thorough examination of the compressor prints and the motor prints, as well as an examination of the service conditions under which the system would operate, a general outline of the system operating limits was established. (See Appendix G)

Next, the type of logic required by the client specifications was examined. For this type machine and application, Aramco specified a positive, fail-safe system which required a positive signal from all networks for proper operation and the loss of a signal initiating shutdown. Also, existence of an acceptable condition required the presence of a signal; positive control over all aspects of the operation was required. For example, operation of the motor required the positioning of a hand switch in two of three possible positions (the third position was off); one position placed the motor lubrication pump in operation and the other placed it in standby. The switch discriminated between operation of the pump in the main or auxiliary mode. One configuration of the shutdown logic would have allowed the pumps to operate with only two signals originating from the switch, but Aramco specifications called for all lines to have a signal during normal operation, even during periods that the motors are off. This condition caused an additional 5 logic circuts to be included.

Maintaining the proper design configuation and trying to reduce the number of gates for the system proved to be a challenging but perplexing problem. The situation was complicated when the client requested that all "not" gates be eliminated. However, these problems were overcome and the system was successfully completed.

It should be pointed out, though, that shortly after the author left Fluor to return to A&M, the client established the requirement that all or most logic systems be standardized. This required the scrapping of most of the ESD system.

INSTRUMENTATION POWER REQUIREMENTS

The NGL centers make extensive use of electrical power in the operation of their control equipment and the gas treating processes. Temporary, ½ cycle, loss of electrical power would have a sever impact on a plant, so there existed the need for a backup power system to provide emergency electricity to the center's control systems should normal power service be disrupted. Also, because of the extensive use of microelectronics, a majority of the instrumentation in the plant required a highly regulated power source. To accomplish both of these tasks, an Uninterruptible Power System (UPS) was specified to power the control room instruments and all field instruments. The UPS system was composed of four mainline systems located in the control building to power those instruments in the control building plus 15 additional UPS systems located at power substations throughout the plant. Should a major loss of power occur, the UPS would continue to provide power for the instruments until either power was restored or plant shutdown was required. Failure to provide power to accomplish an orderly plant shutdown would cause unnecessary risks and create a potentially dangerous situation. The system takes normal line voltage from an incoming power line, rectifies it, and uses it to charge banks of batteries, which, in turn, provide electricity to an alternator which powers the instruments and controls.

Since the vast majority of instruments receiving power from the UPS were the responsibility of Control Systems, the author was given the assignment to calculate the total loading requirements placed on the UPS by the instruments. The control room UPS's were capable of providing only 90 KVA each while the substation UPS's were rated at only 15 KVA each. The study was conducted to insure that excessive power requirements were not placed on the UPS's, either as a whole or on any one branch, and to insure that power would be available to all or most instruments in case of a double failure of the main power system and one UPS system.

This task proved quite educational, allowing the intern to view exactly how some of the idiosyncrasies of a design might adversly effect the actual operation of a system, and to apply himself to the design fo a complex engineering system.

First, all field and panel mounted instruments were identified. Vendor data was gathered (when available) which gave nominal operating characteristics such as operating voltages, inrush current, and power factor. Data which was simply not available was approximated using the best possible means, either through approximations by comparing the instrument to one with known characteristics or by mathematical approximation. Field instruments were located on a plot plan so that cable runs could be calculated; owing to the extremely long cable runs, the contribution of the cable had to be included in the operating characteristics. Services where the instruments were being used were identified and those which required critical attention and monitoring during shutdown were singled out. Summary sheets were prepared for each power consumer and the module/control panel which it affected was named.

It had been determined early in the project that all field instruments not receiving power for the control room would be powered from the local UPS's. Therefore, the appropriate loads were grouped according to panel as well as module, and the load requirements for the panels were computed. In keeping with the philosophy of a completely fail-safe system, all backup power supplies and secondary power systems were segregated from the circuits feeding the majority of the specific panel instruments.

Once all power requirements had been identified and processed, panels and instruments were assigned to branch circuts of the UPS system. Distribution of the circuts was made using the concept that failure of one UPS would not cause the loss of another system or cause a major reduction in plant operation. Individual loads which were identified as being very critical were given particular attention and provided with detailed backup power. The loads were distributed throughout the UPS's in such a manner as not to overload one single system. Through proper assignment of loads, should the plant lose its main power service plus any one of the mainline UPS systems, operations could still be maintained for a period of time, sufficient to shut down the plant.

This summation of the power loads was presented to the Electrical Engineering Department just prior to the end of the internship. Since that time it has been used as the basis for the complete sizing of fused circuits connected to the UPS and for the assignment of newly created loads.

MATERIAL COORDINATION

As a tool in learning material resource management and to satisfy the non-engineering experience requirements for this phase of the internship, the author was assigned the additional duty of material tracking and monitoring of purchase orders originating from Control Systems. Over 400 P.O.s for some 39,000 tagged items were required for the Shedgum NGL Center, and three distinct Control Systems groups were parcelled the responsibility for specifying and initiating the orders. Fluor management had previously established the policy that each discipline was responsible for the monitoring of its own purchase orders, and in the Control Systems Department the task was consolidated through the Control Systems Material Coordinator. The author was the sole Control Systems Engineer responsible for the effort over the four months he was with the corporation.

The Material Status List was the master document on which the status of each P.O. was maintained. The list consisted of the Jobsite Needed Date (JSND) and information associated to the shipping date required for the equipment to reach Saudia Arabia by the JSND. The JSND was obtained from the Commodity Procurement Schedule which was constructed from the Field PERT/CPM. Information concerning the Vendor Promise Date and the fabrication times was either estimated (if no report had been received from the vendor) or extracted from tracking logs maintained by the Expediting Department. The status of the P.O.s was updated daily and items which fell beyond the estimated time table were brought to the attention of both Expediting and to the intern's supervisor. This afforded the Control Systems Department the opportunity to know daily when specific items could be expected to arrive at the jobsite and if specific construction dates could be met.

The weekly Critical Items List was a summation of those items which were projected to be behind schedule. This report which was prepared by the author was used as the basis by Fluor management in applying needed emphasis to vendors to better or beat promised shipping dates.

LESSONS LEARNED AT FLUOR

Although the internship experiences at Fluor were quite varied and useful, the two areas which were the most impressive were in the areas of client relationships and project planning. Neither of the areas were specifically assigned for study, but their impact was felt in almost every aspect of the internship.

Because of the scope of the Aramco SAGP program, several members of the Aramco engineering and management staffs were present at the Fluor-Houston office. This situation offered Aramco the chance to closely monitor progress of the plant designs and to correct or modify designs which they felt were not in accordance with established Aramco specifications prior to the expenditure of a large amount of effort which would be wasted. When used in this context, the presence of the client in-house has its advantages, but close monitoring of the activity of the client's own personnel is required. Situations could develop where conflicting policy is applied to different areas of the project when different elements of the two parties are interacting daily. This is commonly refered to as "the left hand not knowing what the right hand is doing". In a project the size of the SAGP, this was bound to happen, but the impact that it can have and the problems it can create were never truly appreciated by the author until he was able to experience them.

Additionally, in the SAGP program and in Control Systems in particular, the overlapping of job and design responsibility was extensive. For example, when the author was working on the UPS load study he was required to perform several operations which could be classified as electrical engineering responsibilities. However, because of the close relationship to instrument design and to instrumentation problems, the specification of cable runs and associated electrical characteristics was placed with Control Systems. This demanded that both departments work closely in designing the cable runs because, though Control Systems specified the design, Electrical Engineering was responsible for its installation and hookup.

The problems associated with project coordination and with client relationships are all covered in project planning. Proper planning and proper analysis of the complex engineering and management systems associated with the program were required to maintain a desired level of efficiency; for the most part this was accomplished, but those areas which required closer attention were the areas which caused the most problems. Experience from this internship was quite instrumental in reaffirming the need for thorough project planning.

CONCLUSIONS

INTERNSHIP EVALUATION

As stated previously, the author feels that the internships at both Drilco and Fluor have more than satisfied the requirements set forth for the Doctor of Engineering Program. As with most initial contacts with the business world, the most significant and meaningful experiences were not solely in the areas connected to engineering, but were mainly in those areas associated with human relations and business practices.

The engineering objectives of the internship have been met through the successful completion of the metrication impact study at the Drilco Plant and by fulfilling satisfactorily all the engineering assignments at Fluor E&C. The metrication study gave the intern the opportunity to utilize analytical techniques learned in systems analysis and statistical analysis in describing the problems and reaching solutions which were easily applied. The Fluor internship gave the author the chance to employ knowledge gained in network analysis and in electrical engineering course taken during his undergraduate years. All the projects were of a technically challenging nature, and offered the opportunity to employ many of the methods learned during the author's graduate studies.

The non-engineering objectives of the internship were also met, and the author has gained valuable experience, particularly in the area of working with people. The non-engineering objectives of the Drilco internship covered the areas of public relations, labor relations, and the impact of governmental regulations from the Occupational Safety and Health Administration. The intern was able to observe the activities of the public relations personnel at the Drilco plant and noted their extensive movements throughout plant operations. The author was able to witness some initial union activity (mostly in the form of recruiting attempts) while with company and gained some valuable experience in understanding organizing philosophy. (In Appendix J some literature handed out by a local union and the Drilco response are presented.) The impact of the federal government on the operation of the plant was observed but little extensive study could be done since its impact was of a general nature and no one single department handled the work. While working with Fluor, the author gained valuable experience in dealing with other engineers and with vendors. Specific non-engineering assignments dealing with material management have already been covered.

SUGGESTIONS, RECOMMENDATIONS, AND CONCLUSIONS

After any internship like the one(s) required for the D.E. Program, the intern will have several specific areas where he would like to have had more training or would like to investigate further. However, the following are suggestions that could be incorporated into the general educational curriculum and would be helpful to all engineering students.

First, more use of vendor data sheets in design courses is recommended. As any engineering student will verify, the new engineer tends to fall back on books and courses he had during his formal education; many times the person is not aware that other documents are available which present the required information in a more appropriate fashion. By employing vendor data books and vendor tables in design courses (even in basic or core courses) the students will be exposed to problems more reflective of actual engineering situations. By addressing this situation to firms who interview at A&M or who support the university, the engineering departments could probably receive more than enough literature to satisfy their respective needs.

Second, it is suggested that when applicable the internship be conducted at more than one firm. It is not suggested that each intern be layed-off, but the opportunity should be offered to the student to change working environments and to be able to compare different working conditions. The author is much more aware now of what type firm he is best suited for and under what working conditions he will perform the most efficiently. This suggestion follows in line with the idea of breaking up the intership into two distinct periods. It is the author's opinion that two internships of 4½ to 6 months would be much more benefical than one 10 to 12 month internship.

Finally, it is recommended that a reevaluation be made of the structure of the business aspect of the program with the intent of possibly expanding it. Realizing that the business courses taken by the average D.E. student are designed to equate to an MBA, the more courses taken in business, the more useful the D.E. graduate will become. In particular, it is recommended that an additional course in Accounting and in Management Structures be included in the program requirements. From discussions with other engineers and with contacts in Houston firms, the author has come to the conclusion that more and more firms are placing accounting and resource management responsibilities with their middle managers. It is important that the D.E. student be capable of handling these additional requirements if the ultimate purpose of the program is to be maintained.

In conclusion the author would like to point out that the Doctor of Engineering Program has more than fulfilled the educational desires established by the author prior to entering graduate college. It is not the best program for every graduate engineer nor will it meet all the needs of industry in the future. However, the program is probably the single, best reaction by the university in filling the needs of industry and the modern engineering student.

APPENDICES

APPENDIX A

The following is a copy of the third letter from the internship to Dr. Rodenberger, and it outlines the non-engineering objectives for the Drilco Internship.

DRILCO
Division of Smith International, Inc.

Post Office Box 60068
Houston, Texas 77205
Phone: (713) 443-3370

September 13, 1976

Dr. Charles A. Rodenberger
Assistant Dean of Engineering
Texas A & M University
College Station, Texas 77843

Dear Sir,

This is the third report on my industrial internship activities under the Doctor of Engineering program. Although I have gathered a significant amount of information concerning the metrication of the plant (specifically in the area of costs) during the month, this report will present it in an abbreviated form, rather than the detailed analysis found in the previous two reports. The analysis will be given in the report for the month of September. With regards to the other objectives of the internship, I have already begun activities to satisfy these requirements, and I will present this information at the end of the report.

MACHINE CONVERSION

Enclosed are copies of a machine conversion data work sheet that will be used to summarize the expected costs associated with a hard conversion (rebuilding the machine so that it has metric capabilities only) and a soft conversion (modifying the machine so that it has limited metric capabilities with no ability to turn metric threads). The hard conversion costs will reflect the maximum expected cost required to convert the machinery, while the soft conversion costs will reflect cost for a conversion which would not require metric threading. As can be observed, the worksheets are not yet complete; to date, several firms have not supplied conversion data that was requested. Also, soft conversion costs are incomplete, awaiting a machine-by-machine inspection of dial shafts required to make a more accurate estimate of dual-dial costs. The average value should be in the neighborhood of $200 per axis, giving a soft conversion cost of $27,400. Even if the average goes to $220 per axis, the total cost would be only slightly more than $30,000.

A survey of trepanning equipment was conducted as part of a maximum cost analysis for metrication. As previously pointed out in my second report, cost of items, such as trepanning heads, will probably be very small as the items can easily be converted during normal tool attrition and replacement. However, a rapid conversion, though not anticipated, would demand the immediate replacement of all trepanning heads and associated equipment. The cost of conversion of the heads alone would run in the area of $83,000, with associated equipment costing about $22,000. Therefore, maximum cost for the conversion of the trepanning machinery should be about $105,000.

DRAWING CONVERSION

A complete survey of drawings in use by Process and Plant Engineering was conducted to determine their conversion cost and time required for modification. The work indicated that the drawings of these two departments were quite similar to the drawings of Product Engineering, both in scope and in complexity, and that much information about one set of drawings would be applicable to the other sets.

The survey determined that there were a total of 1,996 active drawings in Process Engineering and 2,373 drawings in Plant Engineering. Combining these with the 4,400 drawings of Product Engineering, there will be about 8,770 drawings to convert, should that course of action be taken. To determine the time required to convert the drawings, 56 product drawings and 50 process drawings were examined, and time to completion estimated; from this, it was determined that, on the average, 3 hours per drawing would be required to complete modification. Accepting this value would mean that total conversion would require some 26,310 man-hours, or about 14 man-years. Costing this at $12,500 per man-year, conversion time would cost about $175,000 to $185,000.

PRECISION TOOLS

A final survey of company owned precision tools currently in use was conducted during the middle of August. The two areas examined in detail were Quality Assurance and the tool crib. Previous estimates had been made based on old price lists with an inflation factor included. However, a re-examination was conducted and the cost of replacing the existing hand tools was recomputed using 1976 price lists. The following price list breakdown was derived from the survey:

Quality Assurance Lab Tools	$13,700	($13,653.75)
Quality Assurance Plant Tools	$16,000	($15,920.85)
Tool Crib Tools	$ 6,800	($ 6,761.40)
SUBTOTAL --------------------	$36,500	
Conversion cost for Pratt & Whitney "Super Mic"	$ 9,000	
Additional of Anilam Digital Readouts @ $2,200 per axis	$13,200	
TOTAL -----------------------	$58,700	

Initial work was started on a survey to estimate the impact of metrication on the individual worker's personal tools. Most machine operators and machinists utilize personal tools to suppliment tools available from the tool crib. Should metrication occur, these workers would need additional measuring tools of metric sizes to maintain their level of output. It would be wise for Drilco to examine this situation thoroughly, as its actions would directly impact the maintenance factor associated with employee morale.

OTHER D.E. OBJECTIVES

Work has also been started on the non-engineering objectives of the project. Meetings have been made with the individuals whose responsibility covers labor relations, public relations, OSHA/EPA, and further discussions are slated.

The area of labor relations seems to be the most interesting since it involves the efforts by Drilco management in frustrating union activities at the plant. The firm has held the position that it will try to alleviate all legitimate grievances by its workers, hence, effectively eliminating the need for a union. To accomplish this, personnel people keep constantly in touch with the hourly workers of the plant and try to identify all problem areas before they have a chance to develop. Records concerning such activities had not been kept until March of 1975, but have been faithfully maintained since.

From first indications, Drilco has had a minimum of activity connected with OSHA and EPA. However, it is now evident that most activity had been in complying with regulations established by these two organizations before the fact rather than meeting the minimum standards after they had been written. This will be examined further in the next few years.

CONCLUSION

The month of September should be the final month where major cost identifying activities take place. If sufficient conversion data is still lacking (data from manufacturers, etc.) this closing date may be extended; however, it is felt that most cost figures should be identified by the 30th. Also, on the 30th, a preliminary report will be given at the monthly management meeting outlining my activity to date and indicating the direction which the final report will take.

Sincerely,

John M. Konopacki
Product Engr. Dept.

JMK:ks

APPENDIX B

METRICATION IMPACT STUDY

METRICATION AT THE HOUSTON PLANT OF DRILCO, INC.: WHY, WHEN, AND HOW

by

John M. Konopacki

30 December 1976

ABSTRACT

The American petroleum industry and Drilco, Inc. will be faced with the requirement of plant and product metrication within the next 5 to 10 years. Several forces are directing this movement, including trade restrictions by the Common Market, enactment of the Metrication Act of 1975, and the creation of metric standards for oil field equipment. Therefore, the firm should initiate a long term metrication program beginning with the conversion of all external reporting, followed by conversion of engineering drawings and graphics, and finally, conversion of the plant assets.

Conversion of the plant could be accomplished for less than $200,000 during a long term conversion program while a short term, extensive plant conversion would cost in excess of $630,000.

Implementation of the conversion program should begin in January of 1977, with completion of the external conversion by 1980, and completion of drawing conversion by 1985.

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I INTRODUCTION

This study was begun with two preliminary concepts governing its writing. First, the study was to be a systems type study, broad in its investigation yet as detailed as possible, while, second, the theme of the study was to be centered about metrication within the American petroleum industry and its supporting downhole tool manufacturing industry. Its ultimate purpose was to indicate if this firm should move toward adopting the metric system of weights and measures, and, if so, when such activity should begin and how it would be conducted. Initially, it was determined that because of the structure of the petroleum industry and its multinational character, inclusion of world-wide trends concerning metrication must be considered as well as forces present within the US and within the petroleum industry itself. Hence, this study can also be used as a basis for examining the general position of metrication within the petroleum industry worldwide, not simply the American petroleum industry.

The conclusions of the study are grouped in four different areas:

(1) Metrication within the US is inevitable and most major conversion activity will be initiated within the next 10 to 15 years. Most of the activity will be in the form of a soft conversion* followed, several years later, by a hard conversion**.

(2) The US petroleum industry will probably experience most of the forces pushing it toward metrication within the above time frame.

(3) Immediate action by this firm (or any other firm) would sub-

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* Soft Conversion - a single direct exchange of measuring units from the customary units or English values to the units of the metric system. No physical changes would take place.

** Hard Conversion - (Hardware Conversion) - the physical alteration of a machine/product/ etc. to reflect whole number metric values in the dimensions.

stantially reduce metric conversion expenditures.

(4) The total conversion costs to Drilco will vary considerably depending upon when the implementation of a metrication program takes place. The longer that conversion activities are delayed, the higher the ultimate conversion costs.

The first two conclusions are based on the findings of the first part of this report which deals with the general and specific trends in metrication at three levels of the American economy:

(A) the US steel industry plus additional supporting industries
(B) the major petroleum firms of the US
(C) governmental actions, both foreign and domestic

The last two conclusions are based on a cost study of metrication at Drilco, which is presented in the second part of the report. Of course, the assumption as made for the second portion of the report that metrication would occur and that varying times exist prior to its implementation.

The first phase of the study (discussed in chapters I thru VII) was conducted to gain a general understanding of the metrication problem and determine some of the trouble areas which might be encountered in a metric conversion program. It dealt with present and recent, past trends in metrication, how the different industries and nations perceive adoption and use of metric units, and what forces are presently shaping future metric activity.

If sufficient activity was not present or outside forces not so dominant or persistant, the conclusion would have been reached that metrication was so far removed that it could be ignored. However, it is believed that sufficient evidence is present to conclude that metrication in the US is at hand.

In the second phase of the study, the actual conversion of Drilco to the metric system was studied. (It was assumed for the sake of argument that Drilco would convert.) Completeness and accuracy was stressed in this portion of the problem, and all aspects of the firm's operation were examined. Major areas that were studied include the product conversions, machine modification and adaption, conversion of mechanical drawings, education and indoctrination of employees, and conversion of supporting peripherals. These five areas were examined in the context that the general flow of information through the firm could be described as either inputs (orders), processing (conversion of orders into products) or output (final product catalogs and supporting literature). Specific costs as well as the need for conversion and extent of conversion were covered in order to establish some value or order for the different conversion plans available.

At this point it should be noted that this report attempts to be as unbiased as possible, but may leave the impression that it is pro-metric. Since there exists very little (if any) anti-metric activity other than the natural tendency to maintain the status quo and a reluctance to accept change, an anti-metric attitude has not been reflected in any present day information. Therefore, most information obtained reflected movement toward the metric system and may leave the reader with the impression that the report was biased. The conclusions were reached soley on the basis of the available information, and should not be construed as favoring either customary or the metric system.

II PROJECT SCOPE

The system studied in the first portion of the report was defined as "the metric activity in the petroleum industry of the United States." This system is considerably more abstract than normally dealt with in systems engineering, which deal mostly with physical systems rather than social or political conditions. None-the-less, this situation does fit the classical systems model, i.e., it is composed of subsystems, it is part of a supersystem, and it exists in a definable universe or environment. Therefore, the study evolves about the system itself, and the interaction of its various components.

The system in question can be viewed as a component of a larger "metrication" system currently functioning within the US; metrication in the agriculture industry, in the machine tool industry, and in the steel industry are other example of integral metrication programs which, too, are part of the general trend toward metrics. As such, the metric activity of one subsystem (component) will have an effect on its sister subsystems, but its degree will vary depending on the situation and the interaction of the two industries. The industry that would have the single most significant impact on petroleum would be the manufacturing of steel because most established petroleum standards for drilling, production, and refining equipment reflect established, customary steel production sizes. For example, petroleum and chemical engineering in the US relies heavily upon standardized tubular steel in refinery design and would have to make significant adjustments should the steel industry adopt an aggressive metrication program. To a lesser degree, conversion of the machine tool industry of America would cause a similar impact, since most design engineers rely heavily on the existance of English size manufacturing tools to build their designs. Conversion in one subsystem will create pressure in another subsystem to adopt metrics, but the degree of interaction between the two subsystems will determine if sufficient force is available to actually cause metrication or simply inconvenience.

One very significant subsystem within the framework of the general metric activity in the US would be the federal government. Metric activity at this level will have far reaching consequences; hence, it should be handled separately and examined in great detail. It is the most likely subsystem in the US to initiate the final movement toward metrics which will force any reluctant segments into metric conversion. The reason that this could happen is that the federal government does not have the same economic forces on it as the private sectors, and the feds will probably view metrication as a move toward greater efficiency. Additionally, the government holds preemtory veto power over other subsystems within the economy and can exert its power unilaterally. If a majority of federal regulatory agencies and informational agencies convert to the metric system, their combined pressure on every segment of the economy will ultimately force adoption of the metric system.

On a much broader scale, the supersystem of world wide metrication will also directly impact the metric activities of the American petroleum industry. To date, this supersystem has been somewhat disorganized and ineffective, and it has asserted little in implementing an international metrication program though it has been successfull (to a limited degree) in establishing a few metric standards. The second most powerful force yet to appear within the western economic block is the European Economic Community which is activily promoting usage of the metric system. For the EEC to gain closer unity and more uniform movement of trade within its member nations, it will begin forced adoption of metrics for all its internal and external trade. The EEC is fostering the development and implementation of ISO standards, as well as the begining of trade restrictions against nonmetric imports. Some of this activity is unilateral in nature. Since the impact of such activity will be so diverse and far reaching, it will effect the American petroleun industry and has been included as a portion of the study.

If the system is now examined along the system lines from the supersystem to its subsystems and components of its subsystems, the general scope of the first portion of the report can be finalized. By defining the major oil firms as the subsystem and the supporting oil firms (such as Drilco) as supporting subsystems, the structure of the system would be represented as shown in Figure 1. To obtain an accurate picture of the metrication process and pressure within the oil industry, all of these areas must be studied. Figure 1 represents how metrication in one industry will effect the level of metrication in preceeding, higher levels.

Note that the metric activity of API is also included at the same level as the major oil firms. API is an industry type organization, controlled and directed by the industry, yet positioned so that it can control various segments of the oil industry. API is in the unique position of creating little original metric activity by itself but reflecting the activity of its member organizations and the pressures placed on its as the spokesman of the petroleum industry. It is included at this level because it best represents its juxaposition in the general structure of the petroleum and natural gas industry, even though, stricty speaking, it is not part of the subsystem, as defined.

Before the system can be examined in detail, the environment in which

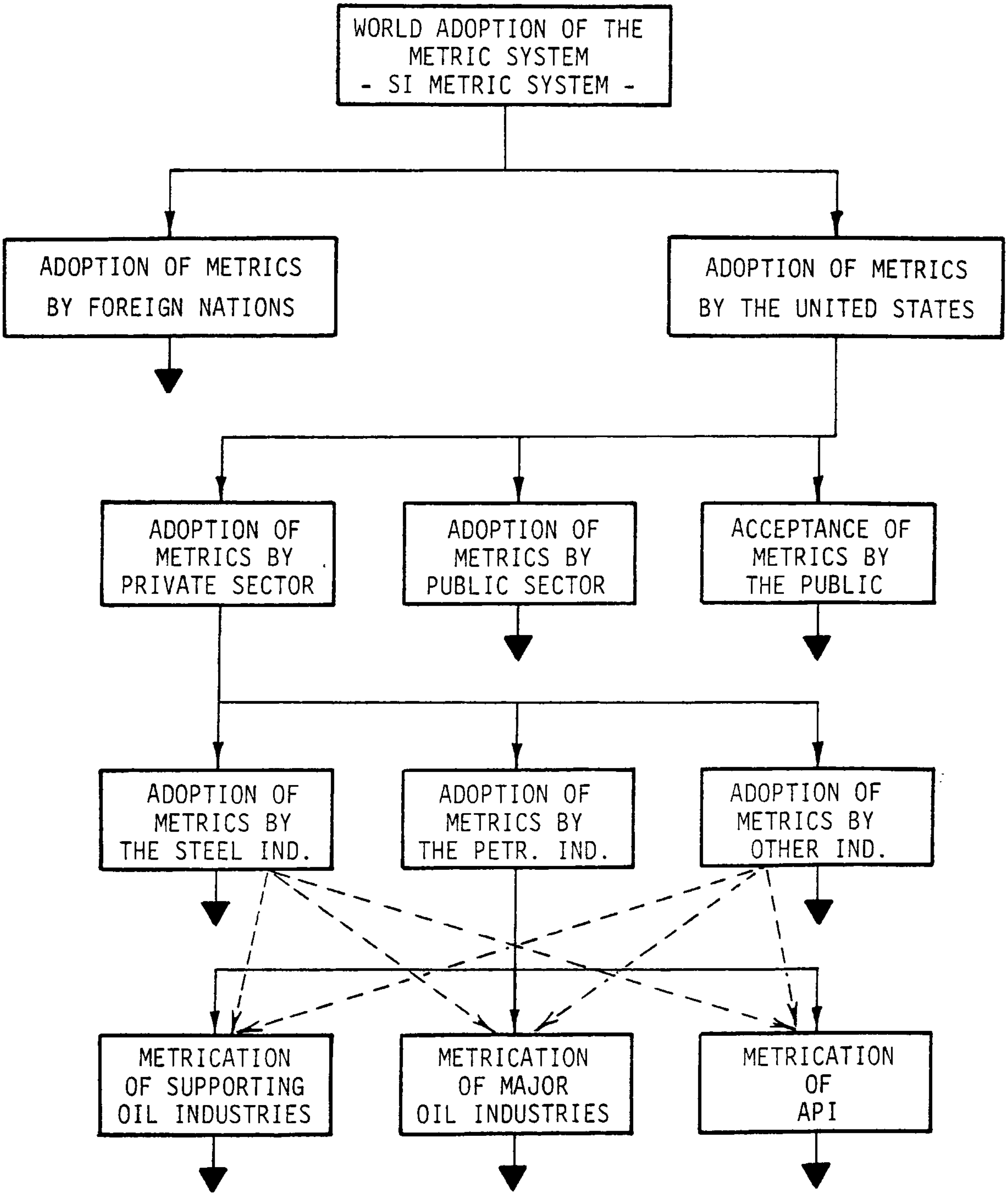
WORLD ADOPTION OF THE METRIC SYSTEM - SI METRIC SYSTEM -
ADOPTION OF METRICS BY FOREIGN NATIONS
ADOPTION OF METRICS BY THE UNITED STATES
ADOPTION OF METRICS BY PRIVATE SECTOR
ADOPTION OF METRICS BY PUBLIC SECTOR
ACCEPTANCE OF METRICS BY THE PUBLIC
ADOPTION OF METRICS BY THE STEEL IND.
ADOPTION OF METRICS BY THE PETR. IND.
ADOPTION OF METRICS BY OTHER IND.
METRICATION OF SUPPORTING OIL INDUSTRIES
METRICATION OF MAJOR OIL INDUSTRIES
METRICATION OF API

FIGURE 7

it operates should also be highlighted. For the case of metrication, as defined in this study, the environment could be taken as those forces not directly affecting the petroleum industries, yet impacting any eventual conversion activities. Familiarity of the metric system by the general public would be one such force. The US educational system is already beginning to instruct students in the use of metric weights and measures, and within the foreseeable future (6 years*), all high school seniors will have been exposed to metrics. This would reduce the requirement of metric training of personnel at the plant in the future, and would create greater acceptance of the system by new employees. As an environmental factor, this educational phenomenon needs to be considered, but would not fall within the framework of the system. It would be a by-product of a higher level system. Prior to arriving at the final conclusion, the environment of the system must be taken into account.

The scope of the metric impact study will need to incorporate the metication activity of conversion within the downhole drilling tool industry plus related environmental forces. The study must be this broad to accommodate the actions of both the US and foreign governments which could be the decisive forces in shaping the petroleum industry plans. Detailed studies of the major influencing factors will be examined.

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*Data based on conversations with Houston Independent School District officals and representatives from the Texas State Teachers Association.

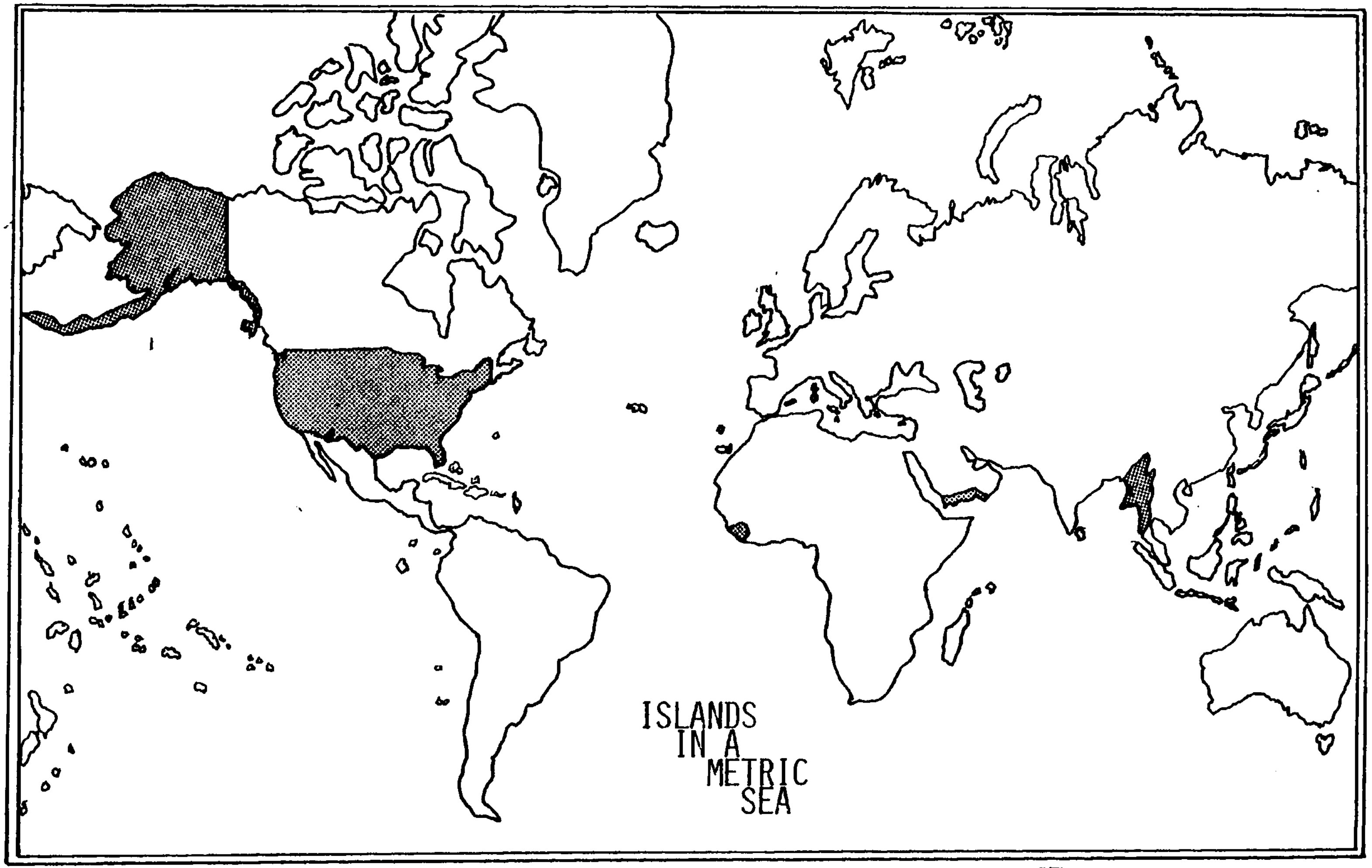
III METRIC ACTIVITY IN THE US AND THE FEDERAL GOVERNMENT

As pointed out in Appendix A, metric activity in the US has been present since 1790 when Thomas Jefferson first proposed a decimal system of weights and measures. In fact the US had been technically a metric nation for nearly 85 years.[1,2,3] Yet, it has been only recently that an effective metrication movement has been initiated. The beginning of this present day activity can be traced back several years, but it received its greatest boost through the decision by Great Britain to abandon its customary system of weights and measures, which it has developed over the last 10 centuries, for the Common Market approved metric SI system (International System of Weights and Measures). This placed the US in the very disadvantageous position of being the <u>only</u> remaining major industrial power to still embrace the Imperial System of measurement. Now, with an excess of 93% [4] of the world's population working with or committed to the metric system (Figure 2), it would become evident that within the near future, the US would be forced into adoption of metric weights and measures.

With the announcement of the British conversion in 1965, pressure was exerted in the US Congress to begin studies aimed at the directing of the US toward adoption or rejection of the metric system. In 1968 this activity resulted in the Congressional authorization of a study to be conducted by the National Bureau of Standards under order of Public Law 90-472 aimed at analyzing the question of metrication in the US. The completed report was presented to Congress on July 31, 1972, with the following observations and recommendations:

(1) The adoption of the metric system by the US is inevitable, and

(2) In order to facilitate the conversion, Congress should back a mandatory conversion bill which would cover a program of 10 years



▨ Non-metric Nations
All other nations are metric
or are committed to metrics.

FIGURE 2

duration. (Similar programs were initiated in Australia, Canada, and Great Britian.)

Included with the report were 12 supplemental volumes (NBS SP 345-1 to 345-12) outlining the specific areas investigated by NBS along with the general impressions and conclusions of the different public and private sectors inputing data to the study.

The general impression left by the investigated segments was that metrication was inevitable, but the total cost and/or impact could not be easily determined. This attitude fostered a reluctance on the part of industry and labor to accept a mandatory conversion program from fear of unexpected costs or problems. Therefore, pressure was exerted on the Senate and the House by these two groups in an effort to protect their established interests. It was not until December of 1975 that enough support could be generated and organized from different factions within Congress to pass any significant metrication legislation; the bill that passed was the Metric Bill of 1975. (see Appendix B) It reflected a compromise stand between organized labor (AFL-CIO) who advocate that any conversion should include Federal subsides for conversion of individual hand tools,and private industry, who felt that any program must be mandatory and that costs should "lie where they fall." The resulting bill provided for only a voluntary conversion with no federal aid.[5]

The Metric Bill of 1975 was far from the stern measures adopted in the Australian and English programs to accomplish their conversions. The bill, as stated, was purely voluntary and non-mandatory, and established a 17 member board to guide and direct the efforts of the economy in the conversion program. In general, the board was formed to carry out a "broad program of planning, coordination, and public education, consistant with other national policy and interests, with the aim of implementing the policy" outlined in the preamble of the act. For the metrication of the US, twelve specific areas of policy implementation were indicated which were to be covered by the board; most of these areas dealt with committee hearings, general studies, and the reporting of information. Of particular interest was paragraph 5 of Section 6, which provided that the board was to "encourage the retention ... of those United States engineering standards (etc) ... internationally accepted" or superior to other standards in use overseas. This portion of the act seemed to lend the support of the federal government to the retention of established American petroleum industry standards which currently govern virtually all free world oil and gas drilling operations.

Since API standards fall into this category and have a great degree of international acceptance, being held as the best petroleum standards in existance, the spirit of the act should encourage their retention until better standards are derived.

On September 28, 1976, President Ford relayed the names of the nominees for the above mentioned US Metric Board. The nominee for chairman was Dr. Louis F. Polk who played a significant role in the 1968 US Metric Study. Other members of the board, their positions, and their terms of office are given in Appendix A. Only two members have been indentified as not being directly involved in metric activity in the past; all others have been active to varying degrees in previous metrication studies and programs. With the extensive background of Dr. Polk in international standardization and metrication and with the structure of the remaining portion of the board, the conclusion could be drawn that the nominees will display a decidedly favorable attitude toward a more aggressive approach to metrication in the

US. This is not to say that the board will try to force metrication, but it shall endorse a more rapid adoption of metrics.

Since the NBS study of 1968 and the passage of the Metric Bill of 1975, some industries have begun limited conversion activity (mostly studies), but, by and large, most private concerns still maintain a "wait and see" attitude. This could change with the approval and seating of the board of nominees. The board chairman will have considerable effect in the attitudes of the board, and an aggressive board even though it has no power, could materially influence major governmental organizations such as DOD and DOT. This situation could have a ripple effect throughout industry and either speed up private metrication activity or fuel low level resistance to the change. Approval by the Senate of the board should come in late 1976 or 1977, and it is doubtful that the first official meeting of the board could take place until spring of 1977. It is doubtful that even the most aggressive board would institute any major actions until it had examined the present position of US industry and evaluate its actions. It is, therefore, doubtful that the board will have much direct impact on current metric activity before the fall of 1977.

There <u>is</u> other activity at the federal level with regard to metrication. To date this activity is relatively minor and only in specific agencies, but as metric activity increases, the combined effects of these areas may force some segments of private industry into metrication. One agency, the US Cadastrical Survey, a subdivision of the Department of the Interior, has been involved with metrication for over 5 years and has recently been providing information on offshore drilling tracts in Southern California in metrics. Over the next several years, the survey has indicated that it will continue to convert maps under its jurisdiction until all such maps are metric. The Federal Communications Commission has been working toward conversion of all its facilities and publications to the metric system for the last two years. These agencies, plus NASA, USDA, and the FDA are all making wide use of metric notation. As activity of this nature increases, it should become apparent that they will have a wider and more intense impact on industry. (Imagine the effect on industry if OSHA should publish all its standards in metric units and demand that all its transactions be made in metrics.

IV METRIC ACTIVITY IN FOREIGN GOVERNMENT AND INTERNATIONAL ORGANIZATIONS

The US petroleum industry and Drilco, particularly, cannot ignore the actions and philosophies of the foreign nations with regard to metrics, nations where oil and natural gas exploration is active or which have industrial bases capable of competing with or undercutting the dominance of American oil field equipment manufacturers. Although this particular United States industry is, by far, the strongest of its kind world wide, the petroleum industry cannot hope to survive in its present form if it does not or will not respond to the actions of its major consumers and the laws imposed on them, If it fails to act, economic pressure will cause the creation of competing industries to furnish the desired product; such a situation could develop its present day petroleum concerns do not move to accommodate recent moves toward the mandatory usage of metrics within select countries. Some countries and economic blocks are pressuring for universal adoption of metric weights and measures to foster standardization in their countries or promote unity. Trade restrictions have been proposed or adopted by several of these nations in an effort to impose such restrictions on the imports of this country. Some restrictions would require that all commercial transactions within the nation be consumated using the metric system of weights and measures. A hard conversion would not be necessary, only that metric values be used for all weights and measures. Even in instances where countries are moving toward metrication and no trade restrictions are in existence, adoption of metrics as a courtesy may provide added markets for a manufacturer.

Drilco must be very conscious of the actions of foreign powers in cases like this. From 30% to 45% of the firm's production is sold domestically with the remaining 55% to 70% ending up over seas. Trade sanctions against

Drilco for failure to meet foreign standards could inflict irreputable harm on the firm. Figure 3 displays the relationship between total sales and Drilco's top 50 customers for 1975. It should be evident that foreign sales represent a majority of the income for the firm. (See Appendix C for method of calculation.)

At present there are two situations within the international community which typify the above statements:

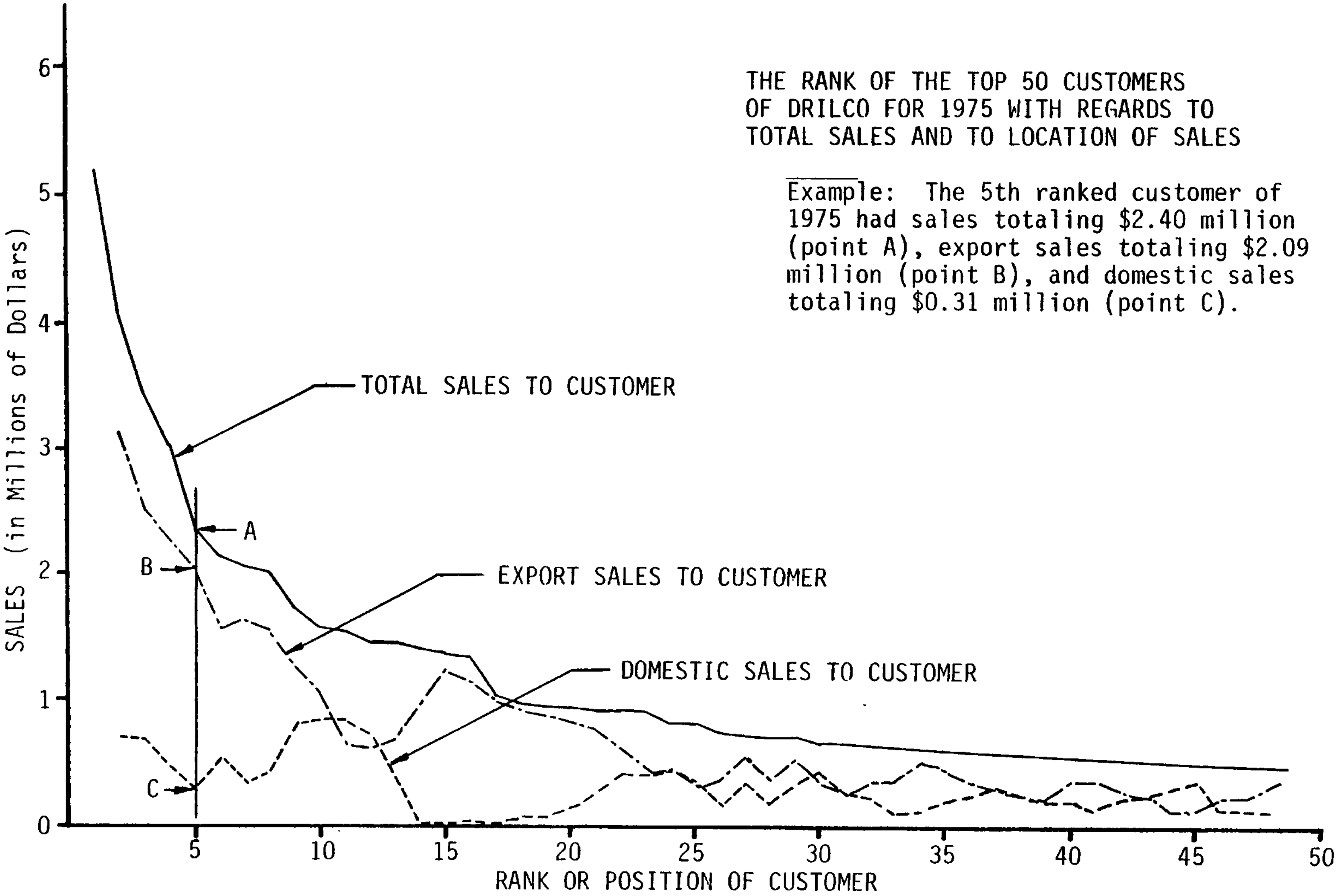
(1) the impending restrictions on the use of English/Imperial/customary units (any non-SI units) in commercial transactions in the Common Market, and

(2) the current metrication program of Canada.

Without a doubt, the most aggessive, multinational metric program in existence today is in the European Economic Community. The Common Market, the colloquial term for the EEC, is a federation of Western European nations with the common purpose of promoting trade and commerce between its member nations. To promote more trade and ease trade restrictions, the EEC adopted in 1971 a directive whose purpose was to foster adoption of the International System of Weights and Measures as the Market's standard descriptive language in commerce (see Appendix D)[6]. The main thrust to the directive was to phase out the use of customary or Imperial units and promote SI metric units by restricting the use of or eliminating entirely the use of customary weights and measures in all commercial type actions. The directive set up the following schedule on the retention or elimination of non-SI metric units.

(1) After 31 December 1977, several minor imperial units, to include the bushel, will no longer be authorized for exclusive use.

(2) After 31 December 1979, additional major imperial units, to include the horsepower, the yard, ton, foot·pound-force, and the degree



THE RANK OF THE TOP 50 CUSTOMERS OF DRILCO FOR 1975 WITH REGARDS TO TOTAL SALES AND TO LOCATION OF SALES

Example: The 5th ranked customer of 1975 had sales totaling $2.40 million (point A), export sales totaling $2.09 million (point B), and domestic sales totaling $0.31 million (point C).

Figure 3

FIGURE 3

Fahrenheit, will be prohibited.

(3) The status of several units, to include the inch, foot, gallon, and the pound, must be reviewed prior to 31 December 1979; unless there is unanimous endorsement of continued use of the unit by all EEC nations the units will be dropped.

(A complete listing of all units to be prohibited and dates that use of the units will be restricted are given in Appendix E.)

The implemenation of this directive will cause an immediate confrontation with the present measuring standards of the American Petroleum Institute. The near monopolistic extent of API standards has encouraged retention of Imperial units in the petroleum industry even in operations in Europe, and in the past there has been no force to initiate conversion to metric units. The EEC directive, unless otherwise circumvented, could force several firms into minor soft conversion programs to maintain sales activity in the North Sea area.

One such firm who will face this situation is Drilco. The North Sea area is one of the most active sales areas for the firm, presently, and approximately 30% (sometime more) of its international sales are destined for use in that area of the world. Translated into total sales, the North Sea Area accounts for at least 15% to 20% of the firm's gross sales. And, all products used in the area will be effected by the EEC directives, i.e., they will come under the jurisdiction and control of the 1971 EEC Directive. This means that by 1980 all products of Drilco destined for use in the North Sea area which have units of force designated, which use degrees Fahrenheit. and which have power ratings (Degassers and Ezy-Torqs) must have the equivalent SI metric measurement on the tool. Additionally, if prior to the beginning of 1980, the EEC does not extend the use of other customary units (inch, foot, gallon, etc.) (approval for extension must be unanimous) then at that time, these units must also be accompanied by or replaced by their equivalant SI values.

The exact replacement procedure for these units has not been formalized, but in all probability the placement of dual customary - SI units will be acceptable. The EEC Directive did not specifically endorse or rule out the use of dual dimensions, and as long as such use does not cause confusion, the practice should satisfy the requirements of the Directive. Where the use of dual dimensioning does create confusion, sources in the EEC have indicated that the customary units would have to be dropped. Such a case would occur in the conversion of pressure gages and precision measuring devices; dual dimensioning might result in misinterpretation of a dial reading. Therefore, by 1980, the use of exclusively measured SI pressure gages must be in operation for imports of the Ezy-Troq to Europe.

Along with dual dimensioned products, related paperwork and documents must include metric values. The directive covers all commerical transactions and includes product specifications, operating manuals, and training equipment associated with the transfer of ownership. Drawings and specifications being transfered to a subsidiary will not need to be converted except when such drawings become part of the sales transactions for tools or production; this exception is due to the fact that the transfer of the drawing would be considered as internal operations of the firm. However, all other documents used for external reporting and sales transactions must have appropriate metric units.

Present metric conversion activity in the Canadian sector may cause metrication problems in the US, too. Canada is currently moving toward a complete adoption of the metric system and the Canadian Petroleum Association is preparing to implement a program designed to convert all external reporting procedures within the industry. The Alberta Sector of CPA has progressed more rapidly than any other sector and has already established expected dates for completion of its activities. By June of 1978, the Alberta Sector hopes to have all external reporting by its member oil firms done using metric values; the conversion program deals with external reorting only, acting under the contention that external reporting will satisfy the requirements of the national conversion plan while allowing the individual firms to convert their internal structures at their own pace. Originally, this conversion activity was to be completed by January 1978, but this date has recently replaced by June of 1978.

Conversion activity within this sector should be of significant importance to the US petroleum industry and to the API because of the similarity in the structure and operation of the two industries. The Canadian Petroleum Association is working closely with API in the conversion of several important publications (see Section V Metric Activity in the American Petroleum Industry). This could prove to be the "testing ground" for the future conversion of the American petroleum industry. If the program continues on schedule, it could provide the first major metric petroleum market for US firms, even before the US is required to cope with the Common Market metrics programs.

Along with the growth of metric markets in Europe and Canada, the American petroleum industry must deal with an additional metric problem. As stated before, API standards are currently accepted worldwide, and these standards are just now being converted to the metric system of weights and measures. But API is not the international organization established to set international standards; ISO (International Standards Organization) is the recognized body which is attempting to establish and regulate international standards. This institution has traditionally set its standards using existing metric standards and is hesitant in adopting non-metric standards. Also, ISO is recognized by law in a significant number of countries and adherence to ISO standards may be required by these nations. ISO has just begun studying a proposed draft (see Part A, Appendix F) for oil field equipment that is a departure from API standards. Although the draft is not too radically different from typical API publications, it does give virtually all dimensions in millimetres and it designates tool joints as API Numbered Connections or in metric values (for example: 3½ IF connection is called an 88,9 IF connection). The draft, as it was originally proposed, was opposed by API for numerous reasons, all being of a non-metric nature. Most of the problems stem from misintrepretations of API standards and accepted manufacturing procedures and do not involve the actual metrication of the old Imperial standards. Therefore, it would seem that the metrication problems offer very little difficulty to the acceptance of ISO standards, and if the other areas can be resolved, ISO standards for oil field equipment may be issued within the next 2½ to 3½ years. The existance of a metric standard of this nature would tend to reduce the argument against metrication of drilling tools because of the non-existance of acceptable standards.

Thus, several forces exist which tend to promote metrication within the US and speed its adoption of metric units. Of the three forces presently pushing the US toward metrication, the most significant would have to be the EEC directive on the importance of non-metrically sized goods, while the most helpful force would be in the Canadian sector. The point that need emphasis is that there are significant, world economic forces at work in the field of metrication, and that as more and more drilling areas come under the influence of metrics, the harder it will be for US manufacturers to resist metrication. These forces offer relatively little chance for improved sales or increased profits (except at the expense of other firms), but can cost the firm, costs in the form of lost sales due to an inability to handle metric orders.

V METRICATION ACTIVITY WITHIN THE AMERICAN PETROLEUM INDUSTRY

This study must, of course, include metric activity within the petroleum industry in the United States and must pay particular attention to activity focused in the direction of the downhole drilling manufacturers. The commonly held belief throughout the study was that the petroleum industry of the past and present would be hard (or at least very reluctant) to convert to the metric system. On the surface, though, it would seem that the industry is no more resistive or reluctant than many other American industries. However, because the industry has most of its assets tied up in capital goods with long lifetimes, hard changes are not normally reflected until equipment attrition and technology can open salients where change can be nurtured. Thus, the industry will change, slowly if metrication is tied only to equipment attrition, more quickly if metrication is promoted through technological advances and/or active metrication support from the major petroleum firms.

At present, metric activity in the major oil firms is recieving mixed response. In one quadrant of the industry, metrication is receiving active support while in another it faces open hostilities. Similarly, metrication in the downhole drilling industry is receiving considerable attention by one manufacturer and little or no attention by most other manufacturers.

(A) Metric Activity Within the Major Petroleum Production Firms

The general attitude among most of the major producers is that metrication is inevitable but that haste should not be made in the adoption of the system. Also, because the US has no established metric policy and no projected time table for conversion to metrics, most firms would prefer to withhold metrication activities and observe the progress of other metrication programs now in progress, such as in the United Kingdom, Australia, and Canada. With the preceived cost of metrication very high*, these firms would prefer to gain more knowledge of costs and problems before taking more action. However, the rudimentary structure of a conversion program is evident in almost all firms, and in-house metrication organizations are gaining more power as time progresses. Most of this activity is still centered on organization of metrication committees and on soft conversion studies, while a few cases exist which deal with hard conversions.

Of the major petroleum firms, only Gulf Oil Corporation has "publicly" stated that it can see no overall economic advantage to metrication and that it will institute conversion activities only when it would be profitable to do so or when ordered to by the Federal Government. Although this is not a "progressive" attitude, it is still founded on well conceived ideas and represents the most conservative stand by any of the oil industries. Gulf has not, though, refused to examine the problem and currently has a semi-active conversion committee. Thus, while Gulf has not discouraged metric activity, it has not encouraged it.

Diametrically opposed to the stand of Gulf is the position assumed by Sun Oil Company. Sun has taken the stand that adoption of the metric system is advantageous to the US; even though the advantage of the system will not be realized for a significant period of time, the firm feels it should still encourage the adoption of the system. Sun has taken an active role in the testing and marketing of its major product in metric-sized quantities and the conversion of present dispensing apparatus to the metric

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* General Motors, in 1966, conducted a metrication cost study and estimated costs for conversion would be astronomically high. However, after the program was initiated, the total cost was revised downward, drastically, and will probably be only about 4% of the original estimate.

system of measure. This activity has, of course, necessitated prior work in the area of internal and external reporting utilizing metric units. Hence, Sun has formed an extensive base for future metrication but has not initiated full scale conversion activities. The reason that Sun has not gone further into metrication is the very reason that Gulf has been reluctant to enter a conversion program at all - there is presently very little or not economic advantage to adopting the metric system within the foreseeable future.

Exxon, Texaco, Conoco, Shell, and Mobil are in various stages of metric conversion, somewhere between the positions established by Gulf and Sun. Mostly, these firms have present policies favorable to the adoption of the metric system, but have retained a "wait and see" attitude. All have metrication subcommittees although none are overly visible in the daily activites of the firms, and most are concerned only with the eventual soft conversion of the firm. Exxon has initiated the metrication of its Research and Engineering Corporation while holding off on other activities (see Appendix G).[8] Again, activity is quite restrained mainly because of the lack of economic pressure to convert their assets located in the US.

(B) Metric Activity Within the Downhole Drilling Tool Industry

Conversion activity within the downhole drilling tool industry is less evident but probably more extensive than is apparent. In general most manufacturers are saddled by the demands of their customers and by the supplies available to them; because metric activity is so miniscule in both of these areas (sales and supplies) there would appear to be little or no reason for adopting the metric system. As evidenced by a survey of composite catalogs and through phone conversations with several manufacturers, it seems that most manufacturers are either unaware or unconcerned with metric activity. (see Appendix H) Some firms, especially those from Europe, offer soft conversion of sizes (as would be expected), but none offer products exclusively in metric values or using hard metric conversions. Hughes Tool Company is probably the <u>only</u> American manufacturer to provide extensive soft converted metric values for their tools. Other manufactures such as Drilco, Reed, Hunt, etc., currently provide little or no metric information.

Metric activity in Hughes seems to be the most extensive of all the American downhole drilling tool manufacturers. Through unofficial conversations with Hughes employees, it has become apparent that the main thrust of the Hughes program is to provide a basis for some future conversion program. A significant number of linear dimensions of drawings have been converted, some design work has been done, the core of a training program has been established, and an active metrication committee is in existance. Therefore, it appears that Hughes is conducting a low key metrication program either in the form of a long term or a short term metrication effort. And, such a program would appear to be quite flexible.

(C) Metric Activity Within the American Petroleum Institute

The American Petroleum Institute is directly affected by any metric activity associated with the petroleum industry and would play an extremely important role in the eventual conversion of the industry. API has concerned itself with metrication for several years, but present day interest was intensified because of the recommendations of the 1968 US Metric Study. To facilitate conversion activity and to promote continued standardization, API has formed a subcommittee on metrication and printed two documents

API 2563 and 2564 (with section 2a of 2564 printed under separate cover) which deal with the conversion of established API standards and publications. Additionally, as documents are revised, all new API publications will include soft conversion data for all tabulated data.

The API subcommittee on metrication cannot be considered a motivating force in the area of metrication, but it is providing a very valuable service. By its very makeup, this committee will reflect the general "go slow" or restrained attitude of the industries it represents (its committee chairman is from Gulf Oil). It is currently functioning as a sounding board for metric action programs and as a governing authority on questions arising from metric activity. The committee will probably make every attempt to facilitate as painless a transition to metrics as possible, one which is the most favorable to the petroleum industry and to API; but it will not actively press the issue of metrication.

In protecting the already established standards of API, the committee has become an active participant in the ISO committee on oil field equipment. This ISO committee had recently submitted its first draft covering the standardization of tool joints and discussed the draft at an ISO meeting in Moscow during the middle of October 1976. The draft was opposed by API on the grounds that it was poorly conceived and had several technical errors. It is noteworthy that the draft was almost exclusively metric to the point of converting customary RSC connection designations to their metric equivalents (3½ IF to 88,9 IF, etc.) and that it was, essentially, a soft conversion of existing API standards. The objections raised by API were of a technical nature and of some merit, but the major structure of the draft was unchallenged, implying that future drafts of a similar format would be acceptable. It would, therefore, not be unrealistic to assume that, given the average time of accepting an ISO standard as 3 to 3½ years from submitting of the inital draft, ISO can have a complete set of standards for the petroleum industry within 7 to 10 years. (API has some 83 publications covering drilling tool standards, bulletins, and recommended practices, plus some 40 more publications covering related drilling practices. ISO may choose to press for the adoption of the related soft-conversions of the API publications, but the first draft proposed by ISO does not relate to any single API publication.)

A synopsis of current metrication efforts in the US petroleum industry would include two points of particular interest. First, the oil industry feels that metrication is inevitable, but that the industry should not embark on a metric conversion program until such time as they are ordered to by the federal government or the market place exerts sufficient economic pressure to force adoption of the system. Second, API, as a tool of the present oil industry, is attempting to maintain the presently accepted standards, thus causing little physical conversion once full metrication activities are initiated. These two situations would seem to typify actions of an industry whose efforts were being directed toward a soft conversion rather than a hard conversion.

VI METRIC ACTIVITY WITHIN THE AMERICAN STEEL INDUSTRY AND OTHER SUPPLIERS

Even if no economic pressure (sales demand) was present for metrically sized drilling tools and there existed no pressure from domestic or foreign governments to implement metrication activities, the petroleum industry would be hard pressed to retain the use of customary units if its suppliers refused to continue manufacturing their supplies according to English sizes and produced only metric sized items. The impact of the sizes and dimensions of raw materials on the design and manufacture of drilling products is too great to be disregarded; a considerable portion of all product dimensions and characteristics are dependent on the sizes and descriptions of the raw materials produced by the steel industry. Hence, it would be wise to examine the metric activities of the drilling tool industry's suppliers prior to arriving at any final conclusions on the status of metrication in the petroleum industry. There are two major supporting industries, steel and machine tools, and a host of peripheral ones, which must be examined.

(A) Metric Activity Within the Steel Industry

The basic raw material for the downhole drilling tool industry is steel, and the fact that steel is produced in certain standard sizes determines, to a great degree, the sizes of tools manufactured for the drilling industry. Casing, the final product employed in finishing a producing well, is normally produced in whole, customary sizes, and its size determines bit sizes, which in turn determines drill collar size and the general makeup of the drilling string. If casing were converted to metric sizes, a cascade effect would occur and several drilling tools would probably be switched to the metric system. This analogy can be extended, on a more limited basis, to production of drill collars, reamers, stabilizers, and drill pipe. If the steel producers embrace the metric system whole heartedly, extreme pressure would be exerted to convert the petroleum industry to metrics, also.

However, if whole hearted (or half-hearted) conversion activities are present, they are not noticeable nor are they actively supported publicly by the steel industry. From policy statements issued by several steel manufacturers and fabricators of steel goods, it is evident that the industry is less prepared or willing to convert than most other segemnts of the economy. The reaction to metrication seems to hinge on the existance of a metric market; the steel producers, evidently, want to begin conversion activities only when assured of a metric market - even if such a conversion is only a soft conversion. This non-aggressive behavior may be fostered by the fear that the industry will lose part of its hold on the US steel market to foreign producers of metrically sized steel.

Appendix I displays several letters from steel producers plus a synopsis of their positions. The general text of the policies, with one exception, is that future metric orders will be filled using current production sizes, i.e., customary sizes, and that once sufficient orders are being received, the respective steel producers will convert to metric units. Crucible, Inc. and Armco Steel both presented rather bleak policies and displayed a reluctance to actually handle orders for metrically sized steel. Republic Steel seems to be more receptive to the problem, but it is evident that their internal structure will remain aligned with customary units until metric orders are much more plentiful. Only US Steel has produced a metric catalog, and apparently, it is generating little metric activity and few orders. The conclusion must be reached that American steel manufacturers will not be a motivation force in metrication in the US.

(B) Metric Activity Within the Machine Tool Industry

Machine tool manufacturers, because of a host of reasons (to include a foreign market for metric tools, advances in automated machinery, and increased demand by selected American customers for metric tools, i.e., the automotive industry), are well advanced in the production of metric machine tools. Additionally, most manufacturers are making provisions for metric conversion kits or metric parts to provide limited metric capabilities for their tools. The general mood concerning metrication within this industry seems to be one of approval; this would not be unusual because most manufacturers preceive an increased demand for their services in an extensive metrication program. However, again, it is doubtful that the immediate and total metrication of this industry would have an immediate impact on petroleum conversion activities because of the tremendous lead time involved in the processing and setting up of production lines. Also, these manufacturers must still be responsive to the needs of their other major customers, and most US firms are simply not ready to begin purchasing metric tools exclusively or even on a limited basis (unless the machines have dual capabilities).

Thus, the major suppliers to the drilling tool industry will probably not exert any force to promote metrication. But, while one seems to resist metrication (the steel industry) and would probably hinder a short term conversion program, the other (the machine tool industry) currently has the capabilities to aid or assist in a metrication effort and would welcome such activity.

Additionally, there remains several peripheral industries affecting the downhole drilling tool manufacturers, anyone of which could bring considerable pressure to bear should they decide to convert. However, lessor degree metric activity is evident in these industries than in the petroleum itself.

The precision tool industry could play an important role in metrication, but because it has long produced both English and metric tools, this industry will most likely foster adherance to both systems in hopes of maximizing its sales. From conversations with representatives of Starrett, Brown & Sharpe, Pratt & Whitney, and Jones & Lanson, it is evident that none of these firms are in the process (or anticipate) of promoting the metric system or dropping the English system. All the industries have expressed interest in the conversion of the US, but they have avoided promotion of either side of the metrication issue and remain stricly neutral.

Hydraulic and pneumatic suppliers have all expressed interest in metrics, but indicate that they must follow other force trends besides the pressure exerted on them by the petroleum industry. These industries could convert with relative ease due to the abundance of and reliance on foreign made, metric assemblies. However, again there seems to be little demand for the units and assemblies when the items are designated in metric units.

All other peripheral industries are in approximately the same position as the precision tool manufacturers and the hydraulic dealers. There is simply very little pressure being placed on these industries to adopt the metric system, and the only area where pressure can be exerted seems to be from the customers of the industries in question.

VII POSSIBLE METRIC CONVERSION SUMMARIES

The activities that have been noted in the previous subjects will at some future point directly effect the metrication activities of the downhole drilling tool industry, but it is not readily apparent as to what extent these situations will impact the industry, nor what their interrelationships are, or when these conditions will begin to effect the production of tools. To aid in forecasting their ultimate effects it is possible to hypothesize and construct several summaries depicting uniquely different avenues along which metric activity can develop. The summaries should be useful in identifying the importance of closely related metric activity and how elements of each situation react to varying stimulii. In fact it should be possible to identify common reactions in each summary and plan for their occurance; in other words, no matter what conditions foster metrication in the future, the summaries should help identify steps which can be taken at this time to help facilitate the future conversion actions.

Of course, there are nearly an infinite number of possible ways which metrication can occur, but only a small number of these have any real chance of happening. The study of the summaries should be limited to those situations which are most likely to occur, and identify the most basic and common events which happen in each. Two basic actions, economic force and government force, should cover most actuating conditions with four related forces acting as catalysts in the actual conversion. In general, metrication could occur because of actions initiated by the oil drilling industry, the main consumer of the tool industry's product, the drilling tool industry's suppliers, the tool industry itself, or some outside force such as governmental action. The first three possiblities are rather remote, while the last would be the most likely conversion force.

(A) Conversion Through the Private Sector

It is possible, but not likely, that the major petroleum industries themselves would begin hard metrication activities, although without some economic force or governmental action, it would seem that such activities would receive little spontaneous support or even limited endorsement. However, one could assume that these firms would embrace metrication and actively support its adoption. Now, the only direct, real contact the major petroleum firms have with the drilling industry is that they can specify the size of casing to be run in the finished hole. If the major firms began to demand metric casing, this move would force the use of metric bits in holes where more than one string of casing was required. Holes, where only one size casing was required, could still be drilled using English sized bits (the hole would be slightly larger than a metric hole). If metric bits were required for drilling, metric sized reamers and stabilizers would also be required and a "domino effect" would lead to the eventual conversion of most or all associated drilling tools.

But, the above sequence of events progressed under the assumption that the casing to be run in the hole had undergone a hard conversion and was of a different physical size than present day casing. If the major petroleum firms moved simply to a soft adoption of the metric system, considerably less pressure would have been brought to bear. Most likely, a buffer zone would be created between the drilling contractors and the oil firm, and one of these industries would do the actual soft conversion before passing the information to industries out of their control. Thus, the tool manufacturer would receive a request for a tool in English units even though the actual request was for a soft converted, metric tool (see Figure 4).

In the above case, use of soft metric conversions would not interfere

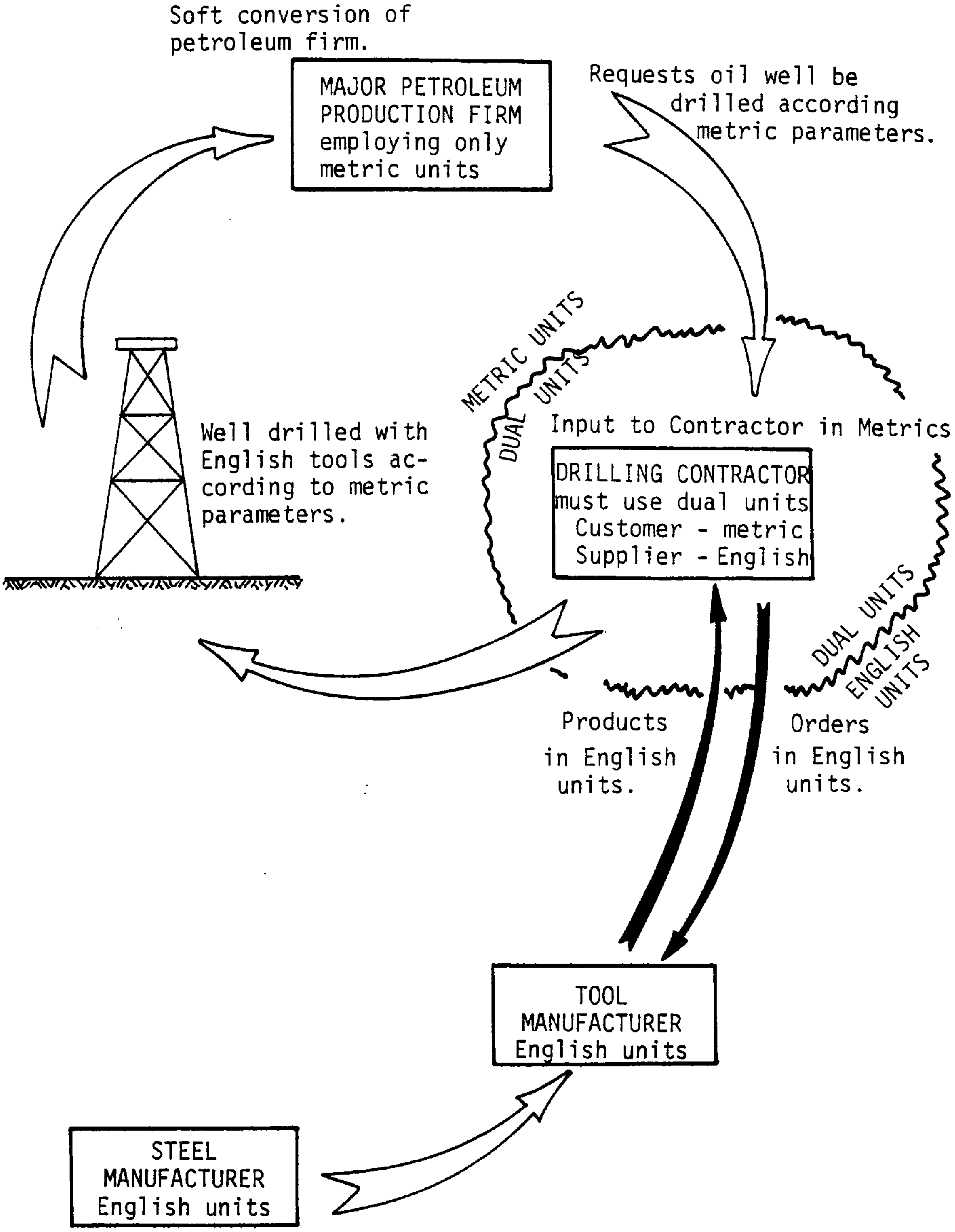
Soft conversion of petroleum firm.
MAJOR PETROLEUM PRODUCTION FIRM employing only metric units
Requests oil well be drilled according metric parameters.
METRIC UNITS
DUAL UNITS
Input to Contractor in Metrics
DRILLING CONTRACTOR must use dual units
Customer - metric
Supplier - English
Well drilled with English tools according to metric parameters.
DUAL UNITS
ENGLISH UNITS
Products in English units.
Orders in English units.
TOOL MANUFACTURER English units
STEEL MANUFACTURER English units

FIGURE 4

with the drilling of any wells nor with the manufacture of any products. If such a situation did develop, it would not be presumptuous to assume that the use of both customary and metric units would be acceptable on descriptive data and transaction in general. This development would not promote rapid conversion but neither would it hinder a gradual conversion within the affected industries. Thus, a soft conversion, conducted rapidly or conducted over a protracted period of time, would have little impact until such time as the exclusion of customary units was deemed appropriate.

Pressure for hard metrication could come from suppliers of raw material, in particular the steel manufacturers, though this situation is the least likely to happen. The reasoning that this avenue is so unlikely is because suppliers are normally responsive to the needs of the consumer and do not normally engage in market manipulation action to channelize their consumer's demands. However, it should be noted that the same "cause and effect" situation would result from this form of metrication as was experienced in the previous instances of casing metrication. Should the steel manufacturers of the US and the world restrict production of steel to strictly hard metric sizes, the total effect would be a more dramatic and perhaps a swifter adoption of metrics, but the adoption would follow lines very similar to the casing conversion. The tool industry would be faced with two pressures:

(1) all casing would be converted to metric sizes, and

(2) raw steel would be sized in metrics, requiring more machining to make some English sized tools.

The singular availability of metric casing would cause an increase in demand for metric bits and associated metric tools, while the absence of English sized raw steel would cause an increase in the cost of producing some English sized tools; the demand for metric tools would increase and the cost of metric tools would drop compared to their customary sized companions. It would then be cheaper to metricate than to remain with the customary units (see Figure 5).

If the hard conversions of casing and steel are similar, it stands to reason that their soft conversions would have equally similar results. This is true with the one exception that if the steel producers metricate, then the tool manufacturers would have to deal directly with a metric industry. In the former case, the tool manufacturers would not have direct contact with metrically sized items, and, hence, would be buffered by either the drillers or by the drilling contractors; they would not deal directly with the agency requesting the metric casing. However, in the latter case, the tool makers would need to deal directly with the steel producers and their metric products - there would be no buffer involved. In this situation, the tool manufacturers would receive added pressure to convert to metrics; the major petroleum firms and drilling would both need to be dealing in metrics because of the dimensioning of steel casing and the steel producers would be selling only metric steel to the tool manufacturers. Therefore, the tool makers would be receiving direct pressure from steel to use metric units plus indirect pressure from the major petroleum firms.

The first steps associated with a soft steel metrication program would, again, deal in transmission of information. The need for a dual dimensioned composite catalog would be present, as it would be useful to the major oil producers, drilling contractors and drillers. The need to handle purchases of raw material in metric units would also develop; Drilco could sell English dimensioned tools in a soft steel conversion situation but would still

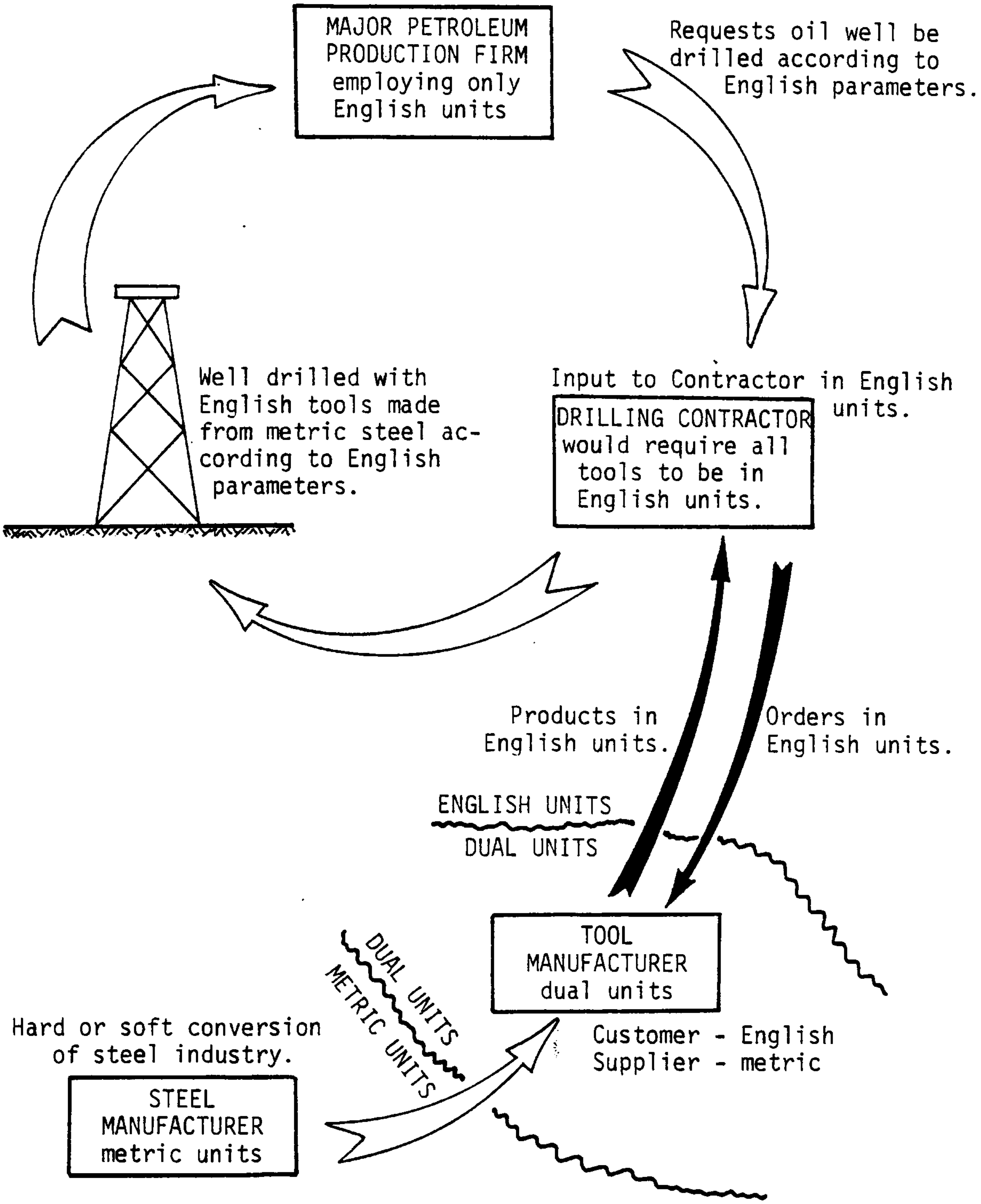
MAJOR PETROLEUM
PRODUCTION FIRM
employing only
English units
Requests oil well be
drilled according to
English parameters.
Well drilled with
English tools made
from metric steel according to English
parameters.
Input to Contractor in English
units.
DRILLING CONTRACTOR
would require all
tools to be in
English units.
Products in
English units.
Orders in
English units.
ENGLISH UNITS
DUAL UNITS
TOOL
MANUFACTURER
dual units
DUAL UNITS
METRIC UNITS
Hard or soft conversion
of steel industry.
Customer - English
Supplier - metric
STEEL
MANUFACTURER
metric units

FIGURE 5

be required to handle the purchasing of the green steel in metrics. There would be the added requirement that the purchasing and inventory personnel of the firm must be capable of handling metric orders, even if the metric values are to be dropped for production purposes. Note, also, that with metric sized raw materials being used in production, the first engineering drawings that must be capable of handling metric units are those dealing with the initial shaping of the raw material into semi-finished products. These drawings would require conversion to handle metric values before any other drawings.

Both of the previous two conversion summaries dealt with economic pressure as it could be applied to the downhole drilling manufacturer. They were based on the rational that either the consumer of a product or the suppliers of a raw material could force conversion of a specific industry. However, the manufactureing industry could retaliate by shifting its sales or by switching its suppliers. In either case the tool manufacturer would have the option not to convert and could possibly remain in business.

(B) Conversion Through the Federal Government

However, governmental actions can have equal or greater effects; not only can they produce economic pressure, but they can also impose legal restrictions on a product. It would not be completely inconceivable that the US government would demand/require a short term conversion to the metric system. With its legal and political powers it could sanction such action and support it with stiff penalties for failure. The government could require metrication of a product/firm or exclude it from sale in the market place. An overnight conversion is <u>highly</u> unlikely but a phased conversion is not. Such a conversion could demonstate the vastness of the power of the federal government, and how it can be the major force in the adoption of the metric system in the US. Ironically, because of the international nature of the drilling market, the downhole drilling tool industry will be forced to cope with both foreign and domestic governmental actions.

One possible way that the federal government could force metrication is through an indirect process. By requiring all federal agencies to deal exclusively in metrics, a significant portion of the private sector output would be forced into handling metric units. Most notably effected would be those industries directly involved with defense procurements and interstate commerce shipment of goods. Of course, several levels of the economy would be effected, but these groups could dampen the impact on related and supporting industries. The petroleum industry, itself, would feel little of the impact, being cushioned through the efforts of its own agencies, and conversion of its sales quantities could easily be accomplished in a soft change. Eventually, the force of such a move would reach Drilco, but such action would be slow in arriving.

Now, the federal government could cause considerably more metric activity by adoption of a mandatory conversion program for the nation as a whole. Such a program would probably be patterned after the Australian or Great Britian programs and similiar to programs previously introduced in Congress. Such a mandatory program would involve establishing time tables for conversion of different sectors of the economy over several years and would probably limit its application to the regulation of external reporting between companies. A mandatory program would force conversion upon all sectors of the economy but only to the extent that data being transmitted outside a firm conform to accepted metric standards. Drilco would be forced to accept metric orders, purchase raw materials using metric values, and conduct shipping using metric values, though the firm could convert these units to customary values for use within its own operation.

Since this would be a soft conversion, this could be done without converting the production plant, although it would present some difficulties. Immediate conversion would require that the purchasing and the operations sector be capable of handling metric orders until the rest of the plant could realign itself to the metric system. Metric orders would arrive, be converted to an appropriate English size, the tool produced, and shipped after converting the description back to metric units. It would be nonsensical to remain in this status for any length of time, but it could be maintained over a short period of time.

(C) Conversion Through Foreign Government Actions

The effects of foreign government intervention are not as clouded as those of the US government. Foreign governments could not impose direct conversion requirements on US manufacturers, but they could restrict the sales of particular products within their national boundaries for failure to meet local measurement standards or codes. As pointed out in Chapter IV at least one major European political block is moving in this direction and seems set on imposing such restrictions.

The placement of a soft conversion requirement on imports to the Common market could cause a major metrication effort in the US, and it would bring to bear additional pressures previously non-existant. These pressures would be similar to those exerted in a highly competitive metric market; previously, there has been no competition to American customary-sized drilling products from corresponding metric-oriented European manufacturers. The effect of the EEC directive would be to :

(1) eliminate a portion of the English-sized drilling tool market, and

(2) reintroduce that same market as a metric-sized drilling market.

To compete in this situation, US manufacturers would have to market metric sized products. It might be suggested that in such a situation, the drilling tool industry would become faced with the same problems other multinational firms have coped with in the past.

External reporting would be the major area effected by foreign government's restrictions on the trade of the customary sized products. Without the existance of established, metric standards, the only possible restriction that could be made is that customary sized units must be converted to metric units (soft). The soft conversion of a small percentage of a firm's output could best be handled by its operations department in conjunction with its sales personnel and its shipping department. Special considerations would be required for each order effected by the trade restrictions, and the operations people would need to insure that the finished products and its accompanying paperwork were properly converted.

These scenerios have been general in their construction because of the uncertainties involved with forecasting some event which might not happen for several years in the future. They should, however, indicate that, no matter which one occurs, any cause or singular motivating event (if there is one) will have approximately the same initial effect on the conversion activities of the firm. First, the external reporting of the firm will be effected. This includes sales catalogs, product literature and descriptions, shipping invoices, and reports not originally at the parent plant for use at that location. As the environment or universe changes to the metric system, more orders will require metrics, and a greater pressure will be exerted to convert other facilities. Eventually, all input and output will use metric values, and this would virtually eliminate any reason for maintaining the customary system.

VIII GENERAL OPERATIONS AT DRILCO AND THE SPECIFIC IMPACT OF METRICATION

Drilco, Inc., is a manufacturer of downhole drilling tools and associated drilling equipment. The main task of the firm is to take green (untreated) bar and rolled steel and green forgings, and machine this raw material into the tools and the products which it sells. Most operations involve the turning of bar ODs and IDs, milling operations, and threading operations (most threading operations involve cutting RSC connections). Products are usually non-standard (severly restricting the firm's ability to produce items in an assembly line manner), and the product designs rely heavily upon standard solid steel rolling stock sizes and standard tubular steel sizes to reduce machining costs. Additionally, sizes, tolerances, and configurations are highly dependent on standards established and accepted by the drilling industry (API standards).

Sales of products are to both domestic and foreign customers with the predominance of products being sold for eventual use overseas. Lifetime of the product is normally in excess of 5 years with decreases in lifetime expectancy occuring when drilling activity is quite high for extended periods of time, or when drilling is under adverse conditions.

From previous surveys*, it was found that most foreign customers can operate using metric or customary values, while most domestic drillers restrict operations to only customary units.

If Drilco was faced with metrication, the following observations can be made as to the type and extent of the conversion:

(1) It is doubtful that the US, especially the petroleum industry, would embrace a hard metric conversion before it had conducted a soft

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* The surveys were in the form of personal interviews with engineers and drilling contractors who operated overseas, plus correspondence with SII representatives in Europe.

metric conversion. Under a soft metrication program, present day standards would be retained, only in metric units, and all present day production could be maintained until more advantageous (technically advanced) metric designs were generated. Conversion to hard metric sizes would be done over an extended period of time (20 to 30 years). Under a soft conversion, only external reporting in metric units would be required and the internal operation of the firm could retain the use of English units until such time as it desired to adopt metric values.

(2) Rotary Shouldered Connections would not change under present day conditions. Currently, a vast majority (if not all) of the rotary shouldered connections employ API standards in their design and are manufactured to whole English sizes. There are no hard metrically designed RSC connections in commercial production; all metric connections of present manufacture are simply soft conversion of existing English sized connections.

(3) If a hard metric conversion within the steel industry occurred and casing sizes were modified to reflect whole metric ODs and IDs, bit sizes would have to be modified but a majority of present day tools and tool sizes could still be retained and utilized. Reamers and stabilizers may need some modification and would have to be examined on an individual basis. Redesign of such hole-size dependent tools would be required, but many tools would require less than 4% reduction in the sizes of their ODs and redesign would probably not be expensive. Most other tools, such as drill collars, heavy walled drill pipe, and drill pipe, would require modification only in rare instances.

Should metrication occur, the firm must be capable of modifying its operations; initially, it would need to handle all external reporting of metrics, and finally, it would have to operate using metric units exclusively. To accomplish this, the firm must be able to modify its existing product and process descriptions, documents, and files, its measuring tools and machinery; and all its graphics, mechanical drawings, and tabulated data. It should do this work in such a fashion so as to be the least disruptive to overall plant operation and production and to employee morale, enthusiasm, and efficiency.

Modification and metrication of external reporting would seem to be a logical first step in an orderly, soft metric conversion. In such a program all sales catalogs, brochures, and publications would carry dual English and metric dimensions, all products would bear both type units on data plates and sales documents, and sales transactions could be made in either or both units (as long as the items sold fit the sizes presented in the firm's brochures). The results of this program would be that the firm would meet all projected trade restrictions, would encourage the use of metric orders (possibly gaining a slight increase in foreign orders), and would begin familiarizing its personnel with metric units. It should be noted that the main thrust behind conversion of external reporting is to satisfy immediate but minimal metric requirements and not to institute major metrication activities; the internal structure of the firm and use of customary units would remain unchanged. It should also help polarize attention on the future conversion problems without causing immediate alienation of all employees.

To establish where the conversion of the external data to internal data should take place, the following system diagram is presented (see Figure 6). The sales department and the customer interact and an order is generated. Or, the customer can interact directly with the operations department of the

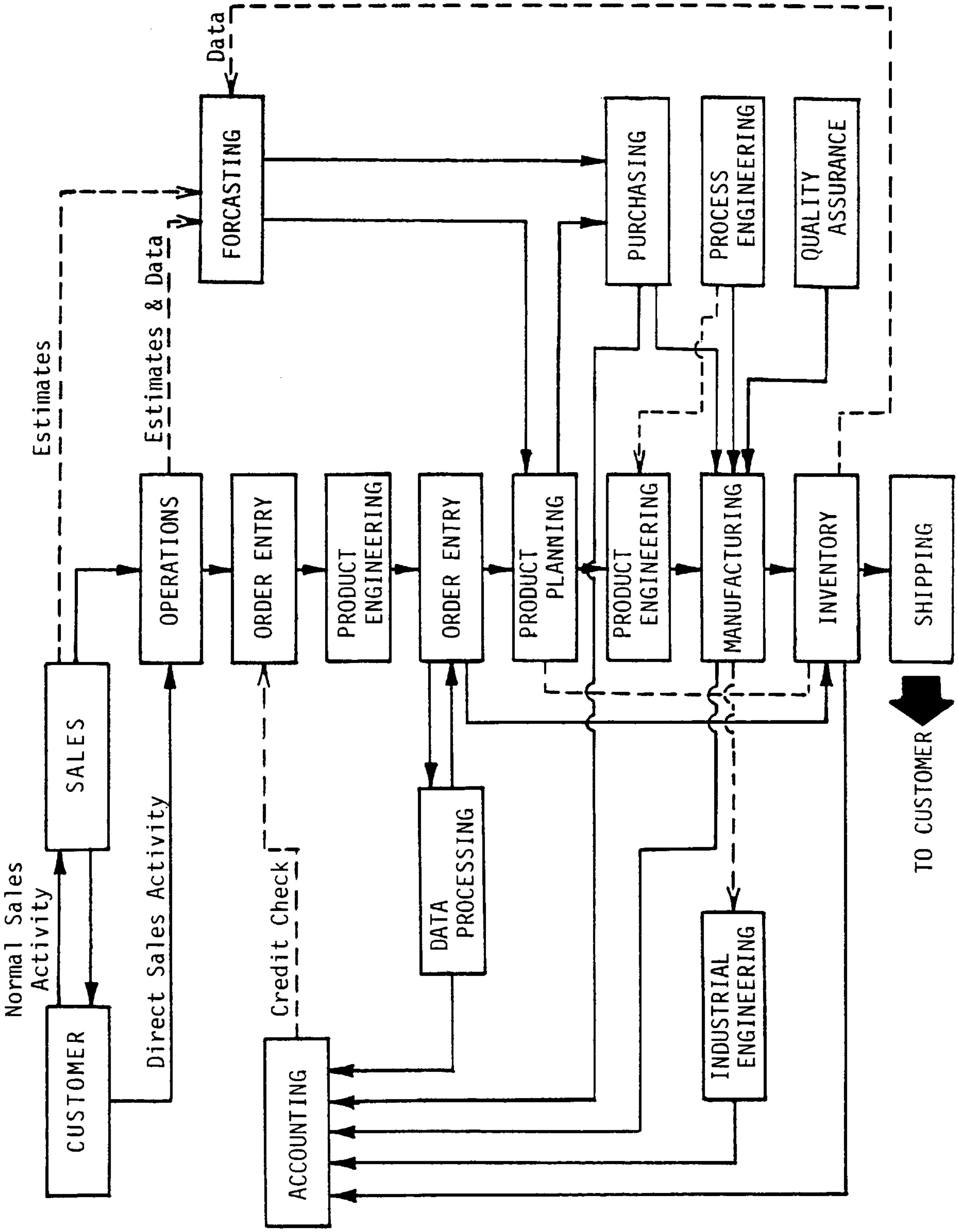
Normal Sales Activity
CUSTOMER
SALES
Direct Sales Activity
Estimates
Estimates & Data
Data
FORCASTING
OPERATIONS
ORDER ENTRY
PRODUCT ENGINEERING
ORDER ENTRY
PRODUCT PLANNING
PRODUCT ENGINEERING
MANUFACTURING
INVENTORY
SHIPPING
TO CUSTOMER
PURCHASING
PROCESS ENGINEERING
QUALITY ASSURANCE
Credit Check
ACCOUNTING
DATA PROCESSING
INDUSTRIAL ENGINEERING

FIGURE 6

firm. The operations department of Drilco tends to maintain an overseer type position, taking orders from customers or salesmem and translating them into data usable by Order Entry, and taking finished goods data and generating the necessary documents for the proper disposition of the product. Order Entry, as its name implies, initiates the order documents and begins the actual processing of the order. Verification of document and requested product correctness follow before Order Entry releases control to product planning whose main purpose is to control the flow of shop orders entering the plant. Product engineering and process engineering provide documentation for the manufacture of the product while quality assurance monitors its actual production inside manufacturing. After the product is finished, it leaves for inventory and, subsequently, to shipping. When the product is ready to leave inventory, Operations again intervenes and initiates invoicing and shipping documents for the order.

From the standpoint of control and of overall effectiveness, customer service (order entry) would seem to be the best location for the institution of an external metrication program. This is the first location of an agency where total input flow and output flow merge and which could be employed to control the use of metric units into and out of the firm. Customer service normally receives its orders from either sales or from quotation; if metric, such orders have traditionally been converted either by sales personnel or by the quotation department and passed to order entry. However, in an external metrication program, orders could be received by order entry where the English units could be dropped and metric units used exclusively. When the order was completed, inventory control, another division of customer service, could reintroduce the metric units to the order. In this fashion both English and metric units could be employed in the field and all external reporting (less brochures, publications, etc.) could be converted at order entry; all internal reporting would remain using English units.

As forms and documents undergo description changes (soft change), the ability to carry the metric units throughout the plant operation would increase. However. from the standpoint of the customer, the product would be metric already (or rather could be metric, as both units of measure would be available). Documents could undergo modification to include metric units whenever they came up for review and reprint. Engineering drawings could be modified on an as needed basis, whenever the drawings came up for redraw, or during filler time for draftsmen. Once all product descriptions and process descriptions had dual dimensions, all Drilco documents could employ either value system; then hard conversion of machinery and precision measuring tools could take place. Hard conversion of all capital items such as lathes and milling machines could not take place simultaneously, and in order to avoid loss of time, it would be necessary to operate the plant for a period of time when both English and metric lathes were present and operations for a product could be performed by either. Once all documents and machinery were converted, the plant could easily continue manufacturing tools dimensioned for customary sized holes yet easily adopt to hard metric conversions.

As pointed out in the first portion of this report, Drilco must operate under the assumption that at least a soft conversion to the metric system is eminent. Such a conversion would impact Drilco in the areas of product and process description, documents and files, tools and machinery, and graphics (drawings and tabulated data). It would be wise to examine each of these areas in detail to determine the actual effect the metrication will have upon them.

IX GENERAL AREAS OF CONVERSION ACTIVITY

(A) Product Descriptions and Process Descriptions

Product and process descriptions used to identify a product during order processing and related non-engineering, non-manufacturing activities will require modification to initiate a metric conversion. These type descriptions are normally used to identify a product in inter and intra office correspondence, and their conversion would be mandatory in any soft conversion program involving external reporting. To accomplish this conversion, existing standards would simply be given in all paperwork in units of both measuring systems; no physical changes would take place and no physical dimensions would be altered. In the case of Drilco, who relies heavily upon API standards, the conversion of its descriptions and the standards it uses should be quite simple. Additionally, because there are no anticipated changes in API standards due to any metric conversion program, conversion of present day standards should be sufficient for several years into the future. Changes in the product descriptions and process descriptions, which would be required for metrication, would be converted directly (soft conversion) and would require no design changes, per se. A proper soft metric conversion would affect product descriptions found in catalogs and brochures, in some tabulated drawings, and in computed listings for the Item Master or other such listing. This would affect any description which involved a final overall product dimension (a nominal dimension), as opposed to descriptions of semi-finished or subsystems parts. Conversion of production related dimensions may require modification of tolerance zones, and must be done using engineering resources (see Section IX(B))

After converting existing values, both English and metric units should be given. This condition would have to be imposed until such time as the majority of customers, suppliers, employees, and products-in-use utilized metric units and there was little demand for the English units. During the initial conversion period, most existing values should be followed by their appropriate metric values, enclosed in brackets. For exmaple, a drill collar having a length of 31 feet would be noted as follows:

Length: 31 ft. ± .5 ft. (9.45 m ± .15 m)
OD: 8 in. (203.2 mm)
ID: 2 13/16 in. (71.4 mm)

This type of dual description could be used for most brochures and some tables. If a tabulated drawing was quite complex, the dual value may cause the chart to become unmanageable, necessitating the employment of two seperate charts representing the same data. Round off errors will, of course, be present, but for the most part, these errors fall easily within the current tolerance zones. API has already established guidelines with respect to appropriate units for specific dimensions and the appropriate rounding off of converted values.[13]

Computer printouts would cause other problems; most existing systems would require double capacity should dual dimensioned product descriptions be employed on all printouts. However, through proper planning, most duplication can be minimized. Dual charts, tables, and master listings can be maintained and updated rather than reprinted (as is normally the case). For an extended period of time, existing tables can be maintained and dual tables can be printed to provide supplemental metric information. When the decision is made that the company should converse in metric units, the role of the tables can be reversed, with metric tables and listings printed instead of corresponding English printouts, and the dual tables maintained to supplement the new metric ones.

It is estimated that about 70% of all printouts would require some modification. The Item Master, the Master Routing File, the Product Structure File, the Work Center File, and the Supply/Demand File would require duplicate dual dimensioned listings during the transition. These listings receive their product descriptions from the Item Master and contain limited physical dimension data of their own. The Item Master conversion would be the most involved and would not lend itself to an easy conversion by the computer. However, with only 15,000 active part numbers, the list could be converted within 4 to 6 weeks at the rate of 500 to 750 part numbers per day. Allowing for input to the computer and miscellaneous costs, conversion of the five master files could be accomplished for less than $10,000 total. Virtually all other files, listings, and paperwork generated by the computer are derived from the master listings, and inclusion of metric data onto these printouts will require only simple format changes.

Therefore, conversion of the Item Master plus minor changes in other file formats will accomplish practically all the necessary metric conversion for computer generated data. The recommended format for this soft conversion is given in Appendix F; this process should be utilized when converting existing product descriptions to new metric values.

(B) Drawing Conversion

Those product descriptions and characteristics which require non-exact conversions, conversions of nominal sizes to approximate metric sizes such as several brochures, some computerized product descriptions, etc., could be handled by non-engineering personnel. However, the complexity and magnetude of the product, process, and Quality Assurance drawings dictate that other considerations must be examined and that the conversion of these drawings be handled seperately by an appropriate engineering faciltiy.

Several formats are available for the conversion of these type items; they range from complete redraw and exclusive use of metric values to the tabulating of English/metric values appearing on a drawing and attaching the list to the print. Keeping in mind that a secondary objective of the conversion is to reduce costs, the type conversion best suited for Drilco would be one which used dual English/metric values on the drawing and provide the greatest degree of flexibility, insuring that the drawing could be used both at the start of the conversion, its end, and for an indefinite period thereafter.

The dual dimensioning of all drawings according to the method set up by ASME in the pubilicaton Y14.5 - 1973, Section 5-7, pages 91-95, would satisfy all the requirements except that its implementation would require extensive redrawing of existing engineering graphics. To complete a major drawing conversion over a relative short time (less than three years) would require the expenditure of considerable funds. However, by extending the time allocated for drawing conversion from less than 3 years to more than 5 years, many of the existing drawings could be converted through a normal updating process. Essentially, the conversion of the drawings could be done without any additional expenditures.

Drilco has approximately 4400 drawings in use by Product Engineering, 3500 drawings in use by Process Engineering, 2400 drawings in use by Plant Engineering, and less than 100 in use by Quality Assurance. Product Engineering has the larger total number of drawings and would be the limiting factor in a conversion process. Current and past rates associated with drawing updating and redrawing, per month excluding the production of new drawings, is approximately 50 drawings per month or about 600 per year.

The redraw capability of the Process and Plant Engineering Departments is about the same as Product Engineering, and their production rate of converted drawings should be similar. QA, however, has few resources to accomplish their conversion of drawings, but because of the few drawings, this should present no problems. After approximately 7½ years, 100% of all engineering drawings should be converted under a normal redraw schedual.

Thus, 8 years after initiating a conversion process to redraw all existing prints and injecting dual dimensioning into the engineering graphics, all of Drilco's engineering drawings should be converted.

Such a conversion venture should not be taken lightly and approved conversion procedures should be followed. API has already published suggested procedures for converting English values to metric values, and these should be adhered to religiously.[9,10] For tolerance zones, it would be advisable to round off any converted values so that the new limits were exactly equal to or within the old tolerance ranges. For example, conversion of a 10.25" ± .005" OD bar to metric values would make the diameter 260.4 mm + .5 mm, -.15 mm. Note that the nominal diameter is no longer located equadistant from the two end points of the tolerance zone. This is to allow a closer fit to the English part <u>if</u> the item was made according to a metric drawing, without loss of product integrity because of round off error. It should also be noted that this procedure results in products with closer tolerance zones.

As a general rule of thumb, tolerance zones in thousandths of an inch would be given in hundredths of a millimetre, and hundredths of an inch would be given in tenths of a millimetre. This sequence could be followed for the conversion of all tolerances. In some rare instances the metric tolerance zone could be wider than its corresponding English zone, but this should be a rare occurance and done only when the new tolerance zone will not adversely effect the product. As an example, a tolerance zone of ± 1/32" would correspond to a metric tolerance zone of ± .79375 mm. It would be easier to write the metric zone as ± .8 mm, since the difference between the two zones is less than .0005", a value not normally measurable on the average micrometer.

Once the procedure for converting drawings is established and the steps taken to initiate the drawing conversion, it would be worthwhile to convert those drawings first which have the highest usage and result in the high income for the firm. Under the assumption that the conversion activity could be drastically increased due to some governmental action or some unforeseen market force, it would be helpful if the most important drawings were converted first, thus assuring that any unforeseen step up in metric activity could be handled with a minimal effect on the firm. An ABC analysis (see Appendix K) would indicate what products and part numbers have a high demand and identify which drawing should be modified first. The present analysis indicated that some 20% of the parts ordered account for about 80% of the revenue for the firm. If this breakdown is maintained, after converting drawings for only 1½ years, about 80% of Drilco's yearly production could be manufactured using metric drawings.

Of course, the preceding discourse was based on the assumption that a crash or forced conversion was not needed or would not occur at the firm. If a forced conversion is initiated and no drawings have been converted, it would require about 14 man years to convert the existing graphics, or about $175,000 to $200,000 (see Appendix L); these figure only reflect the current number of drawings and would have to be increased accordingly to reflect any increases in graphic populations.

By initiating a planned graphics conversion, Drilco could save in excess of $175,000 in the conversion of drawings alone, over a forced conversion situation. Such a program would directly link the existing redraw procedures now in effect in each of the engineering departments to the metrication program. It could be initiated now, on a spare time basis, as opposed to a future, short term, forced conversion.

(C) Machinery Conversion

In an impending metrication program, machinery and precision tool conversion should carry considerable importance: conversion of these areas is normally viewed by management as a particularly expensive and should receive considerable attention and study. Also, the general feeling is that in any metrication program, most heavy, capital equipment, such as lathes and milling machines, plus precision measuring equipment, will require either replancement or expensive, near prohibative modification. Hence, in the past most firms have placed the most significant conversion costs on capital goods. However, capital goods, heavy machinery, and other like items will cause few problems at Drilco, if the metric conversion process is planned and initiated with sufficient lead time.

Heavy equipment at the firm is used to modify, in some form or fashion, the bar stock and forgings entering the plant as raw material. Most of such modifications are in the form of a physical change, such as reducing an item's OD or ID, it's length, or adding threads to the product. With the exception of threads*, all these dimensions can be expressed as lin-

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*The threaded items refered to in the text are products with Rotary Shoulder Connections or RSC connection. Conversion of machinery to produce metric RSC connections would add a new dimension to the problem and the overall ear dimensions.

The high-dollar, capital goods located at the Houston plant of Drilco generally consist of lathes, hob cutters, and milling machines. Under each classification, there are several different types of machines, and each sub classification has its own problem areas. Metric conversion of machinery should consist of additions or changes to the machine's structure so that it could produce an item from metric drawings without converting the drawing to customary units. Therefore, to satisfy the metrication requirements, each machine should receive only those modifications related to its present tasks (see Appendix M). For example, Drilco has two converted lathes turning "zip" grooves on drill collars. The only critical dimension involved in the turning of the recesses would be the change in the collar OD; the only modification needed on the machine would be the conversion of its cross feed to metric units. The lead screw and compound feed would require no modification.

Therefore, the function of each machine and the processes it is used in should dictate the extent of modification of each machine.

The most versatile machine at the plant and those machines which have the heaviest burden are the NC lathes. These machines are used extensively in the drill collar line, tool joint manufacture, and other associated lines. However, to convert them would require little work as most machines already have metric capabilities. Most NC lathes are set up to read either inch or metric tapes (see IX (F)) and perform their functions according to

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extent of the required conversion. However, to date there are <u>no</u> known metric RSC connections in existance, neither in production nor <u>in</u> reseach. It is not possible at this time to predict when, if ever, Drilco will have to produce metric threads and metric RSC connections. However, Drilco already has NC machines which could produce metric tool joints, and through the purchase of one or two metric lathes, the firm could handle most all situations arising from the introduction of a metric RSC connection.

the measuring system selected. All those NC machines which do not have metric capabilities can be converted by the addition of certain circuitry and at a minimal cost (see Appendix N).

Additional NC equipment other than lathes, and equipment controlled by numeric readout would also require minimal modification. Drilco has two NC and one CNC milling machines; only one NC mill (an Ex-cello) will require additional circuitry to handle metric input. There are several milling machines with electronic digital readout capabilities. All of these machines will require modification of their circuitry to display metric units. The cost will only be in the neighborhood of $250 per axis (to include shipping but not machine down time). Once all the NC milling machines and mills with numerical readout are converted, a significant portion of all milling operations will have been converted.

Trepanning lathes and trepanning operations will require few modifications should hard, metrically sized bores be needed. The trepanning operation, itself, will require no change since the operation is dependent on tool size only. Tool modification will only be needed when hard, metrically sized bores are requested.

Engine and turret lathe operations will require modification only to the extent that metric reading dials must be added to their respective feeds. The only lathes that would <u>require</u> conversion of the entire machine to include lead, cross feed, and compound feed screws, their respective nuts and half-nuts, change gears, and associated face plates would be an Axelson and one or two Dean, Smith, & Grace lathes, and only if a hard metric conversion occurred. These would require modification only because they are used in the construction of Ezy-Change stabilizers which have an RSC connection at mid body (QA requires this connection and the pin be single-pointed using the same lathe to maintain the concentricity of the connections. To do this, the machines would require modification.) Modification of the other lathes could be accomplished using dual reading dials. These dials replace conventional ones, and are calibrated in units of either inches or millimetres. Such devices cost between $160 to $650 an axis, with the average cost at $240, and all lathes would require one to four of the dials, depending upon the operation. The dials have a relatively long lifetime and could be added to the machine in a very short time (usually less than 15 minutes per dial).

Hob cutters, which are used to cut rotary shoulder connections, will present few problems to modify. By the addition of 1 to 3 change gears, all hob cutters at Drilco can be modified to cut metric threads. However, to do so, an approved metric RSC connection must be adopted along with the availability of a hole to cut the thread.

Eventually, all machining operations at the plant would be expected to be converted entirely to the metric system. Through the use of inch/metric dials, planned shifting of assets and demands to make maximum use of existing metric capabilities, and through close coordination of production runs, Drilco could produce metric products for several years, during which time existing assets can be modified as the machines experience wear and are rebuilt. Currently, the average lifetime of a machine at Drilco is between 4 and 6 years (a few have lifetimes of 10 years). At the end of this period, the machines undergo extensive rebuilding and several major portions of the unit are replaced. During rebuilding, all feed and lead screws that would require modification to convert the machine to the metric system could be replaced with their metric counterparts. As these items normally require replacement anyway; modification and conversion of an English lathe to a metric lathe at rebuild will cause no additional cost to the firm and could be expensed to the maintenance of the machine. If a schedule is followed judiciously, all of the manufacturing machines at Drilco could be fully converted 10 years after initiating the program.

(D) Precision Tool Conversion

The conversion of precision tools will require a different approach. As a general rule, most precision tools cannot be modified and will require complete replacement. Exceptions to this rule would be those tools of high dollar value, generally ones of complex construction such as comparators and "Supermics" or tools employing electronic digital read out. All other hand tools and related precision tools would require prohibative modification; it would be cheaper to replace them.

A brief observation should indicate that Drilco has two basic areas within the plant where precision tools are use: QA and the tool crib. Conversion of the tools in both of these areas could be accomplished with a minimum cost if judical planning and sufficient lead time are available.

Quality Assurance, as its name implies, has the mission of inspecting all production items during and after manufacture to insure that the products meet those minimum standards established by the company. To accomplish this, QA employs several inspectors who are located on the plant floor and conduct inspections of all machined parts. Additionally, QA maintains a central laboratory where it conducts inspections of hob cutters, gages, and associated prcision milling tools plus a repair service for all precision tools in the plant. Quality Assurance maintains continuous control over its tools and, generally, exercises excellent care of the equipment.

The tool crib, on the other hand, operates as a lending agency for precision tools and gages needed for all phases of actual production (it does not provide the individually owned hand tools necessary for employment). These tools are provided for production and shop personnel and are separate from the precision tools utilized by QA. Depending upon the type of operation, product being manufactured, and phase of product manufacture, different precision tools are necessary for quality production. Machine operators determine what types and sizes of tools are needed for each operation and secure the necessary measuring tools from the tool crib or from their own personal tools. Upon completion of a specific operation or production run, or at the end of a shift. the tools are returned to the tool crib until the operation is resumed.

A significant difference between the tools used by both shops can be found in the abuse of the tools loaned out by the tool crib, as opposed to the tools used by QA. For all practical purposes, the precision tools of QA have an infinite lifetime (in excess of 50 years) and, hence, would outlast any conversion program. On the other hand, the tool crib has a regular turnover in tools with the lifetime of the tools being about two to five years; therefore, over a five year period, all tools in the crib should require replacement

The reason that the previous point was presented is that this situation offers the firm the chance to reduce its capital expenditures for metric precision tools by cycling the obsolete, English tools from QA through the tool crib or through outlying shops. As tools for the tool crib require replacement, the necessary tool can be transferred from QA and a corresponding metric tool purchased in its place. Although not all tools can be recycled in this manner, it is possible to significantly reduce the total expenditures required for the replacement of such items.

Now, several problems could arise if such a course of action is taken. First, the tool replacement program could not be initiated until all drawings (or a significant portion) are converted to dual dimensions. This would mean that the recycling could not begin until 3 to 4 years after the redrawing program was initiated (if redrawing is done on a replacement schedule). It would mean that at some time in the future, parts would be manufactured using customary units, but that QA would utilize metric measuring tools to gage their quality; this would require dual dimensioned and dual toleranced drawings. Finally, close monitoring of the progress of such a conversion would be required, and no segment of production or QA should be using both type tools at the same time. A less confusing, but more expensive process would be to totally convert QA (except for a minimum of customary tools for future work) and allocate the newly released tools to the tool crib.

(E) Education

Conversion to the metric system will require not only modification of machines, but also the retraining of personnel to handle these new machines and to read dual dimensioned drawings. It has been contended by several groups within the US that such retraining will have to be quite extensive and that several classroom hours will be required to adequately prepare almost any affected individual.

Of all the fears connected with the adoption of the metric system, the education problem appears to be the most disproportionate. Although the average American has little knowledge of the system and most express the belief that learning metrics will be quite difficult, experience has shown that acceptance and proficiency in the system would be require a minimal exposure to metrics and little actual classroom work.[11,12] Several firms which have undergone or are undergoing metrication experienced very few problems when retraining their employees. John Deere, Inc., and General Motors, Ltd., both indicated that employee acceptance of metrics was quite rapid and that the transition from customary units to metric units was accomplished with little difficulty.

The scope of education and the necessary training time will, of course, vary from individual to individual and will be greatly dependant upon his/her education and particular job requirements. It is important not to overtrain personnel, but only to indoctrinate them to such an extent that they can perform their job requirements when using either customary or metric units. Engineers and technicians who must deal with the entire design of a mechanism should receive the most detailed training, but because of the higher education of most of this group, many will already be familiar with metrics through their education and should not require extensive training. John Deere's entire training program for engineers and technicians was only four hours in duration; the training program for non-technical, skilled craftsman was only one hour in length.

The reason that the training programs can be abbreviated is that the scope of each program should not extend past the needs of the person being trained. It would be very unwise to require all employees to attend a detailed and all encompassing dissertation on metrics. Most of such a program would be of little use to the average person and would be wasted. Each general group of employees (secretaries and office personnel, technicians, skilled and semi-skilled workers, etc.) should be exposed to only those areas of metrics which will directly effect them. Therefore, classes geared to the engineer should include employment of all approved SI units, to include pascals (pressure) and light intensity (lumens), while craftsmen should be exposed to the basic units of length and measure with emphasis on exactly how they would use the new units.

Appendix P lists those suggested topics for education and the suggested times that such training takes place. Again, the emphasis must be placed on the needs of the individual. Training should never be so extensive that the individual is overwhelmed with the system and the extent of its application. Also, the training should be directed toward practical applications. The popular "Think Metric" concept could be employed, and training without the aid of cutomary units should also be quite beneficial.

(F) Supporting Peripherals

The five previous sections cover the vast majority of areas which will require conversion, yet there remain sections which do not fall in those areas and will require unique consideration as to their conversions. Without regard to their importance, these additional areas will include: production of metric NC tapes and conversion of the existing post processers, conversion of the grinding and sharpening shop, conversion of personal tools, impact of metrication on Central Supply, the position of vendors with regards to metrication, and the impact of metrication on forms.

Although a large majority of Drilco's NC lathers and milling machines have metric input capabilities, Drilco does not have the ability at this time to generate metric tapes for production. All NC tapes are generated by a mini-computer located in Process Engineering. Data for construction of a tape is placed into the computer and massaged by the post processer routine which developes the necessary paths and machine operations from previously stated machine parameters and characteristics. Currently, the post processers for the NC lathes are limited to inch output, although inch or metric input is available to the computer operator. Output consists of tabulated data describing the operation and what tools are required for each phase of manufacturing, plus generating the NC tapes. Through the addition of complimentary software, the post processers would gain metric output capabilities. Additional software costs will run in the neighborhood of $300 to $400 per processer conversion; for all Warner & Swasey NC lathes, the cost of conversion ($725) will cover the two processers which provide output for 4 machines. These new processers will not restrict any inputs or modify, in any way, existing capabilities except to add-on the additional metric modes.

The tool sharpening operation at the firm will also require modification to some extent, but the extent of such work must be tempered by experience in working with new metric units and new metric cutting tools. There are two major sharpening operations, the main tool sharpening department and trepanning head sharpening, and both will require different degrees of modification to handle their metric requirements.

The main tool sharpening department handles most sharpening operations for tools located in the tool crib. These tools consist mainly of cutters, reamers, high speed drills, and hobs. For the most part, the department simply returns the tools to their required sharpness, but will, at times, deal with returning a tool to some geometric shape as in the case of hob cutters. For tools like drills and many cutters for milling machines, sharpness is the only criteria; under the present operation, metric tools of this nature could be sharpened without any grinding machine modification. Should the cutting tool require some specific geometric configuration, the tool grinding department might require additional support in the area of precision measuring tools. This situation would arise only after a metric product was being manufactured and only after the firm was committed to metrication and the production of metric products. It is highly probable that the present grinding and sharpening machines could be used for all or a vast majority of the metric sharpening requirements, but Product and Process Engineering should be aware that metric products may require new tooling.

The trepanning operation presents a unique situation in that the process must cope with a problem inherent in the design of its operation. The trepanning process results in a considerable variation in bore diameter from beginning to termination of the operation. Over a 15' to 20' trepanning operation, bore OD may be reduced by as much as 1/16" or 1.6 mm, and the normal tolerance on a trepanned bore is +1/16, -0.0. In order to maintain the life of the cutting head, the actual OD of the tool is further reduced by an additional 1/16" to 1/8", and the cutting surfaces are designed for replacement. After each trepanning operation the cutters are replaced in the head and resized to the oversized end of the bore diameter. Because of the great tolerances available in the boring of the ID and because of the flexibility needed by each trepanning head, manufacturing and use of existing trepanning equipment should be adequate for most hard metric trepanning operations.

If, however, the decision is made to construct only new trepanning cutters, specifically designed for metric IDs and to phase out existing equipment, a time span of 1½ to 2 years would be required to eliminate the present inventories on-hand at the trepanning shop. The average lifetime of a trepanning head will vary considerably depending upon its abuse and the demand for a paticular hole size. On the average, trepanning head life is about 3 months, with very small and very large sizes having significantly longer lifetimes due to the lack of demand for their use. Phased transition could easily occur through adequate control over inventory levels. It is doubtful that once new metric bore diameters have been accepted demand will be so high as to eliminate the need for present day heads; it is more likely that initial demand will be quite low and the inventory of the shop will increase slowly to handle the additional metric trepanning sizes plus the present customary sized heads.

Central Supply will be the one problem area where conversion will rest almost entirely on the actions and demands of its customers. Under the present situation, Central Supply functions as a buffer for shop demand on consumable supplies and parts required in the operation of the plant. Once metric conversion activities have started on the plant floor, Central Supply must be capable of securing the required metric tools and products for production. The point that must be made is that prior to any hard type conversion, Central Supply must be notified, and prepared to handle any changes in supply demand.

As in other areas of plant operation, a slow transition would be benifical to the conversion of Central Supply. Presently, inventory records and purchase orders employ customary units in describing on-hand items and related purchasing data. The longest period for a form to remain active in Central Supply is two years, with the average lifetime or replacement time being about 1 year. Actual inventory items have widely varying turnover times: about 70% to 80% of all inventory items are consumed in 3 to 6 months while 10% of the inventory may be on the shelf in excess of two years. The "rapidly consumed goods" represent items such as tools, lubricant, etc., items normally having a short shelflife, whereas slower moving items are repair parts for machine assemblies or special tooling items (which may never be used for their intended purpose). Weighing this information, the conclusion could be drawn that as long as the appropriate documents have been converted, losses from the conversion of Central Supply should be minimized.

As pointed out earlier, conversion of precision tools will present a unique problem to the firm. However, the only tools examined in that segment were those tools directly owned by Drilco, and that study did not cover personal tools or tools owned by individual machine operators. Should metrication occur, provisions must be made by the firm to convert those individual machine operators. At the Houston Plant, there are an estimated 450 to 500 employees who are actually engaged in manufacturing operations. Each employee is required to provide for his own personal use the following items:

10 ft. Steel tape measure
12 in. ridgid steel ruler
1 ea. Magnetic base
1 ea. Dial indicator

If these items were purchase in bulk, the replacement costs of the above article would be in the neighbor hood of $30 per man.

Besides these tools, several individuals have collected rather extensive personal tool inventories and use these tools daily in their work. Most of the skilled machinists and machine operators who have an excess of two years in the shop personally own several precision tools which they use in their daily assignments. If the plant switches to metric units as the sole units of measure, some production capacity will be lost unless these personal tools are replaced in some fashion.

Replacement policy and procedures will have to be left almost entirely to the firm's higher level management. The cost of conversion must be born by some segment of the firm, and the decision must be made as to what percentage the firm can or should assume and how much the individual should pay.

Drilco relies heavily upon the support and capabilities of vendors for several integral parts for products and a few entire product assemblies (RWP wear pads, Degasser and Ezy-Torq constructions). Prior to an actual hard conversion, the firm must insure that its supporting vendors can adequately supply the required parts or assemblies; and/or prior to a soft conversion, the firm must insure and arrange for appropriate changes to be made on descriptive plates and accompanying documents. (This is especially important in view of the 1980 EEC trade restrictions which could impact greatly on items like the Ezy-Torq). To date, through conversations with several suppliers, no vendors have expressed intentions of adopting the metric system as their sole measuring system. However, some have indicated that they were aware of the present metrication forces and that they had begun considering the problem. All indicated that they would gladly assist in any conversion at Drilco, but that the firm might incur additional costs for changes in data plates, etc.

Soft conversion of vendor products by the firm would require very little cash outlay. Tabulated data and specific design considerations normally accompanying a vendors's product will usually not be forwarded with the assembled item, but replaced by a Drilco document summarizing the information. In instances where data is afixed to the product, supplementing decals or replacement decals could be used.

Problems may be encountered with vendors when hard conversion activities are initiated. Vendors may be unwilling or unable to deliver products which are metricallly sized, forcing Drilco to either submit their requests in English units or in standard English sizes or change vendors. Either situation is far from optimal but could come about if no economic pressure is present to force conversion fo the vendors. However, hard metric conversion is not anticipated for several years, giving ample time for the market place to develope its metrication forces.

Finally, but not one of the last or least items which must be considered in a metrication program, conversion of forms and records must take place. Presently, Drilco has some 680 approved forms of which 80 deal with weights and measures, and only 11 actually have customary units printed on the form. These documents will require conversion to the extent that any customary unit given or required by a form must have a corresponding space for its metric equivalent.

Currently, all approved forms and documents are under review in a general program to reduce the number of forms active in plant operations. Once reviewed, it would be wise to allocate dual dimensional information on all appropriate forms. Such dual dimensional information will be required in any initial phase of metrication and should be present prior to the institution of external reporting in metric values. Converson of forms must be one of the first steps in a conversion program.

X POSSIBLE METRIC PROGRAMS WITH COSTS

From the previous sections it should be apparent that the US and the petroleum industry will face conversion to the metric system within the recognizable future. It should also be obvious that the exact date or time frame during which America will adopt the metric system has yet to be firmly established. Therefore, the exact conversion process that should be taken, the one which will achieve the maximum results with the smallest capital outlay, cannot be chosen with certainty. However, by making several assumptions, none of them unrealistic, a top and bottom cost figure for conversion can be generated, as well as several cost figures for metrication programs lying in between these two extremes.

The first two opposing assumptions that can be made deal with the lead time before metrication must be completed; the lead time may vary from a few months to several years, depending upon the extent of metrication within the US. If lead time is short, if the complete metrication of the firm must be finished within less than one year, Drilco would incur some severe costs in order to achieve an acceptable level of metric production capability. If, however, metrication did not have to be completed for several years, cost outlays could be capitalized over several years and proper planning would simply eliminate several of the other expenses. A similar situation would develope if the conversion was a simple, soft conversion as opposed to the more extensive hard conversion. Several expenses would not materialize if the conversion was "soft" and the total expenditures needed for the conversion could be drastically reduced.

Therefore, two cost figures must be constructed: one cost figure for the maximum cost and one cost figure for the minimum expenditure. The maximum cost figure would be derived when hard metrication of the plant was required with very little lead time. The lowest cost figure would be derived when only a soft conversion was necessary, the conversion could be implimented slowly, over several years, and a future hard conversion was not expected to take place for several years. Figure 7 summarizes the cost for the first case, the hard metrication program instituted within one year. Realistically, this situation is very unlikely, but it could develop if the firm delays a metrication program until forced into adopting metrics, either by the government or competition. As can be seen, major costs would be incurred in drawing conversion and in machine conversion; also, both figures are based on present day levels of activity and capital investments. If no action is taken until such time that metrication must initiated, the cost for drawing conversion will be significantly higher, due to both inflation and to the increased size of the firm, and machine costs will be higher because of missed opportunities in obtaining dual capacity machinery plus the added expense associated with machine down time during conversion. The cost of conversion for trepanning would amount to about one half of its inventory due to the fact that a complete turnover of trepanning tools occurs about every 1½ to 2 years, and for a short term conversion, roughly one half of the inventory could be consumed prior to complete implementation. Quality Assurance and the tool crib would require about $75,000 to convert their facilities. (Again, these costs are for a short term conversion at present property levels.) Personal tools would also require conversion, although such expenses could be the sole responsibility of the employees.

It should be noted that the hard type conversion would result in the complete modification of production facilities to the metric system and would severly restrict the plant's ability to produce customary sized

HARD CONVERSION COSTS
TABLE 1

Facility/Department to be Converted		Cost (in Dollars)
1. Machinery (less NC machines)	approx.	$240,000.00
2. NC Machinery		2,400.00
3. Engineering Drawings and Graphics		200,000.00
4. Post Processor Modifications		800.00
5. Quality Assurance		75,000.00
6. Training - Plant		16,000.00
Office		5,430.00
7. Computer Software		10,000.00
8. Personal Tools		13,350.00
9. Trepanning Heads	approx.	40,000.00
	TOTAL	$602,980.00

goods.

Costs for a simple soft conversion and a modified soft conversion are given in Figure 8. A simple soft conversion has a much more realistic chance of occurring during the next 20 years than a total hard metric conversion, and a modified soft conversion, altered to allow limited production of metric goods, would give the firm the flexibility it would require in an expanding foreign market. Costs for a simple cost conversion would include all those expenses associated with conversion of existing product descriptions, paper work, and supporting computer capacity. Such a conversion would result in the external reporting of metrics plus establish a basis for future metrication programs. The modified soft conversion program would include a simple, soft conversion program plus the modification of existing machinery and precision measuring tools to allow for limited production of metric products. The cost for a modified soft conversion is less than 1/6th that of a hard conversion, yet allows the firms greater flexibility than offered by the existing system on a hard conversion.

SOFT CONVERSION COSTS
TABLE 2

Facility/Departemnt to be Converted	Cost (in Dollars)
1. Machinery (less NC machines)	$ 50,000.00
2. NC Machines	2,400.00
3. Engineering Drawings and Graphics	14,000.00*
4. Post Processor Modification	800.00
5. Quality Assurance	75,000.00**
6. Training - Plant	16,000.00
Office	5,430.00
7. Computor Software	10,000.00
8. Personal Tools	0.00***
9. Trepanning Heads	0.00
TOTAL	$173,630.00

* - This value is included to cover miscellaneous expenses of the drawing conversion and has no foundation for inclusion except caution.

** - This is the maximum cost of conversion for Quality Assurance and could be reduced substantially by retiring tools from QA through the tool crib.

***- Personal tools could be easily replaced by individual employees over an extended conversion program through normal replacement.

XI RECOMMENDATIONS

In view of the fact that the US has already initiated a metric conversion bill, that several federal agencies are beginning metric activity, that the EEC will begin imposing trade restrictions on non-metrically designated imports in 1980, that the first ISO standards for oil field equipment have been drafted (although not approved), that several other facts point toward increasing metric activity over the next 5 to 10 years, and that a short term metrication program would be prohibative in cost, it is recommended that Drilco initiate a long term, soft conversion program commencing in January of 1977 and terminating at some future date (as yet undetermined). This program will consist of:

(A) Conversion, modification, and additions to existing facilities to institute external metric reporting capabilities by 1980.

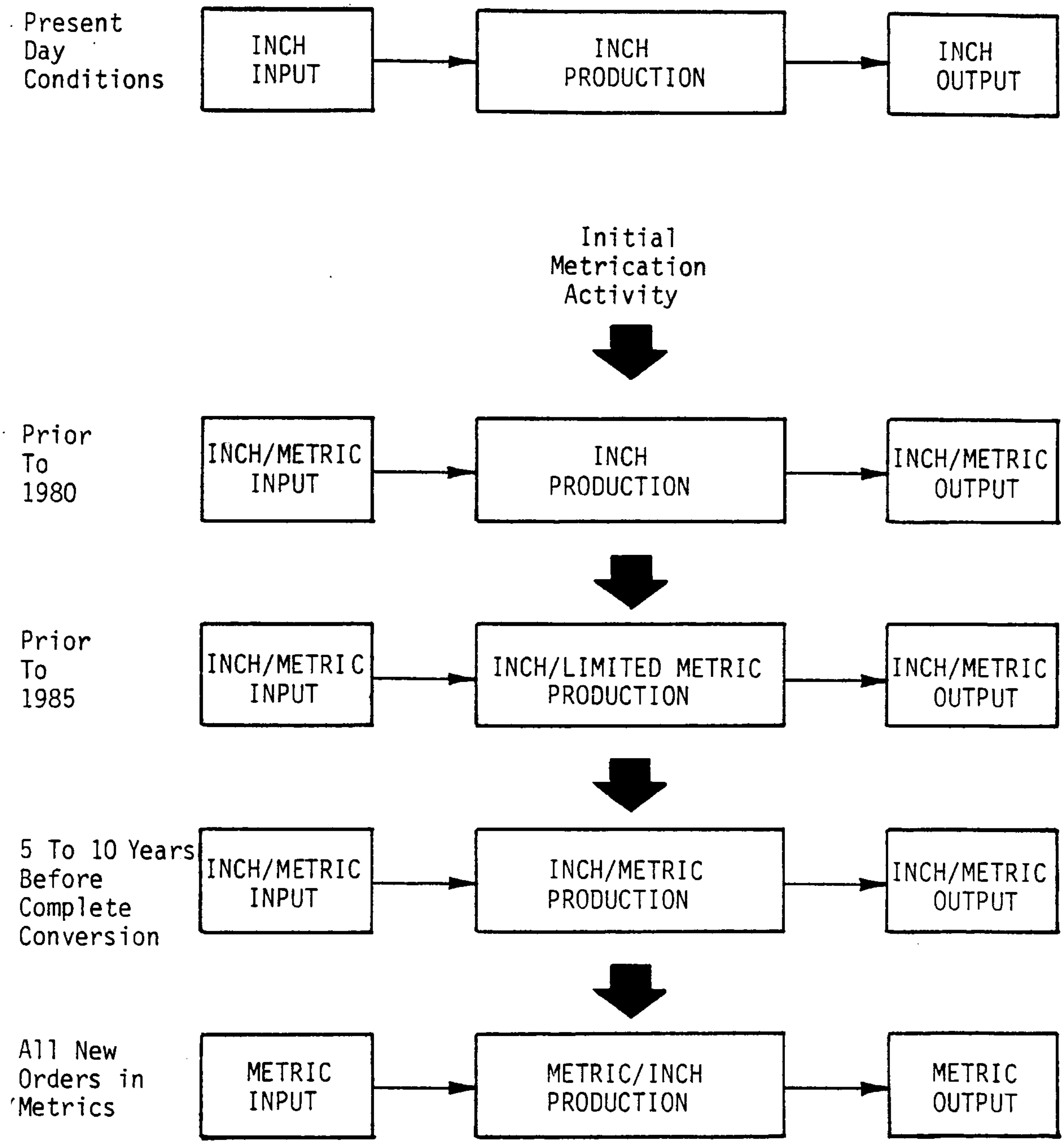
(B) Conversion and modification of existing engineering drawings to dual dimension capabilities by 1985.

(C) Continuous monitoring of metric demand within the downhole drilling tool industry to predict demand for metric tools.

(D) Eventual conversion of existing machinery capabilities to allow the limited production of metric tools by 1985.

Figure 9 and 10 display the expected sequence of events necessary to accomplish a soft conversion of the existing facilities for external reporting by 1980. The reason that 1980 was chosen is that the EEC will be imposing trade restrictions at that time on imports from the US (see Section IV) which do not have SI metric markings and the accompanying doc-

are not metrically marked. Additionally, the Canadian Sector will be well into metrication at that time, and the use of metrics for that market, as well as for the general export market, should help promote sales



After this time frame, limited Inch/English production capabilities must be maintained to handle rework and repair operations on tools manufactured prior to metrication activities. These capabilities can be phased out when management so desires.

FIGURE 7

SOFT CONVERSION OF INTERNAL/EXTERNAL
REPORTING PROCEEDURES

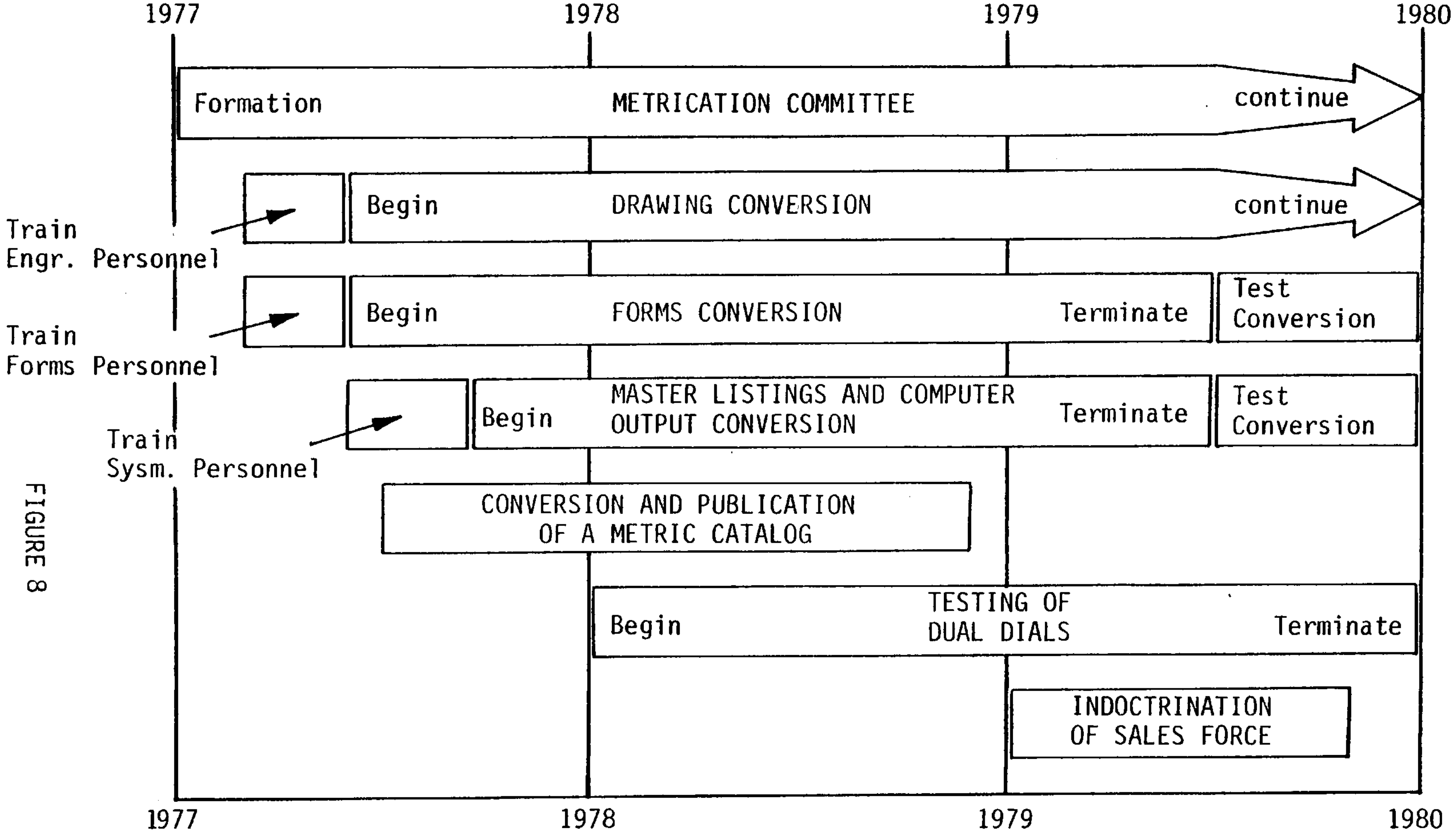


FIGURE 8

of the product in that sector. It is recommended that a strategic metrication committee be formed from the 5 major departments within the managing structure of Drilco: Operations (one member), Manufacturing (two members - chairman from Manufacturing), Engineering (one member), Sales and Marketing (one member), and Accounting (one member). The purpose of this committee will be to evaluate metric activity both internally and externally, and to present recommendations to the president. The committee will be responsible for the establishment or adjustment of starting dates for the different phases of the metrication program contingent upon market influences and economic factors. Training classes should be established for supervisory personnel in systems and document control, for product and process engineers and drafters and for other key personnel involved in the first phase of metrication as displayed in Figure 10. The Classes are to aid in the different instances when dual dimensions must be employed. The classes should be tailored to that group requiring the training (see Section IX and Appendix P) and must be conducted prior to initiating conversion activity. The systems department will be involved with the conversions of the Item Master and supporting master files. Such files must have dual capabilities (see Section IX F) and must be convertered prior to June 1979 to allow time for testing and evaluation. The forms and documents department will be charged with the responsibility of reviewing all forms and suggesting to the form user appropriate methods to modify the document to express dual English/metric units. Engineering will be charged with choosing appropriate methods of designating dual dimensions, plus implementing the complete redraw of existing prints. This area must be closely monitored, as the conversion of the drawings is an integral part of any future metrication program. Each step of the first phase of metrication, with regard to form and description, conversion should be examined for possible exclusions, and in June of 1979, it would be wise to test the entire system to assure its suitability prior to its mandatory implementation. Additionally, all sales personnel and field engineers, especially those located in foreign countries, should be indoctrinated into the use of metrics. Failure to do so would doom the metrication program before it had a chance to succeed. Prior to 1979, a test should be conducted to determine the suitability of dual dials (see Appendix O). Such dials would play an important part in the suggested method of conversion for the plant. Prior to 1979 all catalogs, brochures, and sales advertizing should be converted to dual dimensions, also. Close coordination between the Item Master conversion and conversion of the composite catalog is necessary to insure that the published product description follows closely its description on the Item Master. Finally, it would be wise (but not absolutely necessary) to upgrade all existing NC machines to include metrics. To date, there are three NC machines not capable of producing metic output. Plus, there are two post processors routines which will need conversion. Both of these areas must be dealt with before 1980.

Prior to 1985, the second phase (see Figure 11) of the conversion program must be completed. The significant accomplishment of this phase is the completion of the engineering redrawing project. Once all drawings have been converted and all product descriptions have undergone metrication, conversion of tools and machinery can follow. Also, during this phase, the test results pertaining to the use of dual dimensioned dials can be evaluated and any required modifications could be purchased, installed, and test production runs of metric products could be conducted. This would firmly establish whether the dual dimensioned dials would perform in the

TRANSITION PERIOD FROM SOFT CONVERSION CAPABILITIES
TO DUAL PRODUCTION CAPABILITIES

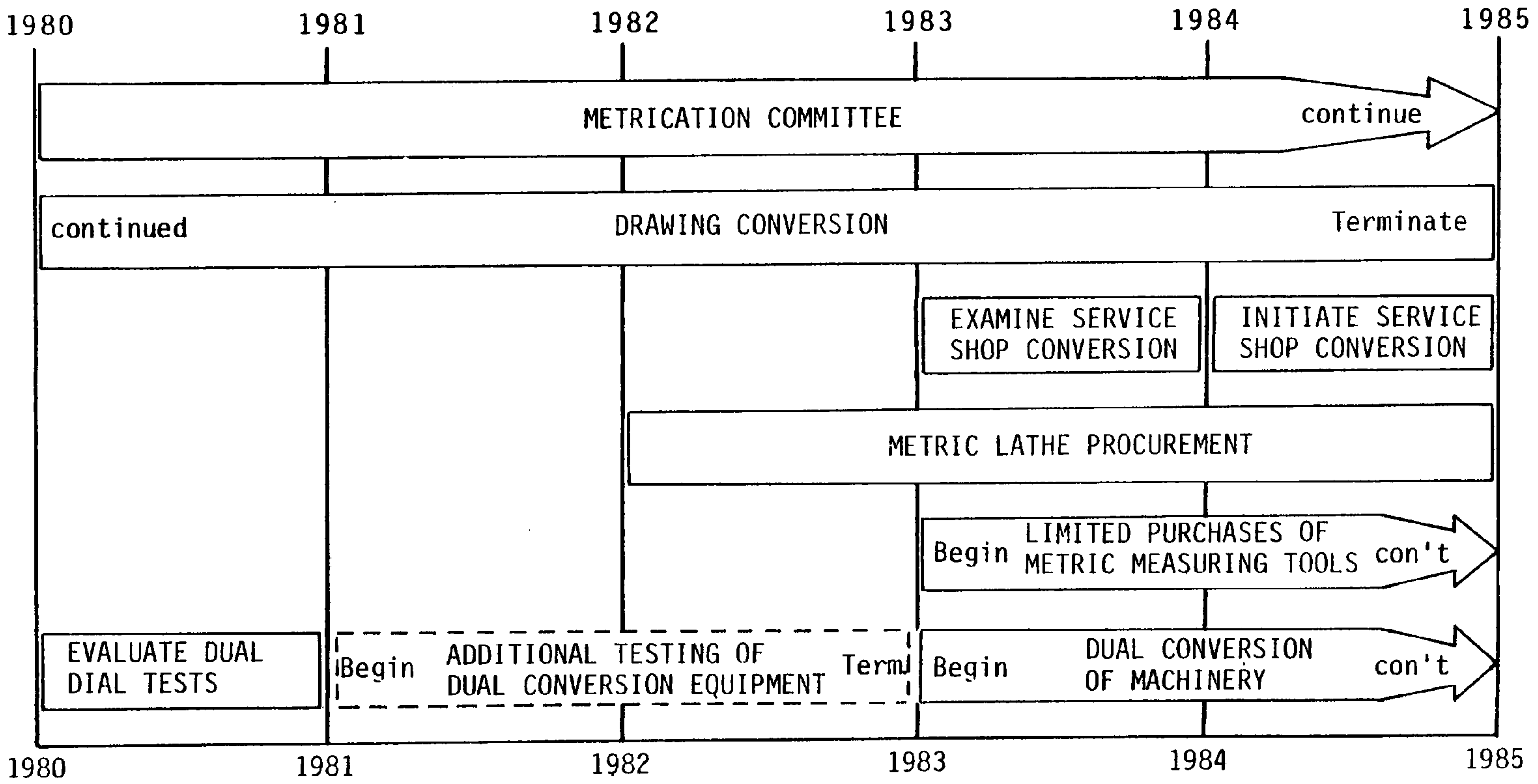


FIGURE 9

plant environment. Along with these test production runs, Quality Assurance could begin testing newly acquired metric measuring tools, and evaluate their appropriateness in checking both inch and metric production items. During 1983 an evaluation of customer service requirements could be made and a metrication program could then be established for this segment of the firm. Finally, although not necessary, it would be wise to purchase one or two metric lathes prior to 1983 and evaluate their performance in producing inch products from dual dimensioned drawings. This would indicate if future purchases of manual machines could be limited to metric only or dual capacity machines.

At the end of this second phase of metric activity, the firm should have the following capabilities:

(1) Review and process orders in either inch/English units or in metric units.

(2) Produce any metric orders after all the dimensions have been converted to English units.

(3) Produce a limited number of products utilizing metric units only as a basis in the manufacturing process.

(4) Provide customary and/or metric units in the description of any order for any shipment from the plant.

At the completion of the second major period of metric activity, using the results of the previous 8 years, and weighing any political pressures which may have developed during that time, the metrication committee could determine when to begin the replacement of precision tools in QA and in the tool crib, when to begin the conversion of heavy equipment (during overhaul), and when to phase out any unnecessary equipment. Figure 12 gives a suggested sequence of events over a 5 to 10 year period during which the

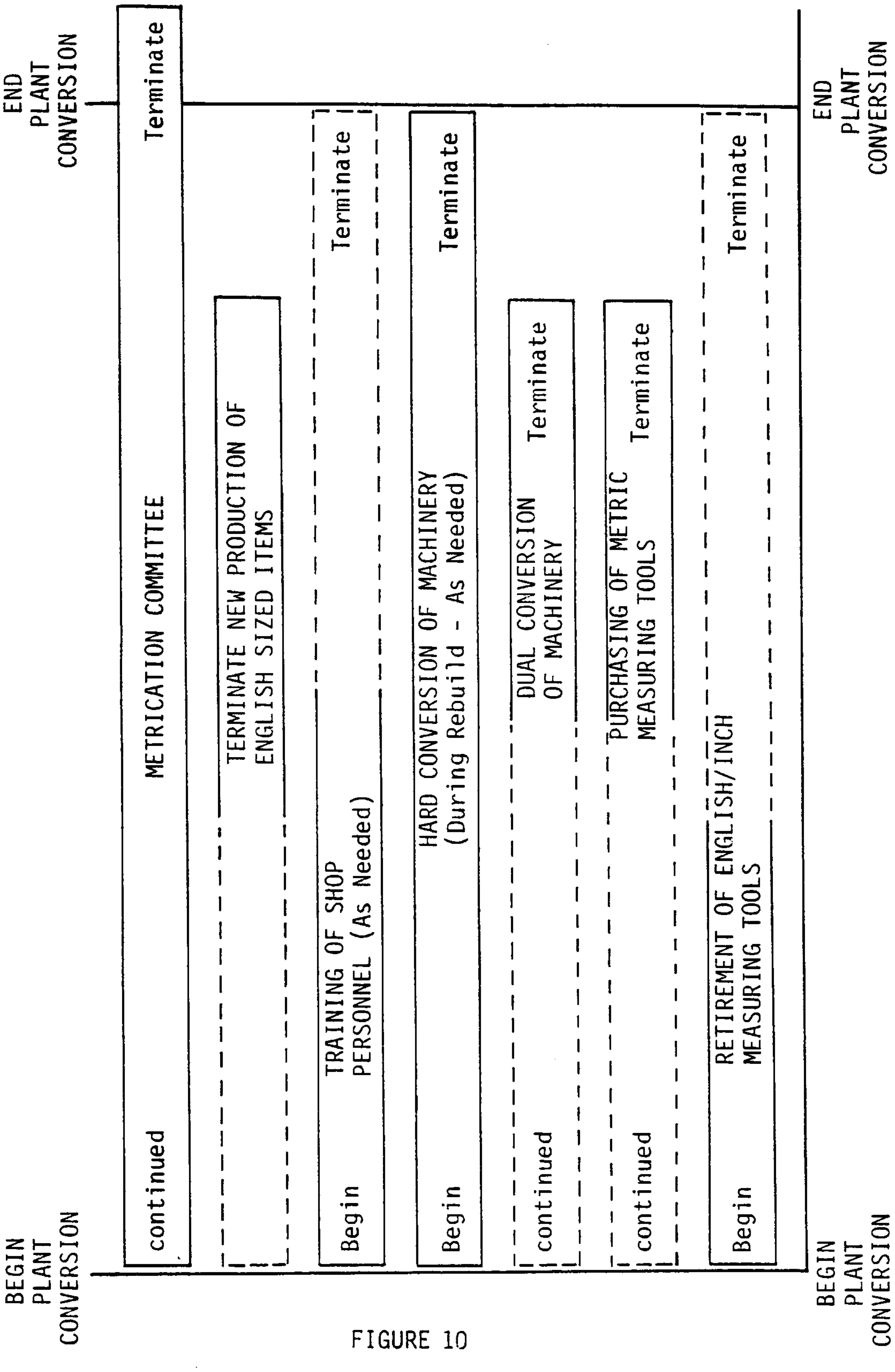

BEGIN PLANT CONVERSION
END PLANT CONVERSION
continued
METRICATION COMMITTEE
Terminate
TERMINATE NEW PRODUCTION OF ENGLISH SIZED ITEMS
Begin
TRAINING OF SHOP PERSONNEL (As Needed)
Terminate
Begin
HARD CONVERSION OF MACHINERY (During Rebuild - As Needed)
Terminate
continued
DUAL CONVERSION OF MACHINERY
Terminate
continued
PURCHASING OF METRIC MEASURING TOOLS
Terminate
Begin
RETIREMENT OF ENGLISH/INCH MEASURING TOOLS
Terminate
BEGIN PLANT CONVERSION
END PLANT CONVERSION

FIGURE 10

firm would achieve a near complete hard conversion. Due to the fact that the period would not start for at least 10 years, the actual sequence of events and projected time tables must be established by the metrication committee.

XII CONCLUSION

This report has attempted to establish two major contentions:

(1) The US will be adopting the metric system within the next 10 years and that a market will exist by then for metrically dimensioned drilling tools, and

(2) implementation of a metrication program at this time will facilitate the eventual conversion of the plant at the greatest possible savings.

The first contention is supported by the fact that the US is the last remaining, major industrial power not committed to the metric system, that continued foreign trade could easily be restricted if the drilling tool manufacturers do not compensate for proposed trade restrictions on non-metrically dimensioned imports, and that several diverse factions of the American economy are slowly moving toward metrication. With the seating of the US Metric Board, the United States will finally receive a regulating agency (although the regulation is purely voluntary) which can help tremendously in coordinating the conversion of the US. Finally, API and ISO are in the process of establishing world wide metric standards for oil field equipment, thus establishing a basis for the metric conversion of the oil drilling industry.

The second contention is supported by the cost figures associated with a short term and long term, soft and hard conversion. In either case, the short term conversion will create large expenses in the areas of drawing conversion, machine modification, and general disruption of plant operations. But, the long term conversion offers reduced expenses and smoother transition from the English system to the metric system.

The conversion of Drilco should occur in four basic steps:

(1) Conversion of all external reporting to dual values by 1980.

(2) Conversion of all drawings and graphics to dual values by 1985.

(3) Introduction of metric measuring tools and metric machine tools.

(4) The eventual dropping of all English values or the severe restriction of their use.

These steps should be taken over an 8 to 10 year period with immediate emphasis given to the adoption of dual English/metric units to all forms of external reporting done by Drilco, including catalogs, brochure, and sales literature.

Finally, the words of Marvin B. Glaser, Manager of the Mechanical Division of the Exxon Research and Engineering Corporation, best exemplify the attitude that must be taken during any metric conversion.

> "...let me say that metrication is not an awesome task, nor is it a technically difficult one. Once a clear-cut need is established, it is simply a matter of doing it."

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12. Interview with Mr. Evert Baugh, General Motors, July 14, 1976

13. API Subcommittee on Metrication, W.J. McGuire, Chairman, minutes of Sept 18, 1975, page 3, paragraph 9(b).

APPENDIX A - THE US METRICATION BOARD

On September 29, 1976, President Ford released a list of his appointees to the U.S. Metric Board. The board, which has the mission of coordinating the voluntary conversion of the U.S. to the SI metric system, is to be composed of representatives from several areas of the nation's economy, and the appointees were all selected from nominees advanced by their respective interest groups. It should be noted that several of the appointees have been very active in past and present metrication programs, and that only the two appointees from labor have appearently had no previous exposure to the problems of metrication. In view of the credentials possessed by the appointees, it is doubtful that the Senate or President-elect Carter will choose to reject or change any of the appointees.

Nominees to the U.S. Metric Board

Chairman: Dr. Louis F. Polk, Louis Polk Inc., former member of the U.S. Metric Study sponsored by the National Bureau of Standards.

Other Appointees

Engineering: Mr. Valerie Antoine, Litton Industries

Science: Dr. Harold M. Agnew, Director, Los Alamos Scientific Laboratory

Manufacturing: Mr. Adrian G. Weaver, IBM Corp.

Commerce and Retail: Ms. Satenig St. Marie, J.C. Penney Co.

State and Local Government: Mr. Harry Kinney, Mayor, City of Albuquerque, New Mexico

Small Business: Mr. Charles Beck, Charles Beck Machine Corp.

Mr. James D. McKevitt, Washington Counsel for the National Federation of Independent Business

Construction: Mr. Francis Dugan, President, Dugan and Meyer Construction Co., Cincinnati, Ohio

Labor: Mr. Ralph Durham Sr., Director, Safety and Health Dept., International Brotherhood of Teamsters

Mr. Andrew H. Kenopenski, National Automotive Coordinator, International Association of Machinists and Aerospace Workers

Weights and Measures: Mr. Sidney D. Andrews, Director, Division of Standards, State of Florida

Education: Dr. Frank Hartman, Federal Liaison, Michigan State Dept. of Education

At-Large: Mr. W.E. Hamilton, American Farm Bureau Federation

Ms. Virginia H. Knauer, Special Assistant to the President for Consumer Affairs and the Office of Consumer Affairs, HEW

Mr. Jerry J. McReal, President, Media Research Associates, Salem, Oregon

Mr. Kenyon Y. Taylor, Chairman of the Board, Regal-Beloit Corp.

APPENDIX B - THE METRICATION ACT OF 1975

The following is a copy of Public Law 94-168, the Metric Conversion Act of 1975. The bill was passed in December 1975 and signed by President Ford on December 23. The act provides for the voluntary conversion of the United States from the current customary system of weights and measures, commonly refered to as the English System, the International System of Weights and Measures, a metric system. The act also provides for the establishment of a 17 member committee to oversee the proposed metric activity until such time as the country has fully converted.

Public Law 94-168
94th Congress, H. R. 8674
December 23, 1975

An Act

To declare a national policy of coordinating the increasing use of the metric system in the United States, and to establish a United States Metric Board to coordinate the voluntary conversion to the metric system.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Metric Conversion Act of 1975".

Metric Conversion Act of 1975.
15 USC 205a note.

SEC. 2. The Congress finds as follows:

15 USC 205a.

(1) The United States was an original signatory party to the 1875 Treaty of the Meter (20 Stat. 709), which established the General Conference of Weights and Measures, the International Committee of Weights and Measures and the International Bureau of Weights and Measures.

(2) Although the use of metric measurement standards in the United States has been authorized by law since 1866 (Act of July 28, 1866; 14 Stat. 339), this Nation today is the only industrially developed nation which has not established a national policy of committing itself and taking steps to facilitate conversion to the metric system.

SEC. 3. It is therefore declared that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States and to establish a United States Metric Board to coordinate the voluntary conversion to the metric system.

15 USC 205b.

SEC. 4. As used in this Act, the term—

Definitions.
15 USC 205c.

(1) "Board" means the United States Metric Board, established under section 5 of this Act;

(2) "engineering standard" means a standard which prescribes (A) a concise set of conditions and requirements that must be satisfied by a material, product, process, procedure, convention, or test method; and (B) the physical, functional, performance and/or conformance characteristics thereof;

(3) "international standard or recommendation" means an engineering standard or recommendation which is (A) formulated and promulgated by an international organization and (B) recommended for adoption by individual nations as a national standard; and

(4) "metric system of measurement" means the International System of Units as established by the General Conference of Weights and Measures in 1960 and as interpreted or modified for the United States by the Secretary of Commerce.

SEC. 5. (a) There is established, in accordance with this section, an independent instrumentality to be known as a United States Metric Board.

United States Metric Board.
Establishment.
15 USC 205d.

(b) The Board shall consist of 17 individuals, as follows:

Membership.

(1) the Chairman, a qualified individual who shall be appointed by the President, by and with the advice and consent of the Senate;

(2) sixteen members who shall be appointed by the President, by and with the advice and consent of the Senate, on the following basis—

(A) one to be selected from lists of qualified individuals recommended by engineers and organizations representative of engineering interests;

(B) one to be selected from lists of qualified individuals recommended by scientists, the scientific and technical community, and organizations representative of scientists and technicians;

(C) one to be selected from a list of qualified individuals recommended by the National Association of Manufacturers or its successor;

(D) one to be selected from lists of qualified individuals recommended by the United States Chamber of Commerce, or its successor, retailers, and other commercial organizations;

(E) two to be selected from lists of qualified individuals recommended by the American Federation of Labor and Congress of Industrial organizations or its successor, who are representative of workers directly affected by metric conversion, and by other organizations representing labor;

(F) one to be selected from a list of qualified individuals recommended by the National Governors Conference, the National Council of State Legislatures, and organizations representative of State and local government;

(G) two to be selected from lists of qualified individuals recommended by organizations representative of small business;

(H) one to be selected from lists of qualified individuals representative of the construction industry;

(I) one to be selected from a list of qualified individuals recommended by the National Conference on Weights and Measures and standards making organizations;

(J) one to be selected from lists of qualified individuals recommended by educators, the educational community, and organizations representative of educational interests; and

(K) four at-large members to represent consumers and other interests deemed suitable by the President and who shall be qualified individuals.

Term of office.

As used in this subsection, each "list" shall include the names of at least three individuals for each applicable vacancy. The terms of office of the members of the Board first taking office shall expire as designated by the President at the time of nomination; five at the end of the 2d year; five at the end of the 4th year; and six at the end of the 6th year. The term of office of the Chairman of such Board shall be 6 years. Members, including the Chairman, may be appointed to an additional term of 6 years, in the same manner as the original appointment. Successors to members of such Board shall be appointed in the same manner as the original members and shall have terms of office expiring 6 years from the date of expiration of the terms for which their predecessors were appointed. Any individual appointed to fill a vacancy occurring prior to the expiration of any term of office shall be appointed for the remainder of that term. Beginning 45 days after the date of incorporation of the Board, six members of such Board shall constitute a quorum for the transaction of any function of the Board.

Quorum.

(c) Unless otherwise provided by the Congress, the Board shall have no compulsory powers.

(d) The Board shall cease to exist when the Congress, by law, determines that its mission has been accomplished.

Policy implementation.
15 USC 205e.

SEC. 6. It shall be the function of the Board to devise and carry out a broad program of planning, coordination, and public education, consistent with other national policy and interests, with the aim of implementing the policy set forth in this Act. In carrying out this program, the Board shall—

(1) consult with and take into account the interests, views, and conversion costs of United States commerce and industry, including small business; science; engineering; labor; education; consumers; government agencies at the Federal, State, and local level; nationally recognized standards developing and coordinating organizations; metric conversion planning and coordinating groups; and such other individuals or groups as are considered appropriate by the Board to the carrying out of the purposes of this Act. The Board shall take into account activities underway in the private and public sectors, so as not to duplicate unnecessarily such activities;

(2) provide for appropriate procedures whereby various groups, under the auspices of the Board, may formulate, and recommend or suggest, to the Board specific programs for coordinating conversion in each industry and segment thereof and specific dimensions and configurations in the metric system and in other measurements for general use. Such programs, dimensions, and configurations shall be consistent with (A) the needs, interests, and capabilities of manufacturers (large and small), suppliers, labor, consumers, educators, and other interested groups, and (B) the national interest;

Comments and hearings.

(3) publicize, in an appropriate manner, proposed programs and provide an opportunity for interested groups or individuals to submit comments on such programs. At the request of interested parties, the Board, in its discretion, may hold hearings with regard to such programs. Such comments and hearings may be considered by the Board;

(4) encourage activities of standardization organizations to develop or revise, as rapidly as practicable, engineering standards on a metric measurement basis, and to take advantage of opportunities to promote (A) rationalization or simplification of relationships, (B) improvements of design, (C) reduction of size variations, (D) increases in economy, and (E) where feasible, the efficient use of energy and the conservation of natural resources;

(5) encourage the retention, in new metric language standards, of those United States engineering designs, practices, and conventions that are internationally accepted or that embody superior technology;

Consultation and cooperation.

(6) consult and cooperate with foreign governments, and intergovernmental organizations, in collaboration with the Department of State, and, through appropriate member bodies, with private international organizations, which are or become concerned with the encouragement and coordination of increased use of metric measurement units or engineering standards based on such units, or both. Such consultation shall include efforts, where appropriate, to gain international recognition for metric standards proposed by the United States, and, during the United States conversion, to encourage retention of equivalent customary units, usually by way of dual dimensions, in international standards or recommendations;

Public information and education programs.

(7) assist the public through information and education programs, to become familiar with the meaning and applicability of metric terms and measures in daily life. Such programs shall include—

(A) public information programs conducted by the Board, through the use of newspapers, magazines, radio, television, and other media, and through talks before appropriate citizens' groups, and trade and public organizations;

(B) counseling and consultation by the Secretary of Health, Education, and Welfare; the Secretary of Labor; the Administrator of the Small Business Administration; and the Director of the National Science Foundation, with educational associations, State and local educational agencies, labor education committees, apprentice training committees, and other interested groups, in order to assure (i) that the metric system of measurement is included in the curriculum of the Nation's educational institutions, and (ii) that teachers and other appropriate personnel are properly trained to teach the metric system of measurement;

(C) consultation by the Secretary of Commerce with the National Conference of Weights and Measures in order to assure that State and local weights and measures officials are (i) appropriately involved in metric conversion activities and (ii) assisted in their efforts to bring about timely amendments to weights and measures laws; and

(D) such other public information activities, by any Federal agency in support of this Act, as relate to the mission of such agency;

(8) collect, analyze, and publish information about the extent of usage of metric measurements; evaluate the costs and benefits of metric usage; and make efforts to minimize any adverse effects resulting from increasing metric usage;

Surveys. Recommendations to Congress and President.

(9) conduct research, including appropriate surveys; publish the results of such research; and recommend to the Congress and to the President such action as may be appropriate to deal with any unresolved problems, issues, and questions associated with metric conversion, or usage, such problems, issues, and questions may include, but are not limited to, the impact on workers (such as costs of tools and training) and on different occupations and industries, possible increased costs to consumers, the impact on society and the economy, effects on small business, the impact on the international trade position of the United States, the appropriateness of and methods for using procurement by the Federal Government as a means to effect conversion to the metric system, the proper conversion or transition period in particular sectors of society, and consequences for national defense;

Report to Congress and President.

(10) submit annually to the Congress and to the President a report on its activities. Each such report shall include a status report on the conversion process as well as projections for the conversion process. Such report may include recommendations covering any legislation or executive action needed to implement the the programs of conversion accepted by the Board. The Board may also submit such other reports and recommendations as it deems necessary; and

Report to Congress and President.

(11) submit to the Congress and to the President, not later than 1 year after the date of enactment of the Act making appropriations for carrying out this Act, a report on the need to provide an effective structural mechanism for converting customary units to metric units in statutes, regulations, and other laws at all levels of government, on a coordinated and timely basis, in response to voluntary conversion programs adopted and implemented by various sectors of society under the auspices and with the approval

of the Board. If the Board determines that such a need exists, such report shall include recommendations as to appropriate and effective means for establishing and implementing such a mechanism.

Committees, establishment. 15 USC 205f.

SEC. 7. In carrying out its duties under this Act, the Board may—

(1) establish an Executive Committee, and such other committees as it deems desirable;

(2) establish such committees and advisory panels as it deems necessary to work with the various sectors of the Nation's economy and with Federal and State governmental agencies in the development and implementation of detailed conversion plans for those sectors. The Board may reimburse, to the extent authorized by law, the members of such committees;

Hearings.

(3) conduct hearings at such times and places as it deems appropriate;

Contracts.

(4) enter into contracts, in accordance with the Federal Property and Administrative Services Act of 1949, as amended (40 U.S.C. 471 et seq.), with Federal or State agencies, private firms, institutions, and individuals for the conduct of research or surveys, the preparation of reports, and other activities necessary to the discharge of its duties;

(5) delegate to the Executive Director such authority as it deems advisable; and

(6) perform such other acts as may be necessary to carry out the duties prescribed by this Act.

Gifts and bequests. 15 USC 205g.

SEC. 8. (a) The Board may accept, hold, administer, and utilize gifts, donations, and bequests of property, both real and personal, and personal services, for the purpose of aiding or facilitating the work of the Board. Gifts and bequests of money, and the proceeds from the sale of any other property received as gifts or bequests, shall be deposited in the Treasury in a separate fund and shall be disbursed upon order of the Board.

(b) For purpose of Federal income, estate, and gift taxation, property accepted under subsection (a) of this section shall be considered as a gift or bequest to or for the use of the United States.

(c) Upon the request of the Board, the Secretary of the Treasury may invest and reinvest, in securities of the United States, any moneys contained in the fund authorized in subsection (a) of this section. Income accruing from such securities, and from any other property accepted to the credit of such fund, shall be disbursed upon the order of the Board.

Unexpended funds.

(d) Funds not expended by the Board as of the date when it ceases to exist, in accordance with section 5(d) of this Act, shall revert to the Treasury of the United States as of such date.

Compensation. 15 USC 205h.

SEC. 9. Members of the Board who are not in the regular full-time employ of the United States shall, while attending meetings or conferences of the Board or while otherwise engaged in the business of the Board, be entitled to receive compensation at a rate not to exceed the daily rate currently being paid grade 18 of the General Schedule (under section 5332 of title 5, United States Code), including traveltime. While so serving, on the business of the Board away from their homes or regular places of business, members of the Board may be allowed travel expenses, including per diem in lieu of subsistence, as authorized by section 5703 of title 5, United States Code, for persons employed intermittently in the Government service. Payments under this section shall not render members of the Board employees or officials of the United States for any purpose. Members of the Board who are in the employ of the United States shall be entitled to travel expenses when traveling on the business of the Board.

5 USC 5332 note. Travel expenses.

Executive Director, appointment. 15 USC 205i.

Sec. 10. (a) The Board shall appoint a qualified individual to serve as the Executive Director of the Board at the pleasure of the Board. The Executive Director, subject to the direction of the Board, shall be responsible to the Board and shall carry out the metric conversion program, pursuant to the provisions of this Act and the policies established by the Board.

5 USC 5101 et seq. 5 USC 5331.

(b) The Executive Director of the Board shall serve full time and be subject to the provisions of chapter 51 and subchapter III of chapter 53 of title 5, United States Code. The annual salary of the Executive Director shall not exceed level III of the Executive Schedule under section 5314 of such title.

(c) The Board may appoint and fix the compensation of such staff personnel as may be necessary to carry out the provisions of this Act in accordance with the provisions of chapter 51 and subchapter III of chapter 53 of title 5, United States Code.

Experts and consultants.

(d) The Board may (1) employ experts and consultants or organizations thereof, as authorized by section 3109 of title 5, United States Code; (2) compensate individuals so employed at rates not in excess of the rate currently being paid grade 18 of the General Schedule under section 5332 of such title, including traveltime; and (3) may allow such individuals, while away from their homes or regular places of business, travel expenses (including per diem in lieu of subsistence) as authorized by section 5703 of such title 5 for persons in the Government service employed intermittently: *Provided*, *however*, That contracts for such temporary employment may be renewed annually.

Financial and administrative services. 15 USC 205j.

Sec. 11. Financial and administrative services, including those related to budgeting, accounting, financial reporting, personnel, and procurement, and such other staff services as may be needed by the Board, may be obtained by the Board from the Secretary of Commerce or other appropriate sources in the Federal Government. Payment for such services shall be made by the Board, in advance or by reimbursement, from funds of the Board in such amounts as may be agreed upon by the Chairman of the Board and by the source of the services being rendered.

Appropriation authorization. 15 USC 205k.

Sec. 12. There are authorized to be appropriated such sums as may be necessary to carry out the provisions of this Act. Appropriations to carry out the provisions of this Act may remain available for obligation and expenditure for such period or periods as may be specified in the Acts making such appropriations.

Approved December 23, 1975.

LEGISLATIVE HISTORY:

HOUSE REPORT No. 94-369 (Comm. on Science and Technology).
SENATE REPORT No. 94-500 (Comm. on Commerce).
CONGRESSIONAL RECORD, Vol. 121 (1975):
    Sept. 5, considered and passed House.
    Dec. 8, considered and passed Senate, amended, in lieu of S. 100.
    Dec. 11, House concurred in Senate amendment.
WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS, Vol. 11, No. 52:
    Dec. 23, Presidential statement.

○

APPENDIX C - "TOP 50" CUSTOMERS OF DRILCO - SALES DATA

Figure 3, page 17, gives a graphical display of the ranking of Drilco's top fifty customers and their respective purchases in 1975. The purchases were further segregated to display which portions of the sales were for eventual use domestically or for export. On the average, the first twenty five customers made significantly more purchses for overseas use than for use in the United States. Hence, the general observation can be made that Drilco is quite dependent on export sales and that at least maintaining its market share would be advisable.

The data used for construction of the graph was extracted from historical sales data provided by the Marketing Department of the firm. However, after initially plotting the data, it was determined that the raw data needed some type of massaging to obtain a more readable figure. Therefore, the information was subjected to a averaging program whose purpose was to reduce the erratic nature of the plotted data. Basically, four data points x_{n-2}............. x_{n+1} were averaged and the resulting point was plotted in place of x_{n-1}. The program reduced the variations in the curves and was helpful in creating a more descriptive graph. Because of the method of construction, the massaged graph lost its end points, and the two curves describing the export and domestic sales levels were shifted slighty to the left. These two characteristics did not effect the interpretation of the information, though.

From the graphs, several vital pieces of information can be recognized. First, and foremost, it should be recognized that in 1975 the first 20 customers, on the average, bought 2 to 3 times as many items for export than for domestic use. 1976 figures indicate that the foreign market slipped and that export sales were less than expected. The foreign market seems to be more volatile and prone to fluctuation than the domestic market. Also, the graph seems to indicate that most of the high dollar sales were for overseas use, but as total sales reached $1.0 million for a customer, sales were equally divided between domestic and foreign use.

Therefore, for Drilco to maintain its current total sales figure, the firm must either dramatically increase its domestic sales, if its foreign sales become slack, or slightly increase its foreign sales, if its domestic sales fall. If the firm can cater to the needs and desires of its overseas customers without sacrificing its service to its domestic customers, it stands the chance to increase its sales considerably.

Averaging Program

The following program was used to massage the raw sales data depicted in Figure 3. The program was written for use with an HP-25, and can be modified for other pocket calculators. Note that the first four data points must be entered before usable information can be extracted.

```
ENTER
STO 0
RCL 1
+
RCL 2
+
RCL 3
+
ENTER
4
÷
ENTER
R/S
RCL 2
STO 3
RCL 1
STO 2
RCL 0
STO 1
9
R/S
```

```
CLX
GT 00
```

After each cycle, the value in storage #3 is eliminated and all other values are moved to the next higher numbered storage unit. To initiate the program, the first three data points must be stored in reverse order in the first three memories starting with point 3 in memory 0. Note also, that the number 9, near the end of the program, is used simply to indicate that the program is complete and that the next value to appear on the screen will be 0.

APPENDIX D - EEC DIRECTIVE 71/354/EEC

The following is a copy of Common Market directive requiring the mandatory use of metric units within the European Economic Community by 1980. The directive, Directive 71/354/EEC, requires all member nations to enact legislation implementing the directive within their own boundaries. To date, France, Italy, Belguim, and Luxemberg have passed appropriate laws, while the remaining nations either have legislation pending or awaiting review of their acts by the council.

COUNCIL DIRECTIVE

of 18 October 1971

on the approximation of the laws of the Member States relating to units of measurement and annex with amendments provided for in the Treaty of Accession

(71/354/EEC)

THE COUNCIL OF THE EUROPEAN COMMUNITIES,

Having regard to the Treaty establishing the European Economic Community, and in particular Article 100 thereof;

Having regard to the proposal from the Commission;

Having regard to the Opinion of the European Parliament[1];

Having regard to the Opinion of the Economic and Social Committee[2];

Whereas the laws which regulate the use of units of measurement in the Member States differ from one Member State to another and therefore hinder trade; whereas application of the rules relating to measuring instruments is closely linked to the use of units of measurement in the metrological system; whereas, in these circumstances and having regard to the interdependence of the rules concerning units of measurement and those concerning measuring instruments, it is necessary to harmonise laws, regulations and administrative provisions to ensure harmonious application of existing and future Community directives relating to measuring instruments and methods of metrological control;

Whereas units of measurement are the subject of international resolutions adopted by the General Conference of Weights and Measures (CGPM) set up by the Metre Convention signed in Paris on 20 May 1875, to which all the Member States adhere; whereas, however, units of measurement, and in particular their names, symbols and use are not identical in the Member countries;

HAS ADOPTED THIS DIRECTIVE:

Article 1

1. Member States shall make the provisions of Chapter I of the Annex binding within five years of the date of entry into force of this Directive.

2. Member States shall, with effect from 31 December 1977 at the latest, prohibit the use of the units of measurement listed in Chapter III of the Annex.

3. The units of measurement temporarily retained in accordance with the provisions of Chapter II or Chapter III of the Annex may not be brought into compulsory use by the Member States where they are not authorised at the date when this Directive enters into force.

Article 2

The obligations arising under Article 1 relate to measuring instruments used, measurements made and indications of quantity expressed in units, whether for economic, public health, public safety or administrative purposes.

Article 3

This Directive shall not affect the use of units which it does not prescribe but which have been laid down by international intergovernmental conventions or agreements in the field of air and sea transport and rail traffic.

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[1] OJ No C 78, 2.8.1971, p. 53.

[2] OJ No C 93, 21.9.1971, p. 18.

Article 4

1. Member States shall put into force the laws, regulations and administrative provisions needed in order to comply with this Directive within eighteen months of its notification and shall forthwith inform the Commission thereof.

2. Member States shall ensure that the texts of the main provisions of national law which they adopt in the field covered by this Directive are communicated to the Commission.

Article 5

This Directive is addressed to the Member States.

Done at Luxembourg, 18 October 1971.

For the Council

The President

A. MORO

ANNEX

CHAPTER I

UNITS OF MEASUREMENT WHICH ARE DEFINITIVELY AUTHORISED

1. SI UNITS AND THEIR DECIMAL MULTIPLES AND SUBMULTIPLES

1.1. SI base units

Quantity	Unit	
	Name	Symbol
length	metre	m
mass	kilogramme	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole[1]	mol

[1] SI base unit adopted by the International Committee of Weights and Measures (CIPM) on 7 October 1969 for approval by the next General Conference of Weights and Measures (CGPM).

Definitions of SI base units:

Unit of length

The metre is the length equal to 1 650 763·73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom. (Eleventh CPGM (1960), Resolution 6).

Unit of mass

The kilogramme is equal to the mass of the international prototype of the kilogramme. (Third CGPM (1901), p. 62 of the Conference Report).

Unit of time

The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom. (Thirteenth CGPM (1967), Resolution 1).

Unit of electric current

The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section and placed 1 metre apart in a vacuum, would produce between these conductors a force equal to 2 × 10^{-7} newton per metre of length. (CIPM (1946), Resolution 2 approved by the Ninth CGPM (1948)).

Unit of thermodynamic temperature

The kelvin is the fraction 1/273·16 of the thermodynamic temperature of the triple point of water. (Thirteenth CGPM (1967), Resolution 4).

Unit of luminous intensity

The candela is the luminous intensity, in the perpendicular direction, of a surface of 1/600 000 square metre of a black body at the temperature of freezing platinum under a pressure of 101 325 newtons per square metre. (Thirteenth CGPM (1967), Resolution 5).

Unit of amount of substance

The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0·012 kilogramme of carbon-12.

Note: When the mole is used the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles or specified groups of such particles.

1.1.1. Special name and symbol of the SI unit of temperature for expressing Celsius temperature

Quantity	Unit		
	Name	Symbol	Value
Celsius temperature	degree Celsius	°C	1 °C = 1 K

Celsius temperature t is defined as the difference $t = T - T_0$ between the two thermodynamic temperatures T and T_0 where T_0 273·15 K.

1.2. Other SI units

1.2.1. Derived SI units

Units derived coherently from SI base units are given as algebraic expressions in the form of power products of the SI base units with a numerical factor equal to 1.

1.2.2. SI units having special names and symbols

Quantity	SI Unit		
	Name	Symbol	Derivation
plane angle	radian	rad	m/m
solid angle	steradian	sr	m^2/m^2
frequency	hertz	Hz	s^{-1}
force	newton	N	$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal[1]	Pa	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$m^2 \cdot kg \cdot s^{-2}$
power	watt	W	$m^2 \cdot kg \cdot s^{-3}$
quantity of electricity, electric charge	coulomb	C	$A \cdot s$
electric tension, electric potential, electromotive force	volt	V	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
electric resistance	ohm	Ω	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens[1]	S	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
electric capacitance	farad	F	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric inductance	henry	H	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
magnetic flux	weber	Wb	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	$kg \cdot s^{-2} \cdot A^{-1}$
luminous flux	lumen	lm	$cd \cdot sr$
illuminance	lux	lx	$m^{-2} \cdot cd \cdot sr$

[1] Proposed by the CIPM for approval by the next CGPM.

Units derived from SI base units may be expressed in terms of the units listed in Chapters I and II, and of those listed in Chapter III so long as these remain in use.

In particular, derived SI units may be expressed in terms of the special names and symbols in the above table. For example: the SI unit of dynamic viscosity may be expressed as $m^{-1} \cdot kg \cdot s^{-1}$ or $N \cdot s \cdot m^{-2}$ or $Pa \cdot s$.

The SI unit of power may be called volt-ampere (symbol 'VA') when it is used to express the apparent power of alternating electric current, and var (symbol 'var') when it is used to express reactive electric power.

1.3. Prefixes and their symbols used to designate certain decimal multiples and submultiples

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{12}	tera	T	10^{-1}	deci	d
10^{9}	giga	G	10^{-2}	centi	c
10^{6}	mega	M	10^{-3}	milli	m
10^{3}	kilo	k	10^{-6}	micro	µ
10^{2}	hecto	h	10^{-9}	nano	n
10^{1}	deca	da	10^{-12}	pico	p
			10^{-15}	femto	f
			10^{-18}	atto	a

The names and symbols of the decimal multiples and submultiples of the unit of mass are formed by attaching prefixes to the word 'gramme' and their symbols to the symbol 'g'.

Where a derived unit is expressed as a fraction, its decimal multiples and submultiples may be designated by attaching a prefix to units in the numerator or the denominator, or in both these parts.

Compound prefixes, that is to say prefixes formed by the juxtaposition of several of the above prefixes, may not be used.

1.4. Special authorised names and symbols

1.4.1. Special names and symbols of decimal multiples and submultiples of SI units

Quantity	Unit		
	Name	Symbol	Value
Volume	litre	l	1 l = 1 dm^3 = 10^{-3} m^3
Mass	tonne	t	1 t = 1 Mg = 10^3 kg
Pressure, stress	bar	bar	1 bar = 10^5 Pa

1.4.2. Special names and symbols of decimal multiples and submultiples of SI units which may be used only in specialised fields

Quantity — Size	Unit		
	Name	Symbol	Value
Area of farmland and building land	are	a	1 a = 10^2 m^2
Mass per unit length of textile yarns and threads	tex*[1]	tex*[1]	1 tex = 10^{-6} kg/m

---

[1] The character * after a unit name or symbol indicates that these have not yet appeared in the lists drawn up by the CGPM or CIPM.

Note: The prefixes listed in item 1.3 may be used in conjunction with the units contained in the tables of items 1.4.1 and 1.4.2.
The multiple 10^2 a is, however, called a 'hectare'.

2. UNITS WHICH ARE DEFINED ON THE BASIS OF SI UNITS BUT ARE NOT DECIMAL MULTIPLES OR SUBMULTIPLES THEREOF

Quantity	Unit		
	Name	Symbol	Value
Plane angle	revolution*	[1]	1 revolution = 2π rad
	grade* or gon*[2]	^{g}* gon*	1^{g} or 1 gon = $\frac{\pi}{200}$ rad
	degree*	°*	$1^{\circ} = \frac{\pi}{180}$ rad
	minute of angle*	′*	$1' = \frac{\pi}{10\,800}$ rad
	second of angle*	″*	$1'' = \frac{\pi}{648\,000}$ rad
Time	minute*	min*	1 min = 60 s
	hour	h	1 h = 3 600 s
	day*	d*	1 d = 86 400 s

[1] No international symbol exists at present although there are national symbols and abbreviations, such as tr, ag.

[2] The symbol ^{g} should disappear in favour of gon. The matter will be reviewed by 31 December 1977.

Note: The prefixes listed in item 1.3 may only be used in conjunction with the names grade and gon and the symbols only with the symbol gon.

3. UNITS DEFINED INDEPENDENTLY OF THE SEVEN SI BASE UNITS

The unified atomic mass unit is 1/12 of the mass of an atom of the nuclide ^{12}C.

The electronvolt is the kinetic energy acquired by an electron passing in a vacuum from one point to another whose potential is 1 volt higher.

Quantity	Unit		
	Name	Symbol	Value
mass	unified atomic mass unit*	u*	. . . .
energy	electronvolt*	eV*	. . . .

The value of these units, expressed in SI units, is not exactly known.

Note: The prefixes listed in item 1.3 may be used in conjunction with these two units.

4. UNITS AND NAMES OF UNITS PERMITTED IN SPECIALISED FIELDS ONLY

Quantity	Unit	
	Name	Value
vergence of optical systems	dioptre*	1 dioptre = 1 m^{-1}
mass of precious stones	metric carat	1 metric carat = $2 \cdot 10^{-4}$ kg

Note: The prefixes listed in item 1.3 may be used in conjunction with the above units.

5. COMPOUND UNITS

Compound units are formed by combining the units in Chapters I, II and III *with the exception of those listed in items 1.4.2 and 4 of Chapter I and item 8.1 of Chapter III* (units permitted in specialised fields only). The use of some of such compound units, where these are not derived SI units, will be examined by 31 December 1977 with a view to deciding whether their use should be restricted or prohibited.

CHAPTER II

UNITS OR NAMES OF UNITS, THE AUTHORISATION OF WHICH IS TO BE REVIEWED BY 31 DECEMBER 1977

6. CGS UNITS

Quantity	Unit		
	Name	Symbol	Value
force	dyne	dyn	1 dyn = 10^{-5} N
energy	erg	erg	1 erg = 10^{-7} J
dynamic viscosity	poise	P	1P = 10^{-1} Pa · s
kinematic viscosity	stokes*	St*	1 St = 10^{-4} M^2/s
acceleration due to gravity	gal*	Gal*	1 Gal = 10^{-2} m/s^2

7. OTHER UNITS

Quantity	Unit		
	Name	Symbol	Value
wavelength, atomic distances	ångström*	Å*	1 Å = 10^{-10} m
effective cross-sectional area	barn*	b*	1 b = 10^{-28} m^2
mass	quintal*	q*	1 q = 10^2 kg
pressure	standard atmosphere	atm	1 atm = 101 325 Pa
activity of a radioactive source	curie	Ci	1 Ci = $3{\cdot}7 \times 10^{10}$ s^{-1}
absorbed dose	rad*	rd*	1 rd = 10^{-2} J/kg
equivalent absorbed dose	rem*	rem*	1 rem = 1 rd
exposure to ionising radiations	röntgen*	R*	1 R = $2{\cdot}58 \times 10^{-4}$ C/kg

Note: The prefixes listed in item 1.3 may be used in conjunction with the units contained in items 6 and 7, apart from the quintal.

CHAPTER III

UNITS, NAMES AND SYMBOLS WHICH ARE TO DISAPPEAR FROM USE AS SOON AS POSSIBLE, AND AT THE LATEST BY 31 DECEMBER 1977

8. QUANTITIES, NAMES OF UNITS, SYMBOLS AND VALUES

8.1. Volume (forestry and timber trade)

Festmeter*	1 Fm*	= 1 m^3
Raummeter*	1 Rm*	= 1 m^3
stère	1 st	

8.2. Force

kilogramme-force*	1 kgf*	= 9·806 65 N
kilopond*	1 kp*	

8.3. Pressure

torr*	1 torr*	= $\frac{101\ 325}{760}$ Pa
technical atmosphere*	1 at*	= 98 066·5 Pa
metre of water (conventional: 1 mH_2O)	1 mH_2O*	= 9 806·65 Pa
millimetre of mercury* (conventional: 1 mmHg = 13·5951 mmH_2O)	1 mmHg*	= 133·322 Pa

8.4. Power

Pferdestärke*	1 PS*	= 735·498 75 W
Paardekracht*	1 pk*	
cheval vapeur*	1 CV*	
cavallo vapore*	1 cv*	

8.5. Quantity of heat

calorie	1 cal*	= 4·186 8 J
thermie*	1 th*	= 4·186 8 × 10^6 J
frigorie* (for measuring a quantity of heat withdrawn from a system)	1 fg*	= 4·186 8 × 10^3 J

8.6. Luminance

stilb	1 sb	= 10^4 cd/m^2

Note: The prefixes listed in item 1.3 may be used in conjunction with the units contained in items 8.2, 8.5 and 8.6, with the stère (item 8.1), with the torr and with the metre of water (item 8.3).

9. SPECIAL CASE WITH REGARD TO TEMPERATURE

The name 'degree Kelvin' and the symbol '°K' may be used instead of 'Kelvin' and the symbol 'K' until 31 December 1977.

Treaty...concerning the accession of the Kingdom of Denmark, Ireland, ..., and the United Kingdom to the European Economic Community and to the European Atomic Energy Community, Annex I, Official Journal of the European Communities, Special Edition, 27 March 1972.

16. *Council Directive No 71/354/EEC* of 18 October 1971
OJ No L 243/29, 29 October 1971

In Article 1(1) and (2), the word "Annex" is replaced by "Annex I".

Article 1(3) is replaced by the following:

> "3. The units of measurement temporarily retained in accordance with the provisions of Annex I, Chapters II and III and Annex II may not be brought into compulsory use by the Member States where they are not authorized at the date when this Directive enters into force."

In Article 1, a paragraph 4 is inserted, worded as follows:

> "4. The classification in Annex I of the units of measurement listed in Annex II shall be decided on 31 August 1976 at the latest. The units of measurement concerning which no decision has been made on 31 August 1976 at the latest, shall disappear on 31 December 1979 at the latest. An appropriate extension of this time limit may be decided for certain of these units of measurement if it should be justified for special reasons."

The title of the Annex is replaced by "Annex I".

An Annex II is inserted, worded as follows:

"*ANNEX II*

Units of measurement of the imperial system, the classification of which in Annex I shall be decided on 31 August 1976 at the latest

Quantity	Name of unit	Conversion Factor: $\frac{\textit{Imperial unit}}{\textit{SI unit}}$
Length Metre (m)	Inch	$2.54 \cdot 10^{-2}$
	Hand	0.1016
	Foot	0.3048
	Yard	0.9144
	Fathom	1.829
	Chain	20.12
	Furlong	201.2
	Mile	1609
	Nautical mile (UK)	1853

Quantity	Name of unit	Conversion Factor: $\frac{\textit{Imperial unit}}{\textit{SI unit}}$
Area Square metre (m^2)	Square inch	$6.452 \cdot 10^{-4}$
	Square foot	$0.929 \cdot 10^{-1}$
	Square yard	0.8361
	Rood	1012
	Acre	4047
	Square mile	$2.59 \cdot 10^{6}$
Volume Cubic metre (m^3)	Cubic inch	$16.39 \cdot 10^{-6}$
	Cubic foot	0.0283
	Cubic yard	0.7646
	Fluid ounce	$28.41 \cdot 10^{-6}$
	Gill	$0.1421 \cdot 10^{-3}$
	Pint	$0.5682 \cdot 10^{-3}$
	Quart	$1.136 \cdot 10^{-3}$
	Gallon	$4.546 \cdot 10^{-3}$
	Bushel	$36.37 \cdot 10^{-3}$
	Cran	$170.5 \cdot 10^{-3}$
Mass Kilogramme (kg)	Grain	$0.0648 \cdot 10^{-3}$
	Dram	$1.772 \cdot 10^{-3}$
	Ounce (avoirdupois)	$28.35 \cdot 10^{-3}$
	Ounce troy	$31.10 \cdot 10^{-3}$
	Pound	0.4536
	Stone	6.35
	Quarter	12.70
	Cental	45.36
	Hundredweight	50.80
	Ton	1016
Force Newton (N)	Pound force	4.448
	Ton force	$9.964 \cdot 10^{3}$
Pressure Pascal (Pa)	Inch water gauge	249.089
Energy Joule (J)	British thermal unit	1055.06
	Foot pound-force	1.356
	Therm	$105.506 \cdot 10^{6}$
Power Watt (W)	Horsepower	745.7
Illuminance Lux (lx)	Foot-candle	10.76
Temperature Kelvin (K)	Degree Fahrenheit	5/9
Speed, velocity Metres per second (m/s)	Knot (UK)	0.51472"

XI. FOODSTUFFS

1. *Council Directive* of 23 October 1962
   OJ No 115/2645, 11 November 1962

as amended by:

- *Council Directive No 65/469/EEC* of 25 October 1965
  OJ No 178/2793, 26 October 1965
- *Council Directive No 67/653/EEC* of 24 October 1967
  OJ No 263/4, 30 October 1967
- *Council Directive No 68/419/EEC* of 20 December 1968
  OJ No L 309/24, 24 December 1968
- *Council Directive No 70/358/EEC* of 13 July 1970
  OJ No L 157/36, 18 July 1970

APPENDIX E - EEC DIRECTIVE 71/354/EEC UPDATE

The Common Market directive governing the mandetory use of the SI metric system within its boundries has been modified since its enactment in 1971. The latest modification, and the most important, was passed by the EEC in June of 1976. It extended the time that the Common Market would tolerate the use of certain English units, but none of the extensions were beyond the original date for complete exclusion of non-metric without corresponding metric values. By 1980, all imports passing through EEC customs must have at least all indicated dimensions stated in metric units.

COUNCIL DIRECTIVE

of 27 July 1976

amending Directive 71/354/EEC on the approximation of the laws of the Member States relating to units of measurement

(76/770/EEC)

THE COUNCIL OF THE EUROPEAN COMMUNITIES,

Having regard to the Treaty establishing the European Economic Community, and in particular Article 100 thereof,

Having regard to the Act of Accession, and in particular Article 29 thereof,

Having regard to Council Directive 71/354/EEC of 18 October 1971 on the approximation of the laws of the Member States relating to units of measurement (¹), as amended by the Act of Accession, and in particular Article 1 (4) thereof,

Having regard to the proposal from the Commission,

Having regard to the opinion of the European Parliament (²),

Having regard to the opinion of the Economic and Social Committee (³),

Whereas, pursuant to the Act of Accession, the classification in Annex I to Directive 71/354/EEC of the units of measurement listed in Annex II to that Directive is to be decided on by 31 August 1976 at the latest;

Whereas, in Directive 71/354/EEC, provision is made for the review before 31 December 1977 of the situation as regards the units and names of units listed in Chapter II of Annex I to that Directive;

Whereas the 15th General Conference of Weights and Measures (CGPM), convened on 27 May 1975 in Paris by the International Committee of Weights and Measures (CIPM), adopted new international resolutions concerning the international system of units,

HAS ADOPTED THIS DIRECTIVE:

Article 1

Article 1 of Directive 71/354/EEC is replaced by the following:

> '*Article 1*
>
> 1. Member States shall make the provisions of Chapter A of the Annex mandatory by 21 April 1978 at the latest.
>
> 2. Member States shall, with effect from 31 December 1977 at the latest, cease to authorize the use of the units of measurement listed in Chapter B of the Annex.
>
> 3. Member States shall, with effect from 31 December 1979 at the latest, cease to authorize the use of the units of measurement listed in Chapter C of the Annex.
>
> 4. The units of measurement, names and symbols listed in Chapter D of the Annex shall be reviewed before 31 December 1979.
>
> 5. The use of the units of measurement temporarily retained in accordance with the provisions of Chapters B, C and D of the Annex may not be made mandatory by Member States where they have not been authorized since 21 April 1973.'

Article 2

The following Article is added to Directive 71/354/EEC:

> '*Article 2a*
>
> Member States may authorize the use of products, equipment and instruments using units which are not authorized under this Directive, which were already on the market prior to the dates laid down in this Directive and the manu-

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(¹) OJ No L 243, 29. 10. 1971, p. 29.

(²) OJ No C 125, 8. 6. 1976, p. 9.

(³) OJ No C 131, 12. 6. 1976, p. 55.

facture, placing on the market and use of products and equipment necessary to complete or replace components or parts of such products, equipment and instruments.'

Article 3

Annexes I and II to Directive 71/354/EEC are replaced by the Annex hereto.

Article 4

1. Member States shall bring into force the laws, regulations and administrative provisions necessary in order to comply with this Directive by 31 December 1977 at the latest and shall forthwith inform the Commission thereof.

2. Member States shall communicate to the Commission the texts of the main provisions of national law which they adopt in the field covered by this Directive.

Article 5

This Directive is addressed to the Member States.

Done at Brussels, 27 July 1976.

For the Council
The President
M. van der STOEL

ANNEX

LIST OF CONTENTS

CHAPTER A

UNITS OF MEASUREMENT THE USE OF WHICH MUST BE MADE MANDATORY AS FROM 21 APRIL 1978 AT THE LATEST

1. SI UNITS AND THEIR DECIMAL MULTIPLES AND SUBMULTIPLES

1.1. SI base units

Quantity	Unit	
	Name	Symbol
Length	metre	m
Mass	kilogramme	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Definitions of SI base units:

Unit of length

The metre is the length equal to 1 650 763·73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton 86 atom.

(Eleventh CGPM (1960), resolution 6).

Unit of mass

The kilogramme is the unit of mass; it is equal to the mass of the international prototype of the kilogramme.

(Third CGPM (1901), page 70 of the conference report).

Unit of time

The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom.

(Thirteenth CGPM (1967), resolution 1).

Unit of electric current

The ampere is that constant current which if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section and placed one metre apart in a vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

(CIPM (1946), resolution 2, approved by the ninth CGPM (1948)).

Unit of thermodynamic temperature

The kelvin, unit of thermodynamic temperature, is the fraction 1/273·16 of the thermodynamic temperature of the triple point of water.

(Thirteenth CGPM (1967), resolution 4).

Unit of amount of substance

The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0·012 kg of carbon 12.

When the mole is used the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles or specified groups of such particles.

(Fourteenth CGPM (1971), resolution 3).

Unit of luminous intensity

The candela is the luminous intensity, in the perpendicular direction, of a surface of 1/600 000 m^2 of a black body at the temperature of freezing platinum under a pressure of 101 325 newtons/m^2.

(Thirteenth CGPM (1967), resolution 5).

1.1.1. Special name and symbol of the SI unit of temperature for expressing Celsius temperature

Quantity	Unit	
	Name	Symbol
Celsius temperature	degree Celsius	°C

Celsius temperature t is defined as the difference $t = T - T_0$ between the two thermodynamic temperatures T and T_0 where $T_0 = 273{\cdot}15$ kelvins. An interval of or difference in temperature may be expressed either in kelvins or in degrees Celsius. The unit of 'degree Celsius' is equal to the unit 'kelvin'.

1.2. Other SI units

1.2.1. Supplementary SI units

Quantity	Unit	
	Name	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

(Eleventh CGPM, 1960, resolution 12).

Definitions of supplementary SI units:

Plane angle unit

The radian is the plane angle between two radii which, on the circumference of a circle, cut an arc equal in length to the radius.

(ISO recommendation R 31, Part 1, second edition, December 1965).

Solid angle unit

The steradian is the solid angle which has its apex at the centre of a sphere and which describes on the surface of the sphere an area equal to that of a square having as its side the radius of the sphere.

(ISO recommendation R 31, Part I, second edition, December 1965).

1.2.2. Derived SI units

Units derived coherently from SI base units and supplementary SI units are given as algebraic expressions in the form of products of powers of the SI base units and/or supplementary SI units with a numerical factor equal to 1.

1.2.3. Derived SI units having names and symbols

Quantity	Unit		Expression	
	Name	Symbol	In other SI units	In terms of base or supplementary SI units
Frequency	hertz	Hz		s^{-1}
Force	newton	N		$m \cdot kg \cdot s^{-2}$
Pressure, stress	pascal	Pa	$N \cdot m^{-2}$	$m^{-1} \cdot kg \cdot s^{-2}$
Energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
Power (1)	watt	W	$J \cdot s^{-1}$	$m^2 \cdot kg \cdot s^{-3}$
Quantity of electricity, electric charge	coulomb	C		$s \cdot A$
Electric tension, electric potential, electromotive force	volt	V	$W \cdot A^{-1}$	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
Electric resistance	ohm	Ω	$V \cdot A^{-1}$	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
Electric conductance	siemens	S	$A \cdot V^{-1}$	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
Electric capacitance	farad	F	$C \cdot V^{-1}$	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
Magnetic flux	weber	Wb	$V \cdot s$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
Mangetic flux density	tesla	T	$Wb \cdot m^{-2}$	$kg \cdot s^{-2} \cdot A^{-1}$
Electric inductance	henry	H	$Wb \cdot A^{-1}$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
Luminous flux	lumen	lm		$cd \cdot sr$
Illuminance	lux	lx	$lm \cdot m^{-2}$	$m^{-2} \cdot cd \cdot sr$
Activity	becquerel	Bq		s^{-1}
Absorbed dose (2)	gray	Gy	$J \cdot kg^{-1}$	$m^2 \cdot s^{-2}$

(1) Special names for the unit of power: the name volt-ampere (symbol 'VA') when it is used to express the apparent power of alternating electric current, and var (symbol 'var') when it is used to express reactive electric power. The 'var' is not included in CGPM resolutions.

(2) And other quantities of ionizing radiations of the same dimensions.

Units derived from SI base units may be expressed in terms of the units listed in Chapter A.

In particular, derived SI units may be expressed by the special names and symbols given in the above table; for example, the SI unit of dynamic viscosity may be expressed as $m^{-1} \cdot kg \cdot s^{-1}$ or $N \cdot s \cdot m^{-2}$ or $Pa \cdot s$.

1.3. Prefixes and their symbols used to designate certain decimal multiples and submultiples

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{18}	exa	E	10^{-1}	deci	d
10^{15}	peta	P	10^{-2}	centi	c
10^{12}	tera	T	10^{-3}	milli	m
10^{9}	giga	G	10^{-6}	micro	µ
10^{6}	mega	M	10^{-9}	nano	n
10^{3}	kilo	k	10^{-12}	pico	p
10^{2}	hecto	h	10^{-15}	femto	f
10^{1}	deca	da	10^{-18}	atto	a

The names and symbols of the decimal multiples and submultiples of the unit of mass are formed by attaching prefixes to the word 'gramme' and their symbols to the symbol 'g'.

Where a derived unit is expressed as a fraction, its decimal multiples and submultiples may be designated by attaching a prefix to units in the numerator or the denominator, or in both these parts.

Compound prefixes, that is to say prefixes formed by the juxtaposition of several of the above prefixes, may not be used.

1.4. Special authorized names and symbols

1.4.1. Special names and symbols of decimal multiples and submultiples of SI units

Quantity	Unit		
	Name	Symbol	Value
Volume	litre	l	$1\ \mathrm{l} = 1\ \mathrm{dm}^3 = 10^{-3}\ \mathrm{m}^3$
Mass	metric ton	t	$1\ \mathrm{t} = 1\ \mathrm{Mg} = 10^3\ \mathrm{kg}$
Pressure, stress	bar	bar	$1\ \mathrm{bar} = 10^5\ \mathrm{Pa}$

1.4.2. Special names and symbols of decimal multiples and submultiples of SI units which may be used only in specialized fields

Quantity	Unit		
	Name	Symbol	Value
Area of farmland and building land	are	a	$1\ \mathrm{a} = 10^2\ \mathrm{m}^2$
Mass per unit length of textile yarns and threads	tex* (1)	tex*	$1\ \mathrm{tex} = 10^{-6}\ \mathrm{kg} \cdot \mathrm{m}^{-1}$

(1) The character * after a unit name or symbol indicates that these do not appear in the lists drawn up by the CGPM, CIPM, or BIPM. This applies to the whole of this Annex.

Note: The prefixes and their symbols listed in 1.3 may be used in conjunction with the units and symbols contained in Tables 1.4.1 and 1.4.2.

The multiple 10^2 a is, however, called a 'hectare'.

2. UNITS WHICH ARE DEFINED ON THE BASIS OF SI UNITS BUT ARE NOT DECIMAL MULTIPLES OR SUBMULTIPLES THEREOF

Quantity	Unit		
	Name	Symbol	Value
Plane angle	revolution* (a)		1 revolution = 2π rad
	grade* or gon*	gon *	1 gon = $\frac{\pi}{200}$ rad
	degree	°	$1° = \frac{\pi}{180}$ rad
	minute of angle	′	$1' = \frac{\pi}{10\,800}$ rad
	second of angle	″	$1'' = \frac{\pi}{648\,000}$ rad
Time	minute	min	1 min = 60 s
	hour	h	1 h = 3 600 s
	day	d	1 d = 86 400 s

(a) No international symbol exists.

Note: The prefixes listed in 1.3 may only be used in conjunction with the names 'grade' or 'gon' and the symbols only with the symbol 'gon'.

3. UNITS DEFINED INDEPENDENTLY OF THE SEVEN SI BASE UNITS

The unified atomic mass unit is one-twelfth of the mass of an atom of the nuclide ^{12}C.

The electronvolt is the kinetic energy acquired by an electron passing in a vacuum from one point to another whose potential is one volt higher.

Quantity	Unit		
	Name	Symbol	Value
Mass	unified atomic mass unit	u	1 u $\approx 1{\cdot}6605655 \times 10^{-27}$ kg
Energy	electronvolt	eV	1eV $\approx 1{\cdot}6021892 \times 10^{-19}$ J

The value of these units, expressed in SI units, is not exactly known.

The above values are taken from CODATA Bulletin No 11 of December 1973 of the International Council of Scientific Unions.

Note: The prefixes and their symbols listed in 1.3 may be used in conjunction with these two units and with their symbols.

4. UNITS AND NAMES OF UNITS PERMITTED IN SPECIALIZED FIELDS ONLY

Quant	Unit	
	Name	Value
Vergency of optic ıs	dioptre*	1 dioptre = 1 m^{-1}
Mass of precious st	metric carat	1 metric carat = 2×10^{-4} kg

Note: The prefixes listed 1.3 may be used in conjunction with the above units.

5. COMPOUND UNITS

Compound units are formed combining the units mentioned in Chapter A.

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CHAPTER B

UNITS OF MEASUREMENT REFERRED TO IN ARTICLE 1 (2)

6. SPECIAL UNITS

Quantities, names of units, symbols and values:

6.1. Volume (forestry and timber industry)

Festmeter*	1 Fm* = 1 m^3
Raummeter*	1 Rm* = 1 m^3

6.2. Force

kilogramme force	1 kgf	= 9·806 65 N
kilopond*	1 kp*	

6.3. Pressure

torr	1 torr = $\frac{101\,325}{760}$ Pa
technical atmosphere*	1 at* = 98 066·5 Pa
metre of water* (conventionally: 1 mH_2O)	1 mH_2O* = 9 806·65 Pa
millimetre of mercury* (1) (conventionally: 1 mmHg)	1 mmHg* = 133·322 Pa

6.4. Power

Pferdestärke*	1 PS*	= 735·498 75 W
paardekracht*	1 pk*	
cheval vapeur*	1 CV*	
cavallo vapore*	1 cv*	

6.5. Quantity of heat

calorie 15 °C	1 cal^*_{15} = 4·185 5 J
thermie*	1 th* = 4·185 5 × 10^6 J
frigorie*	1 fg* = 4·185 5 × 10^3 J
calorie IT	1 cal_{IT} = 4·186 8 J
thermo-chemical calorie*	1 cal^*_{thch} = 4·184 J

6.6. Luminance

stilb	1 sb = 10^4 cd · m^{-2}

Note: The prefixes and their symbols listed in 1.3 may be used in conjunction with the units and symbols contained in 6.5 and 6.6, with the torr and with the metre of water (see 6.3.).

7. SPECIAL CASE OF TEMPERATURE

The name 'degree kelvin' and the symbol '°K' (instead of kelvin, symbol K) may be used until 31 December 1977.

---

(1) Except where this unit is used for measuring blood pressure (see Chapter C, section 11).

8. IMPERIAL UNITS*

Quantities, names of units, symbols and approximate values

8.1. Length

chain	1 chain = 20·12 m
furlong	1 fur = 201·2 m
nautical mile (UK)	1 nautical mile = 1 853 m

8.2. Area

rood	1 rood = 1 012 m^2

8.3. Volume

cubic yard	1 cu yd = 0·7646 m^3
bushel	1 bu = 36·37 × 10^{-3} m^3

8.4. Mass

dram	1 dr = 1·772 × 10^{-3} kg
cental	1 ctl = 45·36 kg

8.5. Pressure

inch of water	1 in H_2O = 249·089 Pa

8.6. Force

ton-force	1 tonf = 9·964 × 10^3 N

8.7. Illuminance

foot candle	1 ft candle = 10·76 lx

8.8. Speed

knot (UK)	1 knot = 0·51477 $m \cdot s^{-1}$

CHAPTER C

UNITS OF MEASUREMENT TO IN ARTICLE 1 (3)

9. IMPERIAL UNITS*

Quantities, names of units, symbols and approximate values

9 1. Length

hand	1 hand = 0·1016 m
yard	1 yd = 0·9144 m

9 2. Area

square inch	1 sq in = 6·452 × 10^{-4} m^2
square yard	1 sq yd = 0·8361 m^2
square mile	1 sq mile = 2·59 × 10^6 m^2

9.3. Volume

cubic inch	1 cu in = 16·39 × 10^{-6} m^3
cubic foot	1 cu ft = 0·0283 m^3
cran	1 cran = 170·5 × 10^{-3} m^3

9.4. Mass

grain	1 gr = 0·0648 × 10^{-3} kg
stone	1 st = 6·35 kg
quarter	1 qr = 12·70 kg
hundredweight	1 cwt = 50·80 kg
ton	1 ton = 1 016 kg

9.5. Force

pound-force	1 lbf = 4·448 N

9.6. Energy

British thermal unit	1 Btu = 1055·06 J
foot pound-force	1 ft lbf = 1·356 J
therm	1 therm = 105·506 × 10^6 J

9.7. Power

horsepower	1 hp = 745·7 W

9.8. Temperature

degree Fahrenheit	1 °F = $\left(\frac{5}{9}\right)$ K

10. CGS UNITS

Quantities, names of units, symbols and values

Quantity	Unit		
	Name	Symbol	Value
Force	dyne	dyn	1 dyn = 10^{-5} N
Energy	erg	erg	1 erg = 10^{-7} J
Dynamic viscosity	poise	P	1 P = 10^{-1} Pa · s
Kinematic viscosity	stokes	St	1 St = 10^{-4} $m^2 \cdot s^{-1}$
Acceleration of free fall	gal	Gal	1 Gal = 10^{-2} $m \cdot s^{-2}$

11. OTHER UNITS

Quantities, names of units, symbols and values

Quantity	Unit		
	Name	Symbol	Value
Wavelength, atomic distances	ångström	Å	1 Å = 10^{-10} m
Effective cross-sectional area	barn	barn	1 b = 10^{-28} m^2
Mass	quintal* (a)		1 quintal = 10^2 kg
Pressure	standard atmosphere	atm	1 atm = 101 325 Pa
Blood pressure	millimetre of mercury* (conventionally: 1 mmHg)	mmHg*	1 mmHg = 133·322 Pa
Volume (forestry and timber trade)	stere	st	1 st = 1 m^3

(a) No international symbol exists.

Note: The prefixes and their symbols listed in 1.3 may be used in conjunction with the units and symbols contained in sections 10 and 11, apart from the 'quintal'.

CHAPTER D

UNITS, NAMES AND SYMBOLS REFERRED TO IN ARTICLE 1 (4)

12. IMPERIAL UNITS*

Quantities, names of units, symbols and approximate values

12.1	**Length**	
	inch	1 in = $2{\cdot}54 \times 10^{-2}$ m
	foot	1 ft = 0·3048 m
	fathom (¹)	1 fm = 1·829 m
	mile	1 mile = 1 609 m
12.2	**Area**	
	square foot	1 sq ft = $0{\cdot}929 \times 10^{-1}$ m^2
	acre	1 ac = 4 047 m^2
12.3.	**Volume**	
	fluid ounce	1 fl oz = $28{\cdot}41 \times 10^{-6}$ m^3
	gill	1 gill = $0{\cdot}1421 \times 10^{-3}$ m^3
	pint	1 pt = $0{\cdot}5683 \times 10^{-3}$ m^3
	quart	1 qt = $1{\cdot}137 \times 10^{-3}$ m^3
	gallon	1 gal = $4{\cdot}546 \times 10^{-3}$ m^3
12.4.	**Mass**	
	ounce (avoirdupois)	1 oz = $28{\cdot}35 \times 10^{-3}$ kg
	troy ounce	1 oz tr = $31{\cdot}10 \times 10^{-3}$ kg
	pound	1 lb = 0·4536 kg

(¹) For marine navigation only.

13. OTHER UNITS

Quantities, names of units, symbols and values

Quantity	Unit		
	Name	Symbol	Value
Activity of a radioactive source	curie	Ci	1 Ci = $3{\cdot}7 \times 10^{10}$ Bq
Plane angle		g* (¹)	$1\ g = \frac{\pi}{200}$ rad
Absorbed dose	rad	rd (²)	1 rd = 10^{-2} Gy
Equivalent absorbed dose	rem*	rem*	1 rem = 1 rd
Exposure to ionizing radiations	röntgen	R	1 R = $2{\cdot}58 \times 10^{-4}$ $C \cdot kg^{-1}$

(¹) Symbol for 'grade'.
(²) The symbol recommended by the International Bureau of Weights and Measures (BIPM) is 'rad'.

Note: The prefixes and their symbols listed in 1.3 may be used in conjunction with the units and symbols contained in this section, with the exception of 'g'.

14. COMPOUND UNITS (TO BE USED TEMPORARILY)

Until the dates indicated in Article 1, the units listed in Chapters B, C and D may be used in conjunction with one another or with those contained in Chapter A to form compound units.

APPENDIX F - ISO DRAFT FOR OIL FIELD EQUIPMENT

In March of 1976 the International Standards Organization submitted for inspection and comments a proposed draft of standards covering the manufacture and design of tool joints for steel drill pipe for oil or natural gas wells. Part A of this Appendix gives the text of the draft while Part B summarizes the objections API had to the draft.

PART A

DRAFT INTERNATIONAL STANDARD ISO/DIS [illegible]

ISO/TC	Secretariat
67	IRS
Submitted on	Voting terminates on
1976-03-25	1976-09-25

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION · МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ · ORGANISATION INTERNATIONALE DE NORM

Materials and equipment for petroleum and natural gas industries — Tool joints for steel drill pipe for oil or natural gas wells

UDC 622.24.05

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CONTENTS

DRAFT INTERNATIONAL STANDARD ISO/DIS 3962

Materials and equipment for petroleum and natural gas industries — Tool joints for steel drill pipe for oil or natural gas wells

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the characteristics of tool joints for steel drill pipe in conformity with ISO 2644 for use in oil or natural gas wells. It covers only those tool joints that are connected to the drill pipes by electric butt welding. It does not deal with tool joints connected to the drill pipes by fast-on threads.

2 DEFINITIONS

For the purposes of this International Standard, the following definitions apply.

2.1 tool joint : The two components, one with a male thread and the other with a female thread, prolonging drill pipes to which they are connected in an indissoluble way.

2.2 rotary shouldered connection : The pin and box which are threaded and machined with shoulders to mate with each other.

3 DATA TO BE GIVEN BY THE PURCHASER

The purchase order (tool joints only, drill pipes with tool joints) shall list the following elements which are necessary for the precise specification of tool joints.

3.1 Nominal size and style (according to table 1 or 6).

3.2 Shoulder type of tapered or square elevators (figure 1).

3.3 Direction of thread : to be specified only for left-hand type threads.

? 3.4 Local hardening of tool joints : type of outside diameter (see 4.1.2).

3.5 Anti-sticking treatment of threaded rotary shouldered connections (see 4.1.3).

3.6 Optional markings by agreement between purchaser and manufacturer.

3.6.1 Useful length between shoulders, rounded off to the nearest 0,5 cm (applicable by the enterprise carrying out the welding work).

3.6.2 Date of manufacture :

- of drill pipes only;
- of tool joints only;
- of the welds only.

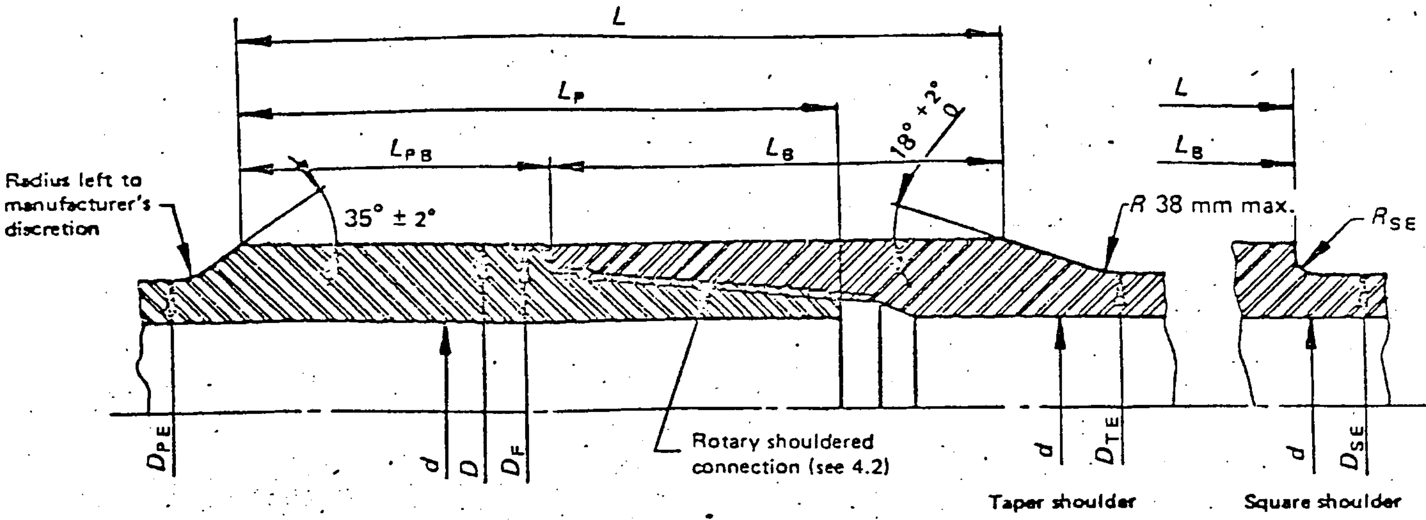


FIGURE 1 — Tool joint — Taper shoulder and square shoulder (see table 1)

TABLE 1 – Dimensions, in millimetres, of tool joints for steel drill pipes of grades E, X, G and S

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Drill pipes				Tool joints									
Designation of tool joint 1)	Dimension and style	Mass per unit length of drill pipes 2) 5) kg/m	Grade	Outside diameter, pin and box D ± 0,8	Inside diameter, pin 3) d + 0,4 − 0,8	Diameter of shoulder chamfer, pin or box D_F ± 0,4	Total length of pin L_P + 6,4 − 9,5	Place for spanner on pin L_{PB} ± 6,4	Place for spanner on box L_B ± 6,4	Combined length of pin and box L ± 12,7	Diameter of pin at upset of elevator 5) D_{PE} max.	Diameter of box at upset 5) D_{TE} max.	Ratio of pin to box for torsion 6)
NC 26 (60,3 IF)	60,3 E.U.	9,91	E 75	85,7*	44,4*	82,9	228,6	152,4	177,8	330,2	65,1	65,1	1,10
			X 95	85,7*	44,4*	82,9	228,6	152,4	177,8	330,2	65,1	65,1	0,87
			G 105	85,7*	44,4*	82,9	228,6	152,4	177,8	330,2	65,1	65,1	0,79
NC 31 (73,0 IF)	73 E.U.	15,5	E 75	104,8*	54,10*	100,4	241,3	152,4	203,2	355,6	81,0	81,0	1,03
			X 95	104,8*	50,8	100,4	241,3	152,4	203,2	355,6	81,0	81,0	0,90
			G 105	104,8*	50,8	100,4	241,3	152,4	203,2	355,6	81,0	81,0	0,82
			S 135	111,1	41,3	100,4	241,3	152,4	203,2	355,6	81,0	81,0	0,82
NC 38 4)	88,9 E.U.	14,15	E 75	120,7*	76,2	116,3	266,7	177,8	241,3	419,1	98,4	98,4	0,91
NC 38 (88,9 IF)	88,9 E.U.	19,81	X 95	127	65,1	116,3	279,4	177,8	241,3	419,1	98,4	98,4	0,87
			G 105	127	61,9	116,3	279,4	177,8	241,3	419,1	98,4	98,4	0,86
			S 135	127	54,0	116,3	279,4	177,8	241,3	419,1	98,4	98,4	0,80
		23,1	E 75	127	65,1	116,3	279,4	177,8	241,3	419,1	98,4	98,4	0,97
			X 95	127	61,9	116,3	279,4	177,8	241,3	419,1	98,4	98,4	0,83
			G 105	127	54,0	116,3	279,4	177,8	241,3	419,1	98,4	98,4	0,90
NC 40 (101,6 IF)	88,9 E.U.	23,1	S 135	139,7	57,1	127,4	292,1	177,8	254	431,8	98,4	98,4	0,87
	101,6 I.U.	20,85	E 75	133,3*	71,5*	127,4	292,1	177,8	254	431,8	106,4	106,4	1,01
			X 95	133,3*	68,3	127,4	292,1	177,8	254	431,8	106,4	106,4	0,86
			G 105	139,7	61,9	127,4	292,1	177,8	254	431,8	106,4	106,4	0,93
			S 135	139,7	50,8	127,4	292,1	177,8	254	431,8	106,4	106,4	0,87
NC 46 (101,6 IF)	101,6 E.U.	20,85	E 75	152,4*	82,5*	135,7	292,1	177,8	254	431,8	114,3	114,3	1,43
			X 95	152,4*	82,5*	135,7	292,1	177,8	254	431,8	114,3	114,3	1,13
			G 105	152,4*	82,5*	135,7	292,1	177,8	254	431,8	114,3	114,3	1,02
			S 135	152,4*	76,2	135,7	292,1	177,8	254	431,8	114,3	114,3	0,94
	114,3 I.U.	24,73	E 75	152,4*	82,5*	135,7	292,1	177,8	254	431,8	119,1	119,1	1,09
			X 95	152,4*	76,2	135,7	292,1	177,8	254	431,8	119,1	119,1	1,01
			G 105	152,4*	76,2	135,7	292,1	177,8	254	431,8	119,1	119,1	0,91
			S 135	158,8	69,9	135,7	292,1	177,8	254	431,8	119,1	119,1	0,81
	114,3 I.E.U.	29,8	E 75	152,4*	76,2	135,7	292,1	177,8	254	431,8	119,1	119,1	1,07
			X 95	158,8	69,9	135,7	292,1	177,8	254	431,8	119,1	119,1	0,96
			G 105	158,8	63,5	135,7	292,1	177,8	254	431,8	119,1	119,1	0,96
			S 135	158,8	57,1	135,7	292,1	177,8	254	431,5	119,1	119,1	0,81
4 1/2 FH**	114,3 I.U.	24,73	E 75	152,4*	76,2*	135,7	279,4	177,8	254	431,8	119,1	119,1	1,12
			X 95	152,4*	69,9	135,7	279,4	177,8	254	431,8	119,1	119,1	1,02
			G 105	152,4*	69,9	135,7	279,4	177,8	254	431,8	119,1	119,1	0,92
			S 135	158,8	63,5	135,7	279,4	177,8	254	431,8	119,1	119,1	0,81
	114,3 I.E.U.	29,8	E 75	152,4*	76,2*	135,7	279,4	177,8	254	431,8	119,1	119,1	0,95
			X 95	152,4*	63,5	135,7	279,4	177,8	254	431,8	119,1	119,1	0,95
			G 105	152,4*	63,5	135,7	279,4	177,8	254	431,8	119,1	119,1	0,86
NC 50 (114,3 IF)	114,3 E.U.	24,73	E 75	161,9*	95,2	150,4	292,1	177,8	254	431,8	127	127	1,23
			X 95	161,9*	95,2	150,4	292,1	177,8	254	431,8	127	127	0,97
			G 105	161,9*	95,2	150,4	292,1	177,8	254	431,8	127	127	0,88
			S 135	161,9*	88,9	150,4	292,1	177,8	254	431,8	127	127	0,81
	114,3 E.U.	29,8	E 75	161,9*	95,2	150,4	292,1	177,8	254	431,8	127	127	1,02
			X 95	161,9*	88,9	150,4	292,1	177,8	254	431,8	127	127	0,98
			G 105	161,9*	88,9	150,4	292,1	177,8	254	431,8	127	127	0,86
			S 135	168,3	76,2	150,4	292,1	177,8	254	431,8	127	127	0,87
	127 I.E.U.	29,06	E 75	161,9*	95,2*	150,4	292,1	177,8	254	431,8	130,2	130,2	0,92
			X 95	161,9*	88,9	150,4	292,1	177,8	254	431,8	130,2	130,2	0,86
			G 105	165,1	82,8	150,4	292,1	177,8	254	431,8	130,2	130,2	0,89
			S 135	168,3	69,9	150,4	292,1	177,8	254	431,8	130,2	130,2	0,86
	127 I.E.U.	38,13	E 75	161,9*	88,9	150,4	292,1	177,8	254	431,8	130,2	130,2	0,86
			X 95	165,1	76,2	150,4	292,1	177,8	254	431,8	130,2	130,2	0,86
			G 105	168,3	69,9	150,4	292,1	177,8	254	431,8	130,2	130,2	0,87
5 1/2 FH**	127 I.E.U.	38,13	E 75	177,8*	88,9	170,6	330,2	203,2	254	457,2	130,2	130,2	1,21
			X 95	177,8*	88,9	170,6	330,2	203,2	254	457,2	130,2	130,2	0,95
			G 105	184,1	88,9	170,6	330,2	203,2	254	457,2	130,2	130,2	0,99
			S 135	184,1	82,5	170,6	330,2	203,2	254	457,2	130,2	130,2	0,83
	139,7 I.E.U.	32,62	E 75	177,8*	101,6	170,6	330,2	203,2	254	457,2	144,5	144,5	1,11
			X 95	177,8*	95,2	170,6	330,2	203,2	254	457,2	144,5	144,5	0,98
			G 105	184,1	88,9	170,6	330,2	203,2	254	457,2	144,5	144,5	1,02
			S 135	190,6	76,2	180,2	330,2	203,2	254	457,2	144,5	144,6	0,96
	139,7 I.E.U.	36,3	E 75	177,8*	101,6	170,6	330,2	203,2	254	457,2	144,5	144,5	0,99
			X 95	184,1	88,9	170,6	330,2	203,2	254	457,2	144,5	144,5	1,01
			G 105	184,1	88,9	170,6	330,2	203,2	254	457,2	144,5	144,5	0,92
			S 135	190,5	76,2	180,2	330,2	203,2	254	457,2	144,5	144,5	0,86

* Standard inside or outside diameter.

** "Old" rotary shouldered connection.

1) The tool joint designation (column 1) indicates the dimension and style of the applicable connection.

2) Masses per unit length, threads and tool joints (column 3) are indicated for identification in the order.

3) The inside diameter (column 6) does not apply to the box, the diameter of which is left to the manufacturer's discretion.

4) The length of the male thread is reduced to 88,9 mm (reduction by 12,7 mm) to take account of the internal diameter of 76,2 mm.

5) Neck diameters (D_{PE} and D_{TE}) and internal diameters (d) of tool joints before welding are at the manufacturer's option. Table 1 indicates finished dimensions after final machining of the assembly.

6) No torsion ratio (i.e. ratio of the pin torsion to the box torsion) below 0,80 is indicated.

In some cases, tool joints with noticeably smaller torsion values may be suitable.

4 TOOL JOINTS FOR DRILL PIPES OF DIAMETER > 60,3 mm

4.1 Mechanical requirements

4.1.1 Steel

Tool joints shall be manufactured from a steel such as to achieve, after appropriate heat treatment and final machining, the minimum strength requirements and a minimum yield strength of 90 N/mm^2 (125 000 lbf/in^2) in the thread.

To check this requirement, a Brinell test can be used. However, application of a Brinell test is left to the choice of the manufacturer, provided that the latter is able to supply the purchaser's representative with a justification based on adequate correlations with tensile test pieces.

In case of dispute on the minimum Brinell hardness values chosen by the manufacturer, destructive testing shall take place on tensile test pieces taken as indicated in 4.1.4.

4.1.2 External surface condition

Several processes can be specified by agreement between the purchaser and the manufacturer to harden the outside surface of the box of tool joints in order to improve wear-resistance. None of these processes shall imply covering or modification of the base metal close to the shoulders over a distance less than "x" mm. The maximum diameter of the tool joint in the locally hardened area shall be settled by agreement between the purchaser and the manufacturer without reference to the values of table 1.

4.1.2.1 TOOL JOINTS WITH WEAR BEADS

Carbide addition through fusion. See table 2.

TABLE 2 — **Carbide addition**

	Coarse grain grade		**Fine grain grade**
Deposited length, *L*	**95 mm (3 3/4 in)**		**95 mm (3 3/4 in)**
Deposited thickness	**Thickness** **1,6 mm (1/16 in)** **2,4 mm (3/32 in)** **3,2 mm (4/32 in)**	**Type** **A 18 or A 90** **B 18 or B 90** **C 18 or C 90**	**2,4 mm (3/32 in)**
Carbide grain	**Tungsten carbide** **diameter 0,8 mm (0.032 in)**		**Tungsten carbide** **powder diameter 0,2 mm (0.008 in)**
Diameter of built-up area	**D + 1,6 mm (1/16 in)**		**$D\,{}^{0}_{-0,8}$ mm (1/32 in)**

4.1.2.2 TOOL JOINTS WITH HARDENED SURFACES

Tool joints with hardened surfaces differ from those with wear beads in that the length of their neck is increased by 25 mm.

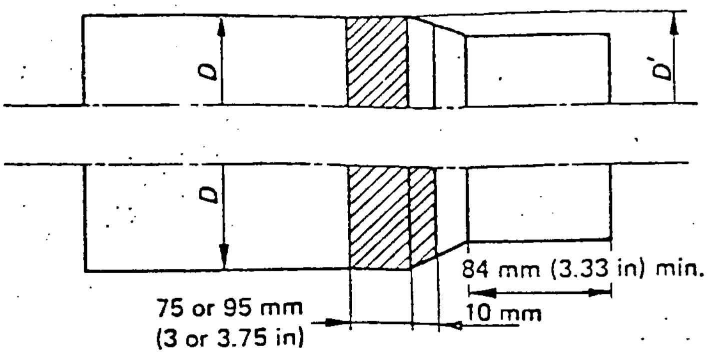


FIGURE 2 — Tool joint with hardened surface

4.1.3 Anti-sticking treatment of the threaded connection

The surfaces of the threaded rotary shouldered connections subjected to friction and screwing or operating pressures due to the drill pipes shall be submitted to an anti-sticking treatment by electroplating or chemical deposition of soft metals (copper-zinc) or chemical formation of a protective coating as agreed between the purchaser and the manufacturer. The process to be used shall not allow hydrogen inclusions, which embrittle steel.

4.1.4 Mechanical tests

- Brinell hardness test

  On the thickest part of each pin and box close to the thrust shoulder.

- Tensile test piece

  By agreement between purchaser and manufacturer, either on the finished tool joint or on a rough tool joint, just after complete heat treatment, or on a "pseudo tool joint" wrought in a way representing normal manufacture, or else on finished tool joints the hardness of which is closest to the minimum declared by the manufacturer.

4.2 Threads

4.2.1 Size and style

Rotary shouldered connections shall be furnished in the sizes and styles shown in table 3, as specified below for the particular drill stem member, or, if not specified below, as specified on the purchase order.

4.2.2 Dimensions

Dimensions of these rotary shouldered connections shall conform to figures 3 and 4 and to tables 3 and 4. All shoulder contact faces shall be square with the thread axis and flat within 0,05 mm (0.002 in). Threads shall be controlled by specified reference master gauges. The thread axes of drill stem members, except bits, shall not deviate from the design axis of the product by an angle greater than 0° 3′ 35″ (1 mm per metre of projected axis). The design axis shall be assumed as intersecting the thread axis at the plane of the joint shoulder.

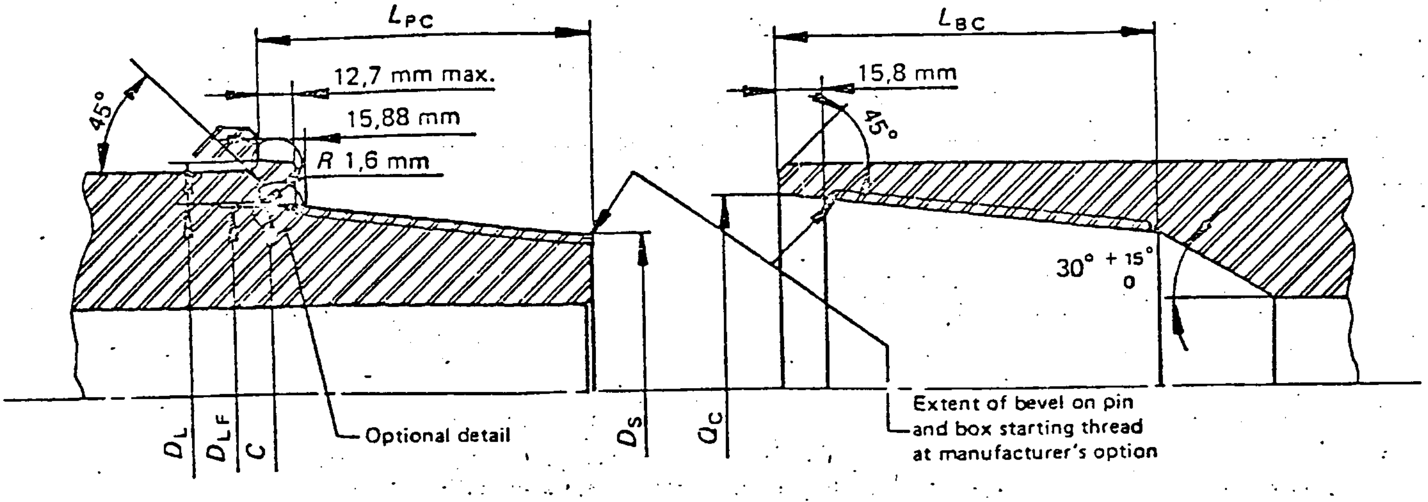


FIGURE 3 — Connecting thread

TABLE 3 — Dimensions of rotary shouldered connections, in millimetres

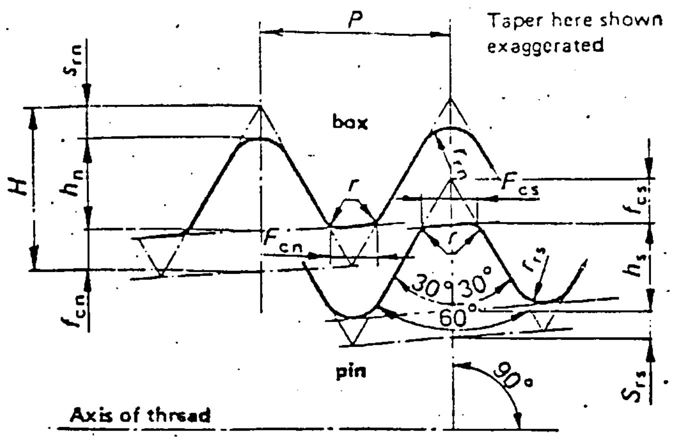
1	2	3		4	5	6	7	8	9	10	11
Connection No.	Thread form	Pitch	Threads per 25,4 mm	Taper on diameter %	Gauge diameter C	Large diameter of pin D_L	Diameter of flat on pin[2] D_{LF} ± 0,40	Small diameter of pin D_S	Length of pin L_{PC} $^{0}_{-3,18}$	Depth of box[3] L_{BC} $^{+9,52}_{0}$	Box counter-bore Q_C $^{+0,79}_{-0,40}$
Numbered style (NC)[1]											
NC 26	V-0.038 R	6,35	4	16,66	67,8	73,1	69,8	60,4	76,2	92,1	74,6
NC 31	V-0.038 R	6,35	4	16,66	80,8	86,1	83,0	71,3	88,9	104,8	87,7
NC 38	V-0.038 R	6,35	4	16,66	96,7	102,0	98,8	85,1	101,6	117,5	103,6
NC 40	V-0.038 R	6,35	4	16,66	103,4	108,7	105,6	89,7	114,3	130,2	110,3
NC 46	V-0.038 R	6,35	4	16,66	117,5	122,8	119,6	103,7	114,3	130,2	124,6
NC 50	V-0.038 R	6,35	4	16,66	128,1	133,4	130,4	114,3	114,3	130,2	134,9
NC 56	V-0.038 R	6,35	4	25,00	142,6	149,3	144,9	117,5	127,0	142,9	150,8
Regular style (REG)											
60,3 REG	V-0.040	5,08	5	25,00	60,1	66,7	—	47,6	76,2	92,1	68,3
73,0 REG	V-0.040	5,08	5	25,00	69,6	76,2	—	54,0	88,9	104,8	77,8
88,9 REG	V-0.040	5,08	5	25,00	82,2	88,9	—	65,1	95,2	111,1	90,5
114,3 REG	V-0.040	5,08	5	25,00	110,9	117,5	—	90,5	108,0	123,8	119,1
139,7 REG	V-0.050	6,35	4	25,00	132,9	140,2	—	110,1	120,6	136,5	141,7
168,3 REG	V-0.050	6,35	4	16,66	146,2	152,2	—	131,0	127,0	142,9	154,0
193,7 REG	V-0.050	6,35	4	25,00	170,5	177,8	—	144,5	133,4	149,2	180,2
219,1 REG	V-0.050	6,35	4	25,00	194,7	202,0	—	167,8	136,5	152,4	204,4
NON-RECOMMENDED PRODUCT DIMENSIONS											
Full-hole style (FH)											
88,9 FH	V-0.040	5,08	5	25,0	94,8	101,4	—	77,6	95,2	111,1	102,8
101,6 FH	V-0.065	6,35	4	16,66	103,4	108,7	105,6	89,7	114,3	130,2	110,3
114,3 FH	V-0.040	5,08	5	25,00	115,1	121,7	—	96,3	101,6	117,5	123,8
139,7 FH	V-0.050	6,35	4	16,66	142,0	148,0	—	126,8	127,0	142,9	150,0
168,3 FH	V-0.050	6,35	4	16,66	165,6	171,5	—	150,4	127,0	142,9	173,8
Internal-flush style (IF)											
60,3 IF	V-0.065	6,35	4	16,66	67,8	73,1	69,8	60,4	76,2	92,1	74,6
73,0 IF	V-0.065	6,35	4	16,66	80,8	86,1	83,0	71,3	88,9	104,8	87,7
88,9 IF	V-0.065	6,35	4	16,66	96,7	102,0	98,8	85,1	101,6	117,5	103,6
101,6 IF	V-0.065	6,35	4	16,66	117,5	122,8	119,6	103,7	114,3	130,2	124,6
114,3 IF	V-0.065	6,35	4	16,66	128,1	133,4	130,4	114,3	114,3	130,2	134,9
139,7 IF	V-0.065	6,35	4	16,66	157,2	162,5	—	141,3	127,0	142,9	163,9

[1] The number of the connection in the numbered style (NC) is the quotient of the gauge diameter of the pin thread in millimetres (at gauge point) and 2,54 (or 10 times the gauge diameter in inches, rounded to two figures).

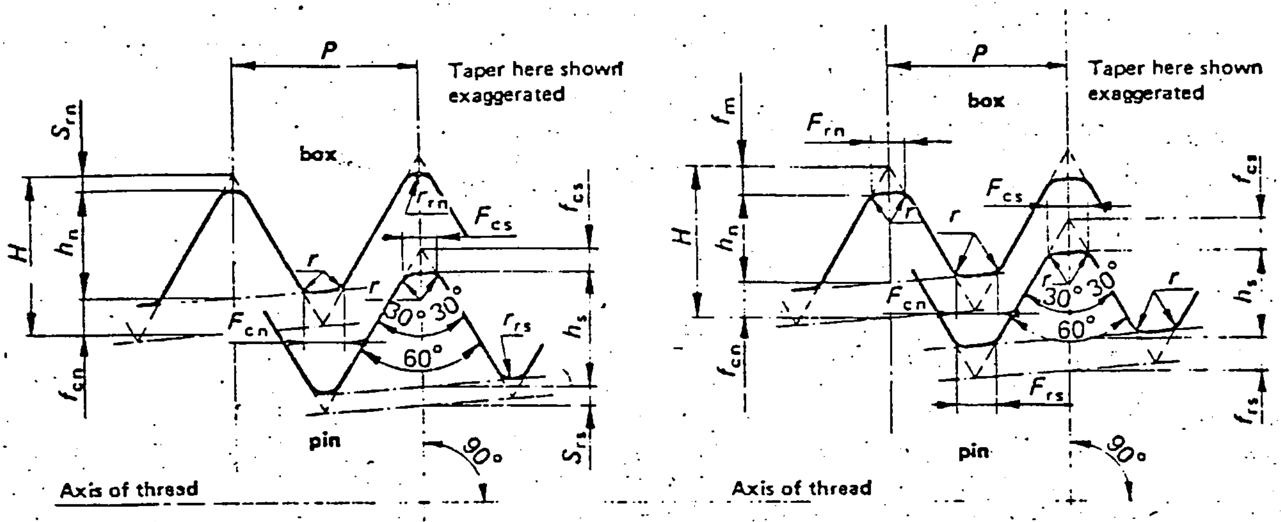
These connections, up to NC 50, are interchangeable with the connections having the same gauge diameter of the types FH and IF (see table 5).

[2] The diameter D_{LF} and the radius 1,6 mm (0.062 in) at the base of the pin (see figure 3) are obligatory for taper-threaded spigots and are at the discretion of the manufacturer for the other items of drilling equipment.

[3] The length of a complete female thread shall be not less than the maximum length of a male thread plus 3,2 mm.



a) V-0.038 R product thread form



b) V-0.040 and V-0.050 product thread form

c) V-0.065 product thread form

(Obsolescent – To be removed at a later date)

FIGURE 4 – Types of thread

TABLE 4 – Thread dimensions of connections, in millimetres

1	2		3	4	5	6	7	8	9	10
Form of thread	Taper		Thread height, not truncated	Thread height, truncated	Root truncation	Crest truncation	Width of flat		Root radius	Radius at thread corners
	% on *D*	inches per foot	H	$h_n = h_s$	$S_{rn} = S_{rs}$ $f_{rn} = f_{rs}$	$f_{cn} = f_{cs}$	Crest $F_{cn} = F_{cs}$	Root $F_{rn} = F_{rs}$	$r_{rn} = r_{rs}$	r
V-0.038 R	16,66	2	5,5	3,1	1,0	1,4	1,7	–	1,0	0,4
V-0.038 R	25,00	3	5,5	3,1	1,0	1,4	1,7	–	1,0	0,4
V-0.040	25,00	3	4,4	3,0	0,5	0,9	1,0	–	0,5	0,4
V-0.050	25,00	3	5,5	3,7	0,6	1,1	1,3	–	0,6	0,4
V-0.050	16,66	2	5,5	3,8	0,6	1,1	1,3	–	0,6	0,4
V-0.065	16,66	2	5,5	2,8	1,2	1,4	1,7	1,4	–	0,4

4.2.3 Tolerances

The following tolerances shall apply to the lead and taper of rotary shouldered connections, except when such connections are used on bits. The dimensions of other thread elements for rotary shouldered connections are given without tolerances and are not subject to inspection by direct measurement (see tables 3 and 4).

4.2.3.1 LEAD TOLERANCE

- On a short base :

equal to the number of complete threads "n" : ± 0,038 mm
(see column 3 of table 3)

- On total thread length L_T

between first and last complete thread : ± 0,114 mm

or, if this sum is greater than 0,114 mm, the sum of 1 µm per millimetre in the total thread length, i.e. : $\frac{L_T}{1\,000}$ mm

NOTE — The lead tolerance on a short base is the maximum allowable error for any distance within the thread number (see column 3 of table 3) over the total thread length.

4.2.3.2 TAPER TOLERANCE ON DIAMETER

Male (pin thread : $^{+\,0,25}_{\;\;0}$ %

Female (box) thread : $^{\;\;0}_{-\,0,25}$ %

Taper tolerances apply to the average taper within the total thread length.

4.2.3.3 TOLERANCE ON THREAD GAUGING DIAMETER (see column 5 of table 3)

The gauging diameter shall be checked by means of male and female thread gauges according to the procedure given in ISO . . .[1] which specifies the requirements for confirmation of the gauges.

4.3 Interchangeability of thread forms

The thread form for numbered rotary shouldered connections (V-0.038R) as shown in figure 4a), is interchangeable with the V-0.065 flat form shown in figure 4c). The V-0.038R form may be substituted, at the option of the manufacturer, for the V-0.065 flat form on any size of IF connections, or any 102 (4 in) FH connection.

4.4 Interchangeability of shouldered connections

Certain dimensions of numbered shouldered connections are interchangeable with connections of other styles of table 3. They differ only in the threading form, and since the forms are interchangeable, the connections are interchangeable. These interchangeable shouldered connections are shown in table 5.

TABLE 5 — Interchangeable shouldered connections

Numbered style connection	Equivalent connection of table 3
NC 26	60,3 IF (2 3/8 IF)
NC 31	73 IF (2 7/8 IF)
NC 38	88,9 IF (3 1/2 IF)
NC 40	101,6 FH (4 FH)
NC 46	101,6 IF (4 IF)
NC 50	114,3 IF (4 1/2 IF)

---

[1] In preparation.

5 TOOL JOINTS FOR DRILL PIPES OF DIAMETER < 60,3 mm

The following specifications applying to work strings are given for information only. The details concerning weld-on tool joint gauges, etc., are being developed.

5.1 Dimensions

See figure 5 and table 6.

5.2 Material requirements

The sub-clauses on steel (4.1.1),

treatment of threaded connection (4.1.3), and

mechanical tests (4.1.4)

can be guaranteed after agreement between the manufacturer and the purchaser.

5.3 Threads

Dimensions : See figure 6 and table 7.

5.4 "O"-ring

Dimensions : See figure 7 and table 8.

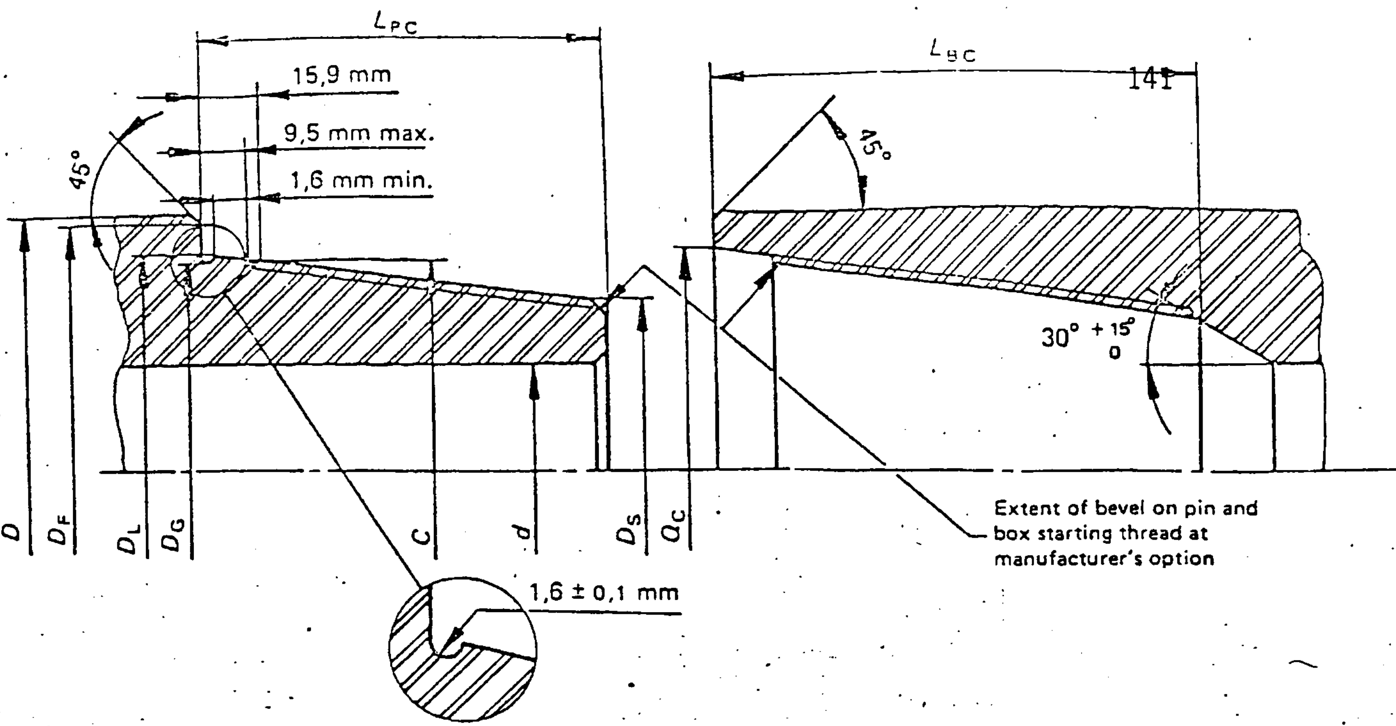
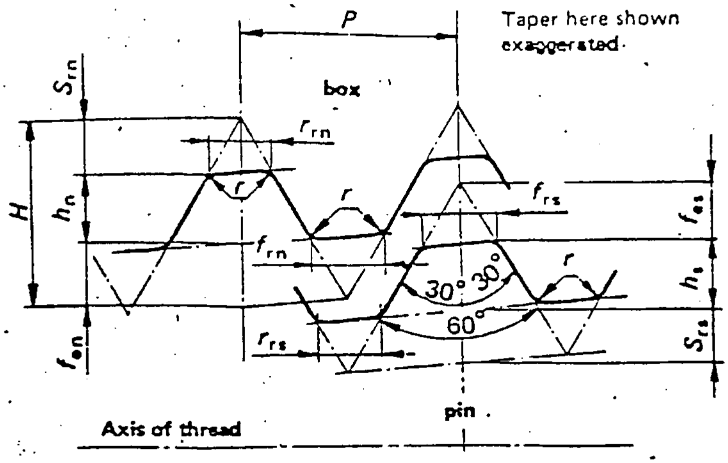


FIGURE 5 — Thread connection

TABLE 6 — Dimensions of joints, in millimetres

1	2	3	4	5	6	7	8	9	10	11
Connection No.	Outside diameter of pin and box D ± 0,25	Inside diameter of pin and box d + 0,13 − 0,25	Bevel diameter D_F ± 0,13	Gauge diameter of thread at gauging point C	Largest reference diameter of pin D_L	Diameter of "O"-ring groove D_G + 0,13 0	Smallest diameter of pin D_S	Length of pin L_{PC} 0 − 3,2	Profile of box L_{BC} + 9,5 0	Counterbore of box Q_C ± 0,13
NC 10	34,9	18,3	34,1	27,0	30,2	26,5	25,5	38,1	54,0	30,6
NC 12	41,3	23,0	39,7	32,1	35,4	31,6	29,8	44,4	60,3	35,7
NC 13	46,0	23,8	44,4	35,3	38,6	34,8	33,0	44,4	60,3	38,9
NC 16	54,0	25,4	52,4	40,9	44,1	40,4	38,5	44,4	60,3	44,5

NOTE — "O"-ring optional for high-pressure use. See table 8 for "O"-ring dimensions. The length of perfect threads in the box shall be not le than the maximum pin length (L_{PC}) plus 3,2 mm.



Taper here shown exaggerated.

FIGURE 6 – Thread form V-0.055

TABLE 7 – Dimensions of threads, in millimetres

1	2		3	4	5	6	7	8	9	10
Thread form	Taper		Pitch	Thread height, not truncated H	Thread height, truncated $h_n = h_s$	Root truncation $S_{rn} = S_{rs}$ $f_{rn} = f_{rs}$	Crest truncation $f_{en} = f_{es}$	Width of flat crest $f_{rn} = f_{rs}$	Width of root of flat thread $r_{rn} = r_{rs}$	Radius at thread corners r
	% on D	inches per foot								
V-0.055	12,5	1,5	4,23	3,7	1,4	1,0	1,2	1,4	1,2	0,4

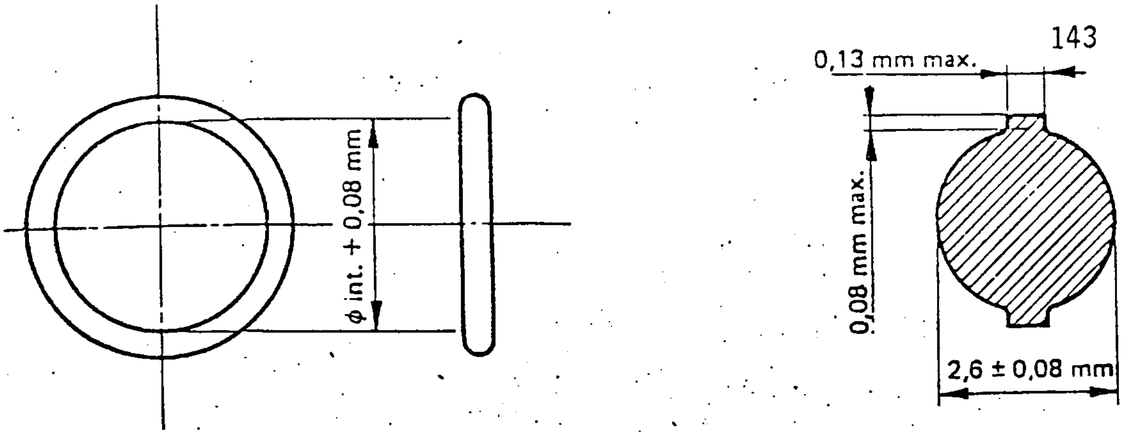


FIGURE 7 – "O"-Ring form

TABLE 8 – Dimensions of "O"-ring, in millimetres (see figure 7)

1	2	3
Connection No.	Internal diameter*	"O"-ring No.
NC 10	20,3	117
NC 12	25,1	120
NC 13	28,2	122
NC 16	31,4	124

* Dimension before installation.

NOTE – For general service, "O"-rings of 90 °C oil-resistant material are recommended. Where temperatures exceed 175 °C, "O"-rings made from heat-resistant material should be used.

6 MARKING OF TOOL JOINTS

The tool joints manufactured in conformity with this specification shall be die-stamped as follows :

6.1 On the outside cylindrical surface

- Manufacturer's mark or name.
- Nominal size and style of tool joint.
- "Numerical" equivalent nominal size, if available in table 1 and if the manufacturer has chosen thread V-0.038 R.
- Direction of thread if this is of left-hand type.

Examples :

a) An NC 38 tool joint which is interchangeable with an 88,9 (3 1/2 IF) joint shall be die-stamped

ABCO NC 38 – 3 1/2 IF
(or mark)

b) An 88,9 (3 1/2 IF) tool joint which is interchangeable with an NC 38 tool joint, if made with a V-0.038R thread form, shall be die-stamped as in example a) above.

c) An 88,9 (3 1/2 IF) tool joint made with a V-0.065 thread form shall be die-stamped

ABCO 3 1/2 IF
(or mark)

d) A 114,3 REG (4 1/2 REG) tool joint with a left-hand thread shall be die-stamped

ABCO 4 1/2 REG – LH
(or mark)

NOTE – LH is the abbreviation of "left-hand" and "helical" (bilingual).

6.2 On the connecting taper of the pin towards the seam

Optional : at the initiative of the purchaser :
useful length between shoulders, rounded off to the closest 0,5 cm.

Optional : date of manufacture of tool joints;
date of manufacture of drill pipes before welding;
date of welding of tool joints.

ANNEX

BASES FOR CALCULATING THE TOOL JOINT CHARACTERISTICS[1)]

(see tables 9 and 10)

A.1 LOAD AT MINIMUM YIELD STRESS

The maximum tensile strength R_m of tool joints is given, in newtons, by the formula :

$$R_m = R_c \times A$$

where

R_c is the minimum yield strength of the joint steel, in newtons per square millimetre;

A is the critical section of the pin of the tool joint, 16 mm from the shoulder, in square millimetres.

A.2 TORSION TORQUE FOR A SPECIFIC FRICTION FACTOR

The maximum torsion torque T of tool joints is given, in newton metres, by the formula :

$$T = R_c \times A \left[\frac{P}{2} + \frac{C_m \times f}{2 \cos \theta} + \frac{D_s \times f}{2} \right] \times 10^3$$

where

R_c is the minimum yield stress of the joint steel, in newtons per square millimetre;

A is the critical section of the tool joint equal to the smaller of the following two values :

A_1 : critical section of tool joint pin measured 19 mm from shoulder,

A_2 : critical section of tool joint box measured 9,5 mm from shoulder;

P is the thread pitch, in millimetres;

C_m is the minimum diameter of the thread, in millimetres, midway along the threaded length;

D_s is the average diameter, in millimetres, of shoulder namely $\frac{D + D_{LF}}{2}$

θ is the thread half-angle;

f is the coefficient of friction on mating faces of thread or shoulder = 0,08.

[1)] For the characteristics of the drill pipe, see ISO 2644 — annex.

TABLE 9 — Tool joints — Types, dimensions, characteristics (compared with grade E drill pipe)

Drill pipe							Tool joint					Mechanical properties							
Nominal diameter		Drill pipe mass per unit length		Drill pipe and tool joint mass per unit length		Type of upset	Type of connection	Outside diameter		Inside diameter		Load corresponding to pipe body proof stress				Torsion torque corresponding to pipe body proof stress			
												Tube		Joint		Tube		Joint	
mm	in	kg/m	lb/ft	kg/m	lb/ft			mm	in	mm	in	N	lbf	N	lbf	N·m	lbf·ft	N·m	lbf·ft
60,3	2.375	9,9	6.65	10,4	7.0	E.U.	NC 26	85,7	3.375	44,4	1.75	614 800	138 220	1 440 000	323 760	8 460	6 240	9 220	6 800
73,0	2.875	15,5	10.40	16,1	10.82	E.U.	NC 31	104,8	4.125	54,0	2.125	953 400	214 340	2 042 300	459 120	15 630	11 530	16 270	12 000
				16,7	11.20	I.U.	H	108,0	4.25	47,5	1.875			2 299 000	516 840			18 170	13 400
				15,4	10.37	I.U.	NC 26	85,7	3.375	44,4	1.750			1 440 200	323 760			9 220	6 800
88,9	3.500	14,1	9.50	15,3	10.25	E.U.	NC 38	120,7	4.750	76,2	3.000	864 100	194 260	1 931 900	434 400	19 140	14 120	18 170	13 400
		19,8	13.30	20,6	13.86	E.U.	NC 38	120,7	4.750	68,3	2.688	1 208 000	271 570	2 678 500	602 160	25 110	18 520	25 350	18 700
				20,9	14.06	I.U.	H	120,7	4.750	61,9	2.438			2 601 700	584 880			23 460	17 300
				20,1	13.51	I.U.	NC 31	104,8	4.125	54,0	2.125			2 042 300	459 120			16 270	12 000
		23,1	15.50	24,4	16.42	E.U.	NC 38	127,0	5	55,1	2.563	1 435 000	322 780	2 951 600	663 550	28 540	21 050	27 900	20 600
				27,21	18.35	E.U.	NC 40	139,7	5.500	57,2	2.25	1 465 420	322 780	4 062 670	994 861	28 540	21 150	45 070	33 240
101,6	4	20,8	14.0	22,5	15.13	I.U.	NC 40	133,4	5.250	71,4	2.812	1 269 300	285 360	3 235 800	727 440	31 520	23 250	32 540	24 000
				23,2	15.56	E.U.	NC 46	146,0	5.750	82,8	3.250			4 087 700	918 960			46 230	64 100
114,3	4.500	24,7	16.60	26,3	17.70	I.U.	F H	146,0	5.750	76,2	3	1 470 400	330 560	4 343 400	976 440	41 690	30 750	46 910	34 600
				26,2	17.64	E.U.	NC 50	155,6	6.125	95,3	3.750			4 265 000	958 800			51 390	37 900
				26,7	17.94	I.U.	NC 46	152,4	6	82,8	3.250			4 087 700	918 960			46 230	34 100
				24,8	16.66	I.U.	NC 38	127,0	5	68,3	2.688			2 676 900	601 800			25 350	18 700
		29,8	20.00	32,3	21.73	I.E.U.	NC 46	152,4	6	76,2	3	1 834 300	412 360	4 741 900	1 066 030	49 950	36 840	53 420	39 400
				32,3	21.73	I.E.U.	F H	152,4	6	76,2	3			4 342 000	976 130			46 910	34 600
				33,2	22.33	E.U.	NC 50	158,8	6.750	92,0	3.625			4 649 300	1 045 200			56 000	41 300
127,0	5	29,0	19.60	31,2	20.99	I.E.U.	NC 50	161,9	6.375	95,3	3.750	1 759 700	395 600	4 265 000	958 800	55 710	41 090	51 350	37 900
		38,1	25.6	40,4	27.17	I.E.U.	NC 50	165,1	6.500	88,9	3.500	2 358 200	530 140	5 021 900	1 128 960	70 720	52 160	60 470	44 600
				41,8	28.08	I.E.U.	F H	177,8	7.000	95,3	3.750			6 442 800	1 448 400			84 600	62 400
139,7	5.500	32,6	21.90	35,6	23.94	I.E.U.	F H	177,8	7	101,6	4	1 944 400	437 120	5 630 900	1 265 880	68 630	50 620	75 520	55 700
		36,8	24.70	34,0	26.66	I.E.U.	F H	177,8	7	101,6	4	2 211 700	497 200	5 630 900	1 265 880	76 560	55 470	75 520	55 700

✓

TABLE 10 — Tool joints — Types, dimensions characteristics (compared with grade N 56 drill pipe)

Drill pipe							Tool joint					Mechanical properties							
Nominal diameter		Drill pipe mass per unit length		Drill pipe and tool joint mass per unit length		Type of upset	Type of connection	Outside diameter		Inside diameter		Load corresponding to pipe body proof stress				Torsion torque corresponding to pipe body proof stress			
												Tube		Joint		Tube		Joint	
mm	in	kg/m	lb/ft	kg/m	lb/ft			mm	in	mm	in	N	lbf	N	lbf	N·m	lbf·ft	N·m	lbf·ft
26,7	1.050	2,31	1.55	2,58	1.73	I.E.U.	NC 10	34,93	1.375	18,26	0.719	157 450	34 680	194 800	42 900	890	656	550	413
33,4	1.315	3,43	2.30	3,78	2.30	I.E.U.	NC 12	41,28	1.625	23,01	0.906	222 100	48 920	252 400	55 600	1 620	1 198	830	615
42,2	1.660	4,90	3.29	5,37	3.61	I.E.U.	NC 13	46,02	1.812	23,80	0.937	330 300	72 750	363 300	80 020	3 110	2 193	1 320	975
48,3	1.900	6,24	4.19	6,93	4.66	I.E.U.	NC 16	54,0	2.125	25,4	1.000	420 050	95 520	576 400	126 950	4 560	3 364	2 410	1 780

EXPLANATORY REPORT FOR ISO/DIS 3962

ISO/TC 67

Secretariat IRS 147

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION·МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ·ORGANISATION INTERNATIONALE DE NORMALISATION

ISO/DIS 3962 - Materials and equipment for petroleum and natural gas industries - Tod joints for steel drill pipe for oil or natural gas wells

At the first meeting of Working Group ISO/TC 67/WG 3 "Study of items to be included in the programme of work" held in Bucarest from 19 to 21 April 1966 a new group ISO/TC 67/WG 5 was set up with the change of studying tubular products used as drill pipes, casing and tubing taking as a basis the API specifications 5 A, 5 AC and 5 AX (Resolution 3).

At a meeting held in Düsseldorf on 7 May 1969, the Working Group ISO/TC 67/WG 3, moreover, entrusted, WG 5 with working out a draft ISO Standard on tool-joints on the basis of sections 4 and 9 of API 7 (Resolution 9).

This question was placed into the programme of future work, at the 4th meeting held in Paris on 1 and 2 October 1970.

The Secretariat worked out this draft proposal which was examined and adopted taking account of the amendments decided during the 5th meeting on 16 and 17 September 1971 in Brussels.

According to Resolution 52, and as no answer has been received by the Secretariat following the supplementary enquiry realized among the P- and O-members of the Sub-Committee, we submit this document to the combined voting of the members of TC 67 and of all ISO Member Bodies as draft International Standard 3962.

PART B

Xtra Life®

TEXAS TECHNICAL ENTERPRISES, INC.

July 23, 1976

Mr. Rob Trimble, Jr.
c/o American Petroleum Institute
300 Corrigan Tower
Dallas, Texas 75201

Dear Rob:

With reference to the draft of International Standards No. 3962 sent to me on June 25, 1976, I offer the following comments:

1. Approve with corrections made as listed by A.P.I. members.

2. Table 1, Page 3 Corrections:

    a. Column no. 14 should be "Ratio of pin to <u>pipe</u> for torsion".

    b. NC38 (88.91.F.) omitted the data on E-75 drill pipe. See attached table 1.

    c. NC40 (101.6 I.F.) should be NC40 (101.6 F.H.)

    d. NC46 (101.61.F.) and 4-1/2 IF. - Column 7 reads 135.7 and should be 145.3 for all weights of drill pipe.

    e. 4-1/2 FH. on X95 and G-105, column 6 should be 76.2 and the ratios in column 14 should be .89 for X-95 and .81 for G-105.

    f. NC50 x 114.3EU x E-75, column 6 should be 92.1.

    g. 5-1/2 FH x 127 IEU x 29.0 data on E-75, X95, G105, and S135 has been omitted. See attached table no. 1.

    h. The attached Table 1 shows all the corrected dimensions and added data. They probably did not have the revised API Spec. 7, Thirteenth Edition, April 1975, and this caused most of the corrections.

i. Foot note no. 2. - "Masses per unit length, threads and tool joints" should be changed to "Masses per unit length, threads and couplings".

j. Foot note no. 6. - "(i.e. ratio of the pin torsion to the box torsion)" should be "(i.e. ratio of the pin torsion to the pipe torsion)".

3. Paragraph 4.1.1 Steel - Page 4
"Minimum yield strength of 90N/mm^2 (125,000 lb./in^2)" should be "Minimum yield strength of 86.4N/mm^2 (120,000 lb./in^2)".

4. Paragraph 4.1.4. Mechanical Tests, Page 5
Replace this paragraph with data from API Spec 7, April 1975 as follows:

TABLE 4.1
MECHANICAL PROPERTIES OF NEW TOOL JOINTS (all sizes)

1	2	3
Minimum Yield Strength, psi	Minimum Tensile Strength, psi	Minimum Elongation percent
120,000	140,000	13

NOTE 1. Mechanical properties shall be determined by tests on cylindrical tensile specimens conforming to the requirements of ASTM A370, 0.2% offset method.

NOTE 2. Specimens shall be taken from the location shown in Fig. 4.1. The entire gage length of the specimen must be within the tapered portion of the pin connections, and the midlength of the gage length shall be 1¼ inches from the pin shoulder. Specimens shall be taken longitudinally and parallel with the axis of the tool joint.

NOTE 3. If the pin section at the specified location is not sufficient to secure a tensile specimen of 0.250 inch diameter (1.00 inch gage length) or larger, a minimum Brinell hardness number of 285 shall be prima facie evidence of satisfactory mechanical properties. The hardness test shall be made at midsection of the pin connection at a distance of 1 inch to 1¼ inches from the pin shoulder.

Note 4. Tensile testing is not necessary or practical on box connections. A minimum Brinell hardness number of 285 shall be prima facie evidence of satisfactory mechanical properties. The hardness test shall be made at midsection of the box connection at a distance of 1 inch to 1¼ inches from the box shoulder.

4.2 Mechanical Properties. The mechanical properties of tool joints, as manufactured, shall not be lower than the minimum values shown in Table 4.1.

When it is necessary to make destructive tests to determine mechanical properties on finished joints, the test specimens shall be obtained from location listed in Note 2 of Table 4.1 and shown in Fig. 4.1.

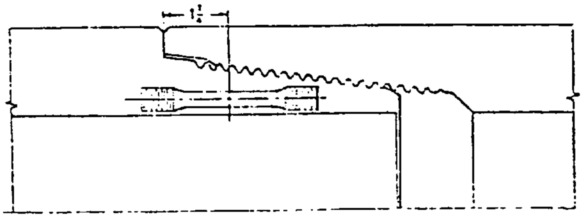


FIG. 4.1
TENSILE SPECIMEN LOCATIONS

5. Figure 3, Page 6
   12.7mm max. - Add "To Perfect Thread"
   15.88mm - Omit this dimension as it is determined by the DLF Diameter.
   The Qc counterbore is not shown correctly. The counterbore is slightly larger than the major diameter of the thread.

6. Paragraph 5. Tool joints for drill pipe of diameter less than 60.3mm.

   I recommend that pages 10, 11, 12 and 13 be removed from I.SO./DIS 3962. These connections are listed as tentative in API Spec. 7, and we do not have API Reference Gages. Very few of these connections are used at this time. Also Table 10 on page 16 should be removed from the book.

7. Table 9 on page 16 has a few minor corrections that have been made in the A.P.I. RP7G, Seventh Edition, April 1976. This table was completely redrawn to make all corrections.

I hope these comments will be of help. Other members are being sent copies, so that if they find errors in my charts, they can call them out.

Sincerely yours,

TEXAS TECHNICAL ENTERPRISES, INC.

G. J. Gilbert

G. J. Gilbert

GJG/pag

cc: Messrs. Sam Loy III
A. Gooch
Tom Smith
Wendel Dixon ✓
Harry Mauzy

Enclosed: Table 1 (2 sheets)
Table 9

1	2	3	4	5	6	7	8	9	10	11	12	13
Designation of T. Joint	Dimension and Style	Mass per Unit Length of Drill Pipe kg/m	Grade	O.D. D ±	I.D. d ±	Diam. DF ±	Total Length of T.J. Lp ±	Place for Stamp on Pin LPB ±	Place for Stamp on Box LB ±	Combined Length of Pin & Box L ±	DPE	DTE
4½ FH	114.3 I.U.	29.8	E75	152.4	76.2	145.3	279.4	177.8	254.0	431.8	119.1	119.
			E95	152.4	63.5	145.3	279.4	177.8	254.0	431.8	119.1	119.
			G105	152.4	63.5	145.3	279.4	177.8	254.0	431.8	119.1	119.
NC50(4½IF)	114.3EU	24.7	E75	161.9	95.3	150.4	292.1	177.8	254.0	431.8	127	127
			X95	161.9	95.3	150.4	292.1	177.8	254.0	431.8	127	127
			G105	161.9	95.3	150.4	292.1	177.8	254.0	431.8	127	127
			S135	161.9	88.9	150.4	292.1	177.8	254.0	431.8	127	127
	114.3EU	27.8	E75	161.9	92.1	150.4	292.1	177.8	254.0	431.8	127.	127.
			X95	161.9	88.9	150.4	292.1	177.8	254.0	431.8	127.	127.
			G-105	161.9	88.9	150.4	292.1	177.8	254.0	431.8	127.	127.
			S-135	168.3	76.2	150.4	292.1	177.8	254.0	431.8	127.	127
	127 I.E.U	29.0	E75	161.9	95.3	150.4	292.1	177.8	254.0	431.8	130.2	130.
			X95	161.9	88.9	150.4	292.1	177.8	254.0	431.8	130.2	130
			G105	165.1	82.6	150.4	292.1	177.8	254.0	431.8	130.2	130.
			S135	168.3	69.9	150.4	292.1	177.8	254.0	431.8	130.2	130.
	127 IEU	38.1	E75	161.9	88.9	150.4	292.1	177.8	254.0	431.8	130.2	130.
			X95	165.1	76.2	150.4	292.1	177.8	254.0	431.8	130.2	130.
			G-105	168.3	69.9	150.4	292.1	177.8	254.0	431.8	130.2	130.
5½ FH	127 IEU	29.0	E75	177.8	95.3	170.7	330.2	203.2	254.0	457.2	130.2	130.
			X95	177.8	95.3	170.7	330.2	203.2	254.0	457.2	130.2	130.
			G105	177.8	95.3	170.7	330.2	203.2	254.0	457.2	130.2	130.
			S135	184.2	88.9	170.7	330.2	203.2	254.0	457.2	130.2	130.
	127 IEU	38.1	E75	177.8	88.9	170.7	330.2	203.2	254.0	457.2	130.2	130
			X95	177.8	88.9	170.7	330.2	203.2	254.0	457.2	130.2	130.
			G105	184.2	88.9	170.7	330.2	203.2	254.0	457.2	130.2	130
			S135	184.2	82.3	170.7	330.2	203.2	254.0	457.2	130.2	130.
	139.7 IEU	32.6	E75	177.8	101.6	170.7	330.2	203.2	254.0	457.2	144.5	144.
			X95	177.8	95.3	170.7	330.2	203.2	254.0	457.2	144.5	144
			G105	184.2	88.9	170.7	330.2	203.2	254.0	457.2	144.5	144.
			S135	190.5	76.2	180.2	330.2	203.2	254.0	457.2	144.5	144.
	139.7 IEU	36.8	E75	177.8	101.6	170.7	330.2	203.2	254.0	457.2	144.5	144.
			X95	184.2	88.9	170.7	336.2	203.2	254.0	457.2	144.5	144.
			G105	184.2	88.9	170.7	330.2	203.2	254.0	457.2	144.5	144
			S135	190.5	76.2	180.2	330.2	203.2	254.0	457.2	144.5	144.

7-6-76

TABLE 11 – TOOL JOINTS – TYPES DIMENSIONS, CHARACTERISTICS – [illegible] DRILLING

DRILL PIPE							TOOL JOINT					LOAD				TORQUE			
Nom. Diam.		Drill Pipe Weight		Drill Pipe and Tool Joint Wt.		Type	Type	Outside Diam.		Inside Diam.		Tube		Joint		Tube		Joint	
mm	In.	Kg/m	LB/FT.	Kg/m	LB/FT.	Upset	Connection	mm	In.	mm	In.	N	LB.	N	LB	N·m	LB-FT.	N·m	LB-FT.
60.3	2.375	9.9	6.65	10.4	7.00	EU	NC26(IF)	85.7	3 3/8	44.5	1 3/4	614800	138220	1395300	313680	8475	6250	9220	6800
73.0	2.875	15.5	10.40	16.1	10.82	EU	NC31(IF)	104.8	4 1/8	54.0	2 1/8	953433	214370	1788900	447130	15660	11550	16000	11800
"	2.875	"	10.40	16.7	11.20	IU	XH	108.0	4 1/4	47.6	1 7/8	"	214340	2246700	505080	15660	11550	18170	13400
"	2.875	"	10.40	15.4	10.37	IU	NC26(SH)	85.7	3 3/8	44.5	1 3/4	"	214340	1395300	313680	"	11550	9220	6800
88.9	3.500	14.1	9.50	15.3	10.25	EU	NC38(WO)	120.7	4 3/4	76.2	3	864100	194270	1867400	419800	19155	14150	17355	12800
"	3.500	19.8	13.30	20.6	13.86	EU	NC38(IF)	"	4 3/4	68.3	2 11/16	1208000	271570	2612500	587310	25150	18550	24540	18100
"	3.500	"	13.30	20.9	14.06	IU	XH	"	4 3/4	61.9	2 7/16	"	271570	2539700	570940	"	18550	23185	17100
"	3.500	"	13.30	20.1	13.51	IU	NC31(SH)	104.8	4 1/8	54.0	2 1/8	"	271570	1988900	447130	"	18550	16000	11800
"	3.500	23.1	15.50	24.4	16.42	EU	NC38(IF)	127.0	5	65.1	2 9/16	1435300	322780	2837600	649160	28595	21090	27525	20300
101.6	4.000	20.8	14.00	23.8	15.98	EU	NC46(IF)	152.4	6	82.6	3 1/4	1269300	285360	4008600	901160	31580	23290	45555	33600
"	4.000	"	14.00	22.5	15.13	IU	NC40(FH)	133.4	5 1/4	71.5	2 13/16	"	285360	3165400	711610	31580	23290	31860	23500
114.3	4.500	24.7	16.60	26.9	18.10	EU	NC50(IF)	161.9	6 3/8	95.3	3 3/4	1470400	330560	4199100	944000	41775	30810	51115	37700
"	4.500	"	16.60	27.4	18.40	IU	NC46(XH)	158.9	6 1/4	82.6	3 1/4	"	"	4008600	901170	"	"	45960	33900
"	4.500	"	16.60	27.0	18.13	IU	FH	152.4	6	76.2	3	"	"	4342200	976160	"	"	47180	34800
"	4.500	"	16.60	24.8	16.66	IU	NC38(S.H)	127.0	5	68.3	2 11/16	"	"	2612500	587310	"	"	24570	18120
"	4.500	29.8	20.00	33.5	22.50	EU	NC50(IF)	161.9	6 3/8	92.1	3 5/8	1834300	412360	4585600	1030820	50030	36900	55860	41200
"	4.500	"	20.00	33.0	22.18	IEU	NC46(XH)	158.9	6 1/4	76.2	3	"	"	4663600	1048450	"	"	53690	39600
"	4.500	"	20.00	32.3	21.73	IEU	FH	152.4	6	76.2	3	"	"	4342200	976160	"	"	47180	34800
127.0	5.000	29.0	19.50	31.2	20.99	IEU	NC50(XH)	161.9	6 3/8	95.3	3 3/4	1759700	395560	4199100	943990	55820	41170	51115	37700
"	5.000	38.1	25.60	40.2	27.01	IEU	NC50(XH)	"	6 3/8	88.9	3 1/2	2358100	530150	4938600	1110240	70855	52260	60875	44900
"	5.000	"	25.60	42.4	28.50	IEU	5 1/2 FH	177.8	7	"	3 1/2	"	"	7202900	1619280	"	"	84330	62200
139.7	5 1/2	32.6	21.90	35.6	23.94	IEU	FH	"	7	101.6	4	1944900	437120	5630400	1265760	68755	50710	76300	56300
"	5 1/2	36.8	24.70	39.9	26.86	IEU	FH	"	7	"	4	2211700	497220	"	"	76700	56570	"	"

APPENDIX G - METRICATION PROGRAM AT EXXON RESEARCH AND ENGINEERING CORP.

Metrication at Exxon Research and Engineering Company

By Marvin B. Glaser
Manager,
Mechanical Division

At the ANMC Conference,
April 5–7, 1976
Washington, D.C.

Metrication at Exxon Research and Engineering Company

There is a close parallel between metrication in the Exxon Corporation and what has been occuring in the U.S. in recent years. Basically, conversion started in segments—or affiliates—of Exxon Corporation and in sectors of U.S. industry well ahead of an official corporate or national policy. For example, in July, 1975, Exxon Corporation's Management Committee issued a metrication policy which included the following statements:

1. "Exxon Corporation considers worldwide standardization of measurement to be in the best interest of all nations and, therefore, supports the trend toward universal adoption of the SI metric system of measurement and the metrication activities in those countries officially embarked upon conversion processes."
2. "Exxon Corporation will change to the SI metric system of measurement in operations, engineering, reporting and accounting in a stepwise and orderly manner, taking into account the pace of change within the major nations in which corporation interests are represented."

Just as the December, '76 U.S. metric bill provided the "icing on the cake", our corporate policy statement actually put the final coordinative aspects on what had been occurring in many separate Exxon affiliates for some time.

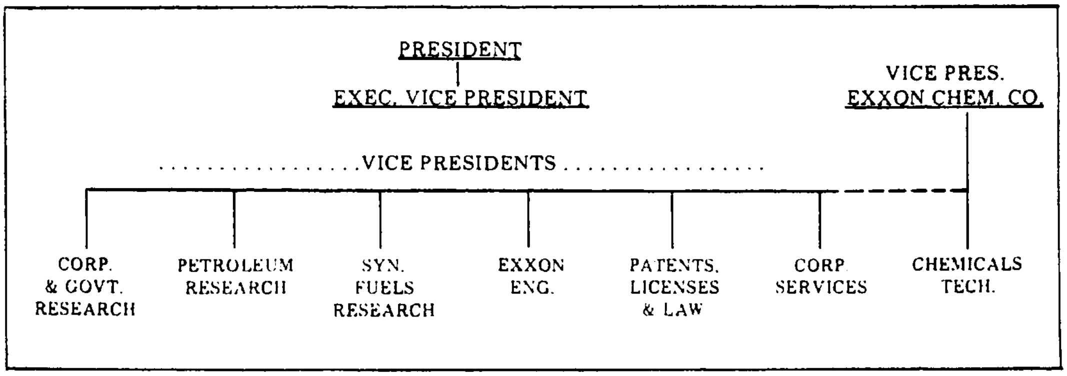
I am going to describe how one of these affiliates, Exxon Research and Engineering Company, has been managing its conversion -- a process which started there in 1972.

Because of our unique role within the parent corporation, metrication at Exxon Research and Engineering Company does provide a case study having the flavor of international corporate policies and problems on the subject. Our prime function is to provide the research, development, engineering and technical services support on processes and products for appropriate Exxon Corporation affiliates who operate in over 100 countries. Obviously, we must be prepared to meet their individual metrication needs. An additional function is the sale of Exxon technology through licensing to non-affiliated domestic and foreign companies. Thus, we must also be ready to work with organizations which may be following other metrication policies and timetables.

To understand the efforts we have undertaken, it is necessary to understand how Exxon Research and Engineering Company is structured. (Figure 1) Basically, the functional areas shown on this figure follow product lines, and each is funded predominently by the affiliates it supports. The Corporate and Government Research vice-presidential area is comprised mainly of pioneering research in new technology areas. They also undertake research under Government contracts from such agencies as the Energy Research and Development Agency, the Department of Defense, and the Environmental Protection Agency.

FIGURE 1

EXXON RESEARCH & ENGINEERING CO.
ORGANIZATION STRUCTURE



The Petroleum Research area covers process and product development work in fuels and lubricants. It is in this area that processes such as fluid cat cracking was developed.

Synthetic Fuels Research includes work towards utilizing coal, shale oil, and tar sands as alternate sources of petroleum products.

Exxon Engineering is responsible for our commerical scale technology and know-how. This area provides planning, designs, estimates, contract coordination, project management and startup assistance for Exxon affiliates worldwide.

Patents, Licenses and Law requires no further explanation, and Corporate Services is the centralized support area for our organization including such functions as pilot plant and laboratory equipment design, analytical support, site operation and maintenanace, financial and employee relations.

Lastly, Exxon Chemicals Technology is actually part of a separate affiliate, Exxon Chemical Co., but, because of its similar research and development, Chemicals Technology works closely with Exxon Research and Engineering Company in many of the same locations. Hence, the dotted line relationship.

To give you a feel for the size of our organization, ER&E and Chemical Technology employ about 3200 personnel split roughly equally between professionals and supporting skills such as technicians, mechanics, and office services. Of these, about 2600 are located in New Jersey at our Linden and Florham Park sites, while about 300 each are located in Baton Rouge, Louisiana, and the Houston, Texas area. Our typical annual operating costs for the two organizations are approximately 200 million dollars.

Based on inputs from the various functional areas, ER&E's Management Council concluded in late 1972 that it was time for us to prepare for conversion to the SI Metric System. This conclusion was based on the fact that we must be in a position to provide metric designs and data by 1978 if we are to continue doing business effectively overseas. Over half of the ER&E and Chemicals Technology research and engineering programs are in support of overseas affiliates, and most of these customers had already converted, or were in the process of converting to the SI Metric System. In fact, some overseas countries, in particular the common market countries, will legally require trade in SI metric terms by 1978.

An ER&E Corporate Metrication Committee was created in early 1973 consisting of representatives from each functional vice-presidential area plus Chemicals Technology. This committee was initially charged with the following responsibilities: to identify specifically what metrication efforts need be undertaken, and, of course, the corollary, what need not be done; to recommend a realistic timetable for the conversion; to estimate the total cost of the metrication program; and, lastly, to recommend the means by which these costs should be financed.

In meeting these objectives, the committee established the following guiding principles. These are not necessarily listed in order of importance.

First, our metrication program must be tailored to meet Exxon Engineering's needs; that is, the research divisions must be in a position to provide data in metric units in time for Exxon Engineering to be able to produce metric designs when needed.

Secondly, our program must be responsive to national legislation.

Next, our program must be responsive to the plans of technical societies and standards setting organizations. Beyond this, it has been our practice to actively participate in metrication activities in these organizations.

Next, our program must be responsive to the needs of the affiliates. Since, as you have seen, we exist almost solely for their benefit, this guideline is a parallel to our research and development philosophy.

Our program should also be timed consistent with the plans of key suppliers and related industries. In this area, we are meeting with only moderate success because many suppliers have not yet faced the problem. On the other hand, because our products are primarily designs and data, a large portion of our efforts only involve "soft conversion".

Finally, no program can proceed without an effort to minimize costs. Our approach, as it applies to our metrication program, can be summed up simply, "Let's not do unnecessary work". Specifically, this means converting long life equipment such as machine shop lathes only on a normal replacement basis where possible; it means converting only those pilot plants and lab apparatus which will continue to be used after the need for metric data has become prevalent; it means purchasing and constructing new equipment to be capable of producing metric data as soon as possible so that it need not be converted later; and it means converting manuals, specifications, data books, and the like at a time when normal revisions are scheduled.

The ER&E Corporate Metrication Committee issued its proposal report in the fall of 1973 covering their recommendations concerning the what, when, how much, and who should finance the effort questions consistent with the specified guiding principles. The proposal was quickly approved and the committee was given further responsibility of monitoring the conversion.

As far as costs, the committee estimated direct metrication costs to be $830,000 for the research divisions, including Chemicals Technology, and $1,900,000 for Exxon Engineering. So the answer to the how much question totalled about 2 ¾ million dollars. Considering the size of our business, this is certainly low enough to dispel the myth that conversion to metric is enormously expensive. For the research divisions, this funding was to cover converting data readout equipment for that laboratory, pilot plant and analytical equipment which met the guidelines, the conversion of our internal standards and manuals, plus formal training. For Exxon Engineering, the funding was targeted primarily for converting our engineering design practices, our petroleum and chemicals data books, the cost estimating manuals, and a multitude of computer programs. Examples of these are shown in our booth in the Exhibit Hall.

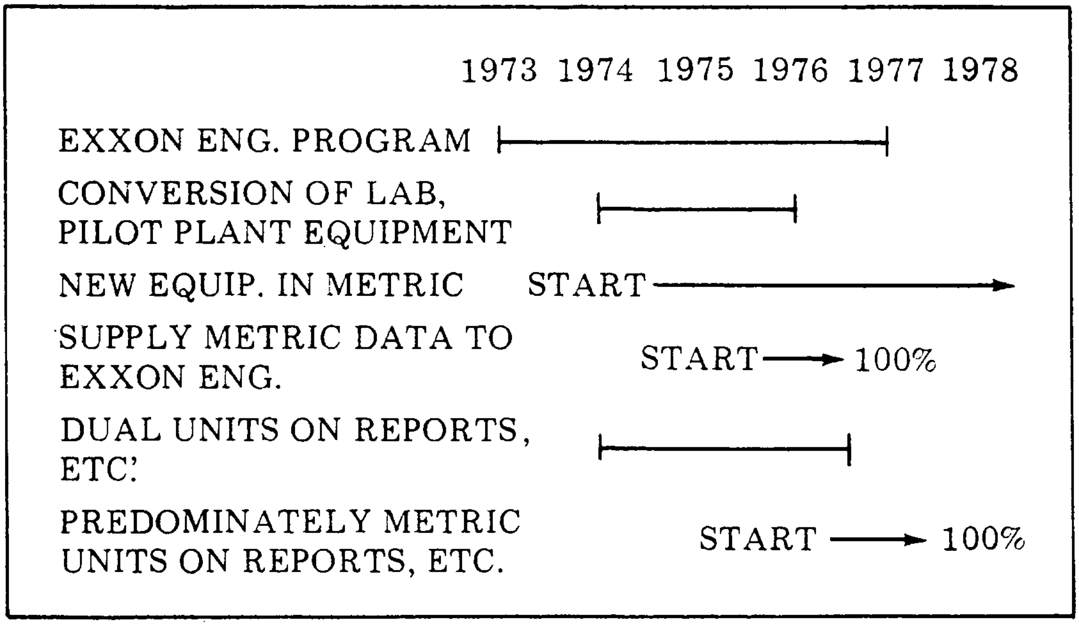
The committee also determined that the best way to manage the conversion was to handle it as a normal business function through normal line management channels. Therefore, each vice president communicated the overall metric policy and plans through line management and each division incorporated these plans as part of their annual goals. It also means each division retaining cost account-ability for its own metrication efforts, thus, in effect, answering the question of how the program should be financed.

As I've mentioned before, the committee formalized the policy of active participation in the standards setting organizations such as API, ASTM, ANSI and key technical societies.

Figure 2 shows the metrication schedule prepared by the committee in answer to the question when. The Exxon Engineering conversion was to begin as soon as the program was approved in 1973 and be completed by late 1977. Conversion of our laboratory and pilot plant equipment was to start as early as possible in 1974 and be finished by mid-1976. Purchase and construction of new equipment with metric readout capabilities was to begin in 1974. These first three time-

FIGURE 2

EXXON RESEARCH AND ENGINEERING COMPANY
ORIGINAL CONVERSION SCHEDULE



tables were set in order that we be able to begin supplying Exxon Engineering with metric data by late 1975 with a full metric data capability by the end of 1976. For reports and documents, etc., the schedule called for dual units beginning in 1974 and lasting through the end of 1976 and a gradual transition to fully metric reports beginning in 1976.

So far I have presented the history of our metrication program, the reasons why it got started, the program objectives and guiding principles, and our answers to the questions: What needs to be done, When should we do it, What will it cost, and, How should it be financed? I'd like now to turn to our progress; and I'll begin with Exxon Engineering.

Engineering's program is proceeding according to the plan adopted in 1973, but the overall schedule has slipped somewhat because of:

1. The delay in adoption of a national metric policy resulted in only moderate progress in development of national SI metric standards.
2. The need to maintain both English and metric versions of our design tools for domestic affiliates.

Hopefully, the recent signing into law of metric legislation should expedite actions by government, industry, trade, etc.

for developing SI metric standards. Overall, Engineering still anticipates meeting the original goal of turning out design specifications engineered in metric units by 1977 where required. The requirement of also furnishing design specifications in English units will remain for several years beyond our original target for phasing this out because the conversion timetables for some constractors and some Exxon affiliates are somewhat longer than we originally projected.

Specifically, the status of the conversion of our various design tools is as follows:

- The metric versions of our petroleum and chemical data books (which fill three large volumes) was completed and these were issued in 1975.
- Our engineering design practices, which are comprised of five volumes of design procedures and proven know-how, are, at this point, about 60% complete. We hope to issue these about 95% complete by late 1976.
- Basic Practices comprise several volumes of standard contractor specifications. Because most of the contractors are not yet prepared to work in SI units, the BP's are being metricated in stages and in dual units. Initially, metric units are simply being shown in parenthesis after the English units. Later the unit positions will be reversed, and finally, the English units will be omitted. This effort is presently about 50% complete. We hope to be at 80% completion by late this year.
- Conversion of the cost estimating manuals started in mid-1975. The schedule calls for completion of an English/metric version by mid-1977.
- Revising the various computer programs is in progress. The procedures being followed is to devise input/output conversion decks while leaving the basic program in English units until a major revision might be required. This is a good example of applied cost minimization.
- The program in our laboratories and pilot plants is also proceeding quite well. We are presently about 60% complete and expect to be wrapped-up on budget by mid-1976. While this program involves replacing literally thousands of dials, scales and gages, the effort has been kept manageable by limiting the facilities being converted to those having long-term use, and by converting ing only that hardware necessary to permit direct metric data read-outs. Both of these limitations are consistent

with the committee guiding principles. Examples of some of the hardware being converted will be shown on a later slide.

We have not been without our problems, however, and I thought you might be interested in the resultant developments and decisions that have come out of some of these problems.

As you know, the pascal is the SI unit of pressure, and, in late 1973, when we began to develop sources of metric components, we could not find an industrial gage manufacturer who could offer a line of pascal pressure gages. Most gage manufacturers had not yet begun to face the problem; those who had were offering kilograms force per square centimeter. Unfortunately, SI reserves the kilogram as a unit of mass, and, since we are proceeding on the basis that literal SI or something very close to it will eventually prevail, this was unacceptable. We were finally able to convince a major gage manufacturer that the decision to metricate was indeed a decision whose time had come, and nine months later the first pascal gages began to trickle into our stockroom.

Another difficulty we've encountered has been long deliveries on special range change parts for older equipment; in particular, weigh scales and temperature recorders. Many of these pieces are obsolete and parts are not available; in other cases, metric scales and dials simply were never available. The usual supplier response in these circumstances has been to offer to sell us new equipment, but considering the quantities involved, this has not been economically feasible. Fortunately, most suppliers have been willing to provide the parts if we wait long enough. And so we established the surveyor approach. A piping man and an instrument man have been designated to survey each area to be converted and list the parts required well in advance of the scheduled conversion date. This has worked fairly well, and we have found that about a three-month lead time is sufficient for the vast majority of parts needed.

Scheduling the available manpower to convert equipment at a time most convenient to the users needs is also never straightforward. In particular, operating pilot plants cannot be shut down just for changing dials, scales and gages. Also, manpower leveling must be considered. Effective coordination between the research area metric program and the support services personnel who physically make the changes was critical in doing this efficiently.

Finally, I thought you might be interested in our decision on the controversy of whether to convert dials and scales to read-out strictly in SI units or to provide dual unit capability with the English units retained. We have chosen to eliminate the English units entirely. The basis for this decision was the belief that the only way for users to get the feel for unfamiliar SI units is to use them, and that if English readings were still available, the SI readings would be ignored. So far, this belief has been substantiated. The disgruntled people seem to be those whose equipment has not yet been converted; those whose conversion work is completed are proceeding without difficulty. In other words, the anticipation has been worse than the fact.

Our new standard pascal pressure gages are now stocked in ranges from 100 kPa to 70 MPa, that is 15 psig to 10,000 psig, in both 2 ½" face brass and 4 ½" face stainless. The crossover from kPa to MPa occurs at 10,000 kPa. One point is noteworthy—that is the ranges seem to be oddly selected. The reason is that these are nothing more than psi gages with new dials and a minor calibration adjustment. This approach has two advantages: first, the numerical values are totally different than standard psi ranges and thus there is less likelihood for confusion; and second, relatively expensive stainless gages can be shipped back to the supplier and be converted at a small fraction of the cost of a new gage.

A simplified list of typical read-out equipment being converted is shown in Figure 3. Most of these are self-explana-

FIGURE 3

EXXON RESEARCH AND ENGINEERING COMPANY
EQUIPMENT BEING CONVERTED

1. PRESSURE GAGES (PSI TO kPa OR MPa)
2. DIAL THERMOMETERS (°F TO °C)
3. WEIGH SCALES (LBS TO kg)
4. TEMP. INDICATORS & RECORDERS (°F TO °C)
5. TEMP. CONTROLLERS (°F TO °C)
6. GAS METERS (FT^3/MIN TO LITERS/MINUTE)
7. PLUS REPLOT OF RANDOM SCALE CALIBRATIONS

tory. Note that we have accepted liters for cubic feet even though liters is only considered a temporarily acceptable SI unit. Dials with the literal SI volume unit, cubic decimeters, are simply not available. The last item in this figure covers an area where effort must be expended even though no hardware change is involved. An example would be replotting a tank gage glass calibration in cubic decimeters per centimeter instead of gallons per inch. In estimating metrication costs, one must be careful not to overlook work of this nature.

Shifting over to the use of dual units for correspondence reports, and manuals has also been progressing. The Technology Sales people within the functional areas have been using dual units since 1974, and reports regarding new pilot plants and those converted to date are also in dual units. Engineering Research and Development reports started issuing in dual units in the spring of 1975. In addition, some Government contract reports cite dual units although in this area, it is also common to leave the text in English units and append a simplified conversion table.

Of our in-house manuals, the rotameter manual, piping and electrical standards manual and pressure vessel procedures manual were converted in 1975. Our safety handbook for laboratory and pilot plant operations has just issued in dual units. Figure 4 illustrates a typical rotameter manual table with flow capacities in proper SI units, but keeping English units where they had existed before. You will notice that while seconds is the preferred unit of time, we have used minutes and hours for flow rates when we judge these to be more practical.

FIGURE 4

TYPICAL ROTOMETER MANUAL TABLE

TUBE		FLOAT		FLOW CAPACITY			
				H_2O	AIR @ STP		
Size	Taper Dt/Df	Size	Material	cm^3/min	dm^3/h	CFH	Stock Number of FLOWRATOR
1/16	13	1/16	Blk Glass	.1–1.3	.28–4.8	.01–.17	GA–2500
1/8	09	1/8	Blk Glass	.4–7.0	1.4 –25.5	.05–.9	GA–2510
1/4	09	1/4	Blk Glass	4–70	14.2 –212	.5 –7.5	GA–2520
1/4	37	1/4	Blk Glass	50–550	113–1303	4 –46	GA–2530
1/4	37	1/4	Carbaloy	200–1900	283–3540	10 –125	GA–2540

The formal aspects of training are well under way. An SI metric manual was prepared and distributed to all employees in the fall of 1974. In this were included background material with listings and definitions of acceptable units, detailed conversion tables, and a number of handy-dandy conversion charts including such items as psi to kPa and MPa, inches to mm including drill sizes, gallons to dm^3, ^oF. to ^oC. and the metric dimensions of pipe sizes and screw threads. We even included such things as a clothing size chart. This manual has been enthusiastically received and we have been besieged with requests for extra copies for employee's children to take to school. Affiliates have also asked for copies to help them prepare their conversion plans.

We also conducted a familiarization or orientation program for all employees in the fall of 1974 and spring of 1975. These sessions covered the historical background of the metric system and the reasoning behind our decision to convert at this time, followed by a detailed explanation of the SI metric system itself. In particular, style and usage were emphasized, because its symbols for SI units and the conventions which govern their use must be strictly followed if we are to avoid potentially significant errors. We closed these sessions on a positive note by pointingout that the SI system will simplify their calculations and dramatically reduce the number of units with which one has to be familiar.

Reaction to these sessions was mixed. I wish I had a nickel for each time I've heard someone say, "Don't bother me with new units, I'll retire before they become commonplace." How wrong they would appear to be! In general, however, most people accepted the need for changing over, and quite a few applauded the decision to proceed now.

Additional training beyond these sessions have or are being developed independently by each line division to suit their specific needs. For example, we have just completed a short course for our Designers and Machinists to cover metric tolerances, screw thread designations, and related practices. To an extent, some divisions have added a touch of Madison Avenue by conducting poster or slogan campaigns, and one division is even publishing a monthly metric newsletter. As you might imagine, these divisions are the ones whose affiliate customers are already using the metric system.

By-and-large, it has not been our practice to devote a lot of effort towards advertising gimickry, but rather to get on with the business of converting our paperwork and data hardware as rapidly as possible. Once again, this is based on the belief that the best way to get the feel for SI units is to use them.

We have found a programmed course to be of some help in developing a feel for SI units, and have made it available to all employees on a voluntary basis.

At this point, I have reviewed our progress in converting the books and computer programs in the Exxon Engineering area, the laboratory and pilot plant data read-out equipment, documents and reports, and training. I'd like now to wrap up my presentation by reviewing the status of the metrication program in each of vice-presidential areas.

The activities of the divisions in the Chemicals Technology area vary from product line to product line. In general, product lines that have substantial foreign applications are converting rapidly—product lines with mainly domestic sales are lagging.

Within the Petroleum area, most divisions are on schedule and are committed to meeting Exxon Engineering needs so that we can be in a position to provide metric designs and data by late 1977. At present, Petroleum Product Specifications Analytical Methods and bulletins, etc., are being issued in dual units to handle both U.S. and foreign needs.

The Synthetic Fuels area has not developed a definitive metrication program yet. Since this will be primarily a domestic industry there is less incentive to do any conversion at this time.

This main effort under way in the Patents, Licenses, and Technology Sales area is the determination of necessary metric equivalents of licensing parameters to replace conventional units such as barrels per day. Considering the millions of barrels of crude produced, shipped and processed each year, I think you can readily appreciate the impact of even a fraction of a penny in rounding off the price per cubic meter converted from per barrel. I really don't know how this is going to be resolved.

Lastly, the Corporate and Government Research Areas are busily converting their laboratory and pilot plant equipment for metric read-out. Several Government agencies are already capable of accepting dual units from our research laboratories—some are requiring it.

This pretty well covers the metrication planning and progress at Exxon Research and Engineering Company to date.

I assume many of you are here today because your company is presently considering taking similar steps. For those of you, let me say that metrication is not an awesome task, nor is it a technically difficult one. Once a clear-cut need is established, it is simply a matter of doing it.

APPENDIX H - SURVEY OF METRIC ACTIVITY IN THE DRILLING TOOL INDUSTRY

The following survey was conducted in an attempt to determine the extent of metrication with the down hole drill tool industry. The 1976-77 Composite Catalog of Oil Field Equipment and Services was examined to indicate what firms were offering which tools in metric units. An additional examination of the
eral evaluation of the extent of metrication within the firm was made. This evaluation was subjective but is probably indicative of the metric conversion programs of Drilco's competitors.

The "Extent of Product Metrication" and the "Extent of Catalog Metrication" columns were both evaluated using the following criteria:

(1) If the product/catalog had all dimensions given in metrics with customary units given in parentheses, the item was judged as employing metrics extensively.

(2) If the product/catalog had all dimensions given in customary units with metric units given in parentheses, the item was judged as employing metrics moderately.

(3) If there was no mention of metric units or of conversion activities, the item was judged as having no metrication.

It should be noted that all cataloges were written in English and that their use was probably for English and American use, exclusively. It is not known if other catalogs were available, if they were written for another language, and if they employed metrics to a different extent.

PRODUCT Drill Collars

Name of Firm	Extent of Product Metrication					Extent of Catalog Metrication				
	Extensive		Moderate		None	Extensive		Moderate		None
Creusot-Loire Gp. (France)	X					X				
Driltrol					X					x
Drissco International Europe					X					X
Eastman Whipstock Inc.					X					X
James Fuirly Steels, Ltd (England)			X					X		
Gammaloy, Ltd.					X					X
Hacker Machine & Supply Co.					X					X
Hughes Tool Co.			X				X			
Hunt Tool Co.					X					X
Industrialexport (Romania)	X					X				
Joy Petroleum Equipment					X					X
Lone Star Tool Co.					X					X
Marep Dunes (France)	X					X				
Omsco Industries					X					X
Reamco, Inc.					X					X
Reed Tool Co.					X					X
Rucker Acme Tool Co.					X					X
Schoeller-Bleckman (Austria)	(none indicated)					(probably extensive)				
Walker-Neer Mfg.					X					X
Weatherford International Inc.					X					X

PRODUCT Heavy Wall Drill Pipe

	Extent of Product Metrication						Extent of Catalog Metrication				
Name of Firm	Extensive		Moderate		None		Extensive		Moderate		None
James Fairly Steels, Ltd (England)			X						X		
Reamco, Inc.					X						X
Rucker Acme Tool Co.					X						X
Sumitomo Metal Industries, Ltd			X						X		
Vallourec-Export			X						X		
Walker-Neer Mfg. Co., Inc.					X						X
Wilson Industries					X						X

PRODUCT Integral Joint Drill Pipe

	Extent of Product Metrication						Extent of Catalog Metrication				
Name of Firm	Extensive		Moderate		None		Extensive		Moderate		None
Hacker Machine & Supply Co.					X						X
Industrialexport (Romania)	X						X				
Mannesmannrohen-Werke	X						X				
Rucker Acme Tool Co.					X						X
Vallourec-Export			X						X		
Wilson Industries					X						X

PRODUCT Kellys

	Extent of Product Metrication					Extent of Catalog Metrication				
Name of Firm	Extensive		Moderate		None	Extensive		Moderate		None
Creusot-Loire Gp (France)	X					X				
Drissco International Europe					X					X
Hacker Machine & Supply Co.					X					X
Industrialexport (Romania)	X					X				
Joy Petroleum Equipment					X					X
Lone Star Tool Co.					X					X
Marep-Dunes (France)	X					X				
Midway Mfg & Sply					X					X
Offshore Drilling Supplies					X					X
Omsco Industries					X					X
Rucker Acme Tool Co.					X					X
Schoeller-Bleckmann (Austria)	(none indicated)					(probably extensive)				

PRODUCT Reamers

Name of Firm	Extent of Product Metrication					Extent of Catalog Metrication				
	Extensive		Moderate		None	Extensive		Moderate		None
Drilprodco, Inc.					X					X
Eastman Whipstock, Inc.					X					X
Gotco International, Inc.					X					X
Grant Oil Tool Co.					X					X
Hendershot Tool Co.					X					X
Industrialexport (Romania)	X					X				
Reamco, Inc.					X					X
Reed Tool Co.					X					X
Servco, Inc.					X					X
Texas Reamer Co.					X					X

PRODUCT Drill Collar Stabilizers

	Extent of Product Metrication						Extent of Catalog Metrication				
Name of Firm	Extensive		Moderate		None		Extensive		Moderate		None
A-Z International Tool Co.					X						X
American Coldset Corp.					X						X
Basco, Inc.					X						X
Drilprodco					X						X
Driltol					X						X
Eastman Whipstock, Inc.					X						X
James Fairly Steels, Ltd (England)			X						X		
Grant Oil Tool Co.					X						X
Griffith Oil Tool, Ltd					X						X
Hendershot Tool Co.					X						X
Hunt Tool Co.					X						X
Industrialexport (Romania)	X						X				
Lion Oil Tool, Ltd					X						X
Lor, Inc.					X						X
Norfield Companies					X						X
Offshore Drill Supplies, Ltd					X						X
Reamco Inc.					X						X
Universal Tools, Inc.					X						X
Walker-Neer Mfg. Co., Inc.					X						X

PRODUCT Rubber Stabilizers

	Extent of Product Metrication						Extent of Catalog Metrication				
Name of Firm	Extensive		Moderate		None		Extensive		Moderate		None
Basco, Inc.					X						X
Christensen Diamond Products, Co.					X						X
Desser/Security					X						X
Driltol					X						X
James Fairly Steels, Ltd (England)			X						X		
Grant Oil Tool, Ltd					X						X
Homco International, Inc.					X						X
Lion Oil Tool, Ltd					X						X
Reamco, Inc.					X						X
Texas Reamer Co.					X						X

PRODUCT Sleeve Stabilizers

	Extent of Product Metrication						Extent of Catalog Metrication				
Name of Firm	Extensive		Moderate		None		Extensive		Moderate		None
Basco, Inc.					X						X
Christensen Diamond Products Co.					X						X
Driltol					X						X
Eastman Whipstock, Inc.					X						X
Lion Oil Tool, Ltd.					X						X
Reamco, Inc.					X						X
Tri-State Oil Tool Ind., Inc.					X						X

PRODUCT Shock Absorbers

Name of Firm	Extent of Product Metrication						Extent of Catalog Metrication				
	Extensive		Moderate		None		Extensive		Moderate		None
Basco, Inc.					X						X
Christensen Diamond Products Co.					X						X
Dresser/Security					X						X
Gotco International, Inc.					X						X
Grant Oil Tool Co.					X						X
Griffith Oil Tool Co.					X						X
Hughes Tool Co.			X						X		
Hydrotrole Offshore, Ltd	(not available)						(not available)				
Johnston Division					X						X
Well Control/Thermotics					X						X

PRODUCT Subs

	Extent of Product Metrication						Extent of Catalog Metrication				
Name of Firm	Extensive		Moderate		None		Extensive		Moderate		None
A-Z International Tool Co.					X						X
Creusot-Loire Gp (France)	X						X				
Domine			X						X		
Driltol					X						X
Drissco International Europe					X						X
James Fairly Steels, Ltd (England)			X						X		
Gotco International, Inc.					X						X
Griffith Oil Tool, Inc.					X						X
Hacker Machine & Supply Co.					X						X
Hendershot Tool Co.					X						X
Industrailexport (Romania)	X						X				
Lion Oil Tool, Ltd					X						X
Lone Star Tool Co.					X						X
LOR, Inc.					X						X
Marep-Dunes	X						X				
Midway Mfg. & Sply					X						X
Norfield Companies					X						X
Offshore Drilling Supplies					X						X
Omsco Industries, Inc					X						X
Reamco, Inc.					X						X
Reed Tool Co.					X						X

PRODUCT Subs (con't)

	Extent of Product Metrication						Extent of Catalog Metrication				
Name of Firm	Extensive		Moderate		None		Extensive		Moderate		None
Red Fox Machine & Sply Co.					X						X
Rucker Acme Tool Co.					X						X
Tri-State Oil Tool Industry, Inc.					X						X
Universal Tools, Inc.					X						X

PRODUCT Thread Protectors

Name of Firm	Extent of Product Metrication						Extent of Catalog Metrication				
	Extensive		Moderate		None		Extensive		Moderate		None
Creusot-Loire Gp (France)	X						X				
Domine			X						X		
Hydril Co.				X						X	
Joy Petroleum Equipment					X						X
Klampon Corp.					X						X
Lion Oil Tool, Ltd					X						X
Marep-Dunes	X						X				
Omsco Industries, Inc.					X						X
Reamco, Inc.					X						X
Standco Industries					X						X
Weatherford International Inc.					X						X

APPENDIX I - METRIC ACTIVITY IN THE STEEL INDUSTRY

As mentioned in the main body of this report, metrication within the steel industry in the U.S. will have a profound effect on the metric activities of the petroleum industry. However, from the response received from inquiries to the steel industry on their plans pertaining to metrication, the general consensus should be that little activity is present and that within the near future little activity is expected. This picture could change should the federal government modify its present position, which is unlikely.

TIMKEN

THE TIMKEN COMPANY
GENERAL OFFICES
CANTON, OHIO, U.S.A. 44706
TELEPHONE: (216) 453-4511

June 29, 1976

RECEIVED
JUL 21 1976
DRILCO — ENGINEERING

Mr. John M. Konopacki
Product Engineering
Drilco
P.O. Box 60068
Houston, Texas 77205

Dear Mr. Konopacki:

We are replying to your recent letter requesting our views and plans concerning metrication. The Timken Company is committed to the metrication of our worldwide Company, and accordingly is supporting government and society efforts toward metrication.

Seamless tubing is the main product supplied to Drilco by the Timken Steel Division, and we are capable of producing this product in any metric size while incurring no additional costs.

If you would require additional or more detailed information on this subject, please feel free to contact our Manager - International Metrication, Mr. W. G. Storm. Mr. Storm is coordinating the entire metrication program for The Timken Company.

Sincerely,

T. W. Burnstad
Manager - Tube Sales
Steel Division

mjp

Republicsteel

Republic Steel Corporation
District Sales Office
5th Floor Post Oak Bank Building
2200 South Post Oak Road
Houston TX 77056
Tel 713/622-8200

Robert C Newlin
District Sales Manager
BD Graves
CE Hodges
WS Shadrach Jr
Assistant District
Sales Managers

June 25, 1976

Mr. John M. Konopacki
Product Engineering
SII Drilco
Division of Smith International, Inc.
Post Office Box 60068
Houston, Texas 77205

International System of Units

Dear Mr. Konopacki:

This will acknowledge receipt of your letter which we received yesterday.

We are pleased to furnish you with the attached policy statement from Republic Steel pertaining to metric conversion.

Very truly yours,

D. G. Hoffman
D. G. Hoffman
Inside Salesman

DGH:pe
Attachment

Republicsteel

REPUBLIC STEEL CORPORATION'S
POLICY STATEMENT ON METRIC CONVERSION

Republic Steel Corporation has always accepted, is now accepting, and will continue to accept orders stated in metric terminology.

In past years most metric orders have been received from foreign customers and shipped overseas. More recently, however, there has been a gradual informal acceptance of the metric system in the United States by business and industry. Republic recognized this development in the early stage and established a formal metric task force to train our people and prepare for the transition to metric units of measure.

However, at present, the great majority of our customers continue to order steel in terms of customary terminology, which remains the normal or standard working terms used by our production personnel. The way in which we measure the product in no way changes its inherent dimensions, and we will continue to make steel to meet customer requirements.

We will accept orders in metric or SI terminology and convert them into customary units for processing, using ASTM E-380-72. All rounding of converted numbers will allow a maximum variable of 1/2% for any number.

When we conclude that circumstances so warrant and a sufficient number of our customers have changed over to metric measurement, metric terminology will become our standard usage and customary units supplementary.

Should you have any specific questions concerning the way in which our policy or procedures might affect our accurate acceptance and processing of your orders, we ask that you contact the Houston District Sales Office, who in turn will review your questions with the Metric Policy Committee and see that you receive a prompt reply. We believe that our policy is consistent with any current or planned action of the American National Standards Institute, International Standards Organization, Society of Automotive Engineers, American Society for Testing Materials, and the American Iron and Steel Institute; and we feel that we will be able to handle your metric orders with accuracy and dispatch.

ARMCO STEEL CORPORATION

METRICATION POLICY

It is the policy of Armco Steel Corporation to proceed with metrication as required to most effectively meet the needs of our customers. Implementation of this policy will concur in every practicable way with such policies as are established by the Federal Government, the American Iron and Steel Institute, and the industries Armco Serves.

Armco will supply metric-dimensioned products whenever possible within the limits of practical economics for both Armco and our customers. By mid-1975 it is Armco's intention to accept orders for flat rolled products in either customary or metric units. Metric-dimensioned orders for such products will be produced in equivalent customary units but invoices and shipping papers will be provided in either set of units, as designated by the customer. Production of all other steel mill and fabricated products in metric standard sizes will be considered by Armco whenever orders for specific products and sizes are large enough to enable the cost of necessary rolls, tools and dies to be amortized adequately.

United States Steel Corporation

SOUTHERN STEEL DIVISION

HOUSTON DISTRICT SALES OFFICE
TENNECO BUILDING—1010 MILAM STREET
HOUSTON, TEXAS
MAIL: P. O. BOX 1590
HOUSTON, TEXAS 77001
713/225-6491

F. W. VOSS
MANAGER OF SALES

PETE MOLLER
ASSISTANT MANAGER OF SALES

July 9, 1976

RECEIVED
JUL 21 1976
DRILCO — ENGINEERING

Smith International, Inc.
Drilco Division
Post Office Box 60068
Houston, Texas 77205

Attention: Mr. John M. Konopacki
Product Engineering

Subject: Metrication Inquiry

Gentlemen:

In an effort to aid Drilco in their study of the effects that eventual conversion to metrication by the United States will have on the oil industry, we at United States Steel Corporation are pleased to offer the following comments:

> Your concern about metrication is understandable and is felt by much of industry today, but progress is very slow.
>
> Relatively few orders are being received for production despite the metric additions to our Price Lists which were published in February 1975. At that time, we published USS Standard Metric Sizes for Sheet, Plate, Rods, Wire and certain Bar products, which were then assembled into a catalogue dated October 1975, a copy of which is enclosed for your use. The hard metric sizes shown are available but production and delivery are subject to development upon receipt of your specific inquiry. Our comments are based upon our limited experience to date.
>
> To date, there has been practically no evidence of demand from Steel Service Centers and we believe that they, like we, are waiting for customers to say what they want.

It appears the pipe and tubular societies are reluctant to change, and there are indications that sizes may not be converted at all to hard metric; instead, today's nominal dimensions may stay in a soft converted stage, such as was printed in our price pages on Page 18-A, see copy enclosed.

If you feel we can be of any further assistance, we welcome the opportunity to serve you.

Very truly yours,

UNITED STATES STEEL CORPORATION

Bill Stamps
C. W. Stamps
Service Representative

CWS/ga

Enclosures

Colt Industries

Crucible Inc
Stainless Steel and Alloy Divisions
P.O. Box 226
Midland, Pa. 15059
412/643-1100

June 28, 1976

Mr. John M. Konopacki
Product Engineering
DRILCO
Post Office Box 60068
Houston, Texas 77205

Dear Mr. Konopacki:

In reference to your recent letter to our Houston office concerning metrication, we wish to advise you that we are giving this project serious consideration only as required by our customers. Several of the automotive companies have already begun converting to metrication on size, however, this is more of a "soft" conversion rather than the "hard" conversion to metric sizes.

We are willing to work with you on any program you feel is deemed necessary towards meeting Drilco's objectives.

We do have the capability of reporting both metric and present day standards but the difficulty will arise if there should be a drastic change in physical dimensions. There are certain tolerances on Hot Roll products whereby slight size changes may not have a serious impact if a "hard" conversion is necessary. This remains to be seen.

We will appreciate your keeping us advised of Drilco's intent on metrication.

Very truly yours,

Frank S Matsukas

F. S. Matsukas
Product Manager
Alloy & Carbon Products

FSM/msb
cc: J.Clark

APPENDIX J - METRICATION OF MASTER COMPUTER LISTINGS

Conversion of the five major listings, employed by Drilco personnel in their daily activities, will be of considerable importance. Metrica- of the computerized lists used to describe products, give part numbers, and indicate costs must be accomplished prior to any major conversion activity. Additionally, the ability to describe all the above in customary or English units must not be lost; hence, there exists the need for dual or double listings which have both units, English and Metric.

In Figure J1 the progression from English units to metric units is depicted. Note that after the decision is made to adopt metric units, two listings would be maintained. This requirement is made to allow for a slower transition, to allow specified areas within the firm to employ or have access to metricly described products while allowing other areas in the firm to continue functioning solely on the customary system. This situation would occur when external reports of metric units was adopted by a firm prior to actual metrication of the organization. Also, note that two listings would be required; one listing would be required for those persons needing the metric units, while the other listings would be used by those in the firm who were to be exposed to customary units only. After the decision was made to utilize metric units as the prefered measuring system, the listings employing English units only would be dropped and listings having only metric units would be substituted. This situation could be maintained until such time as the English or customary units were no longer required.

Now, to accomplish the conversion of the five major listings, the first listing that must be examined would be the Item Master. This listing has a description for each part number which is active; additional lines

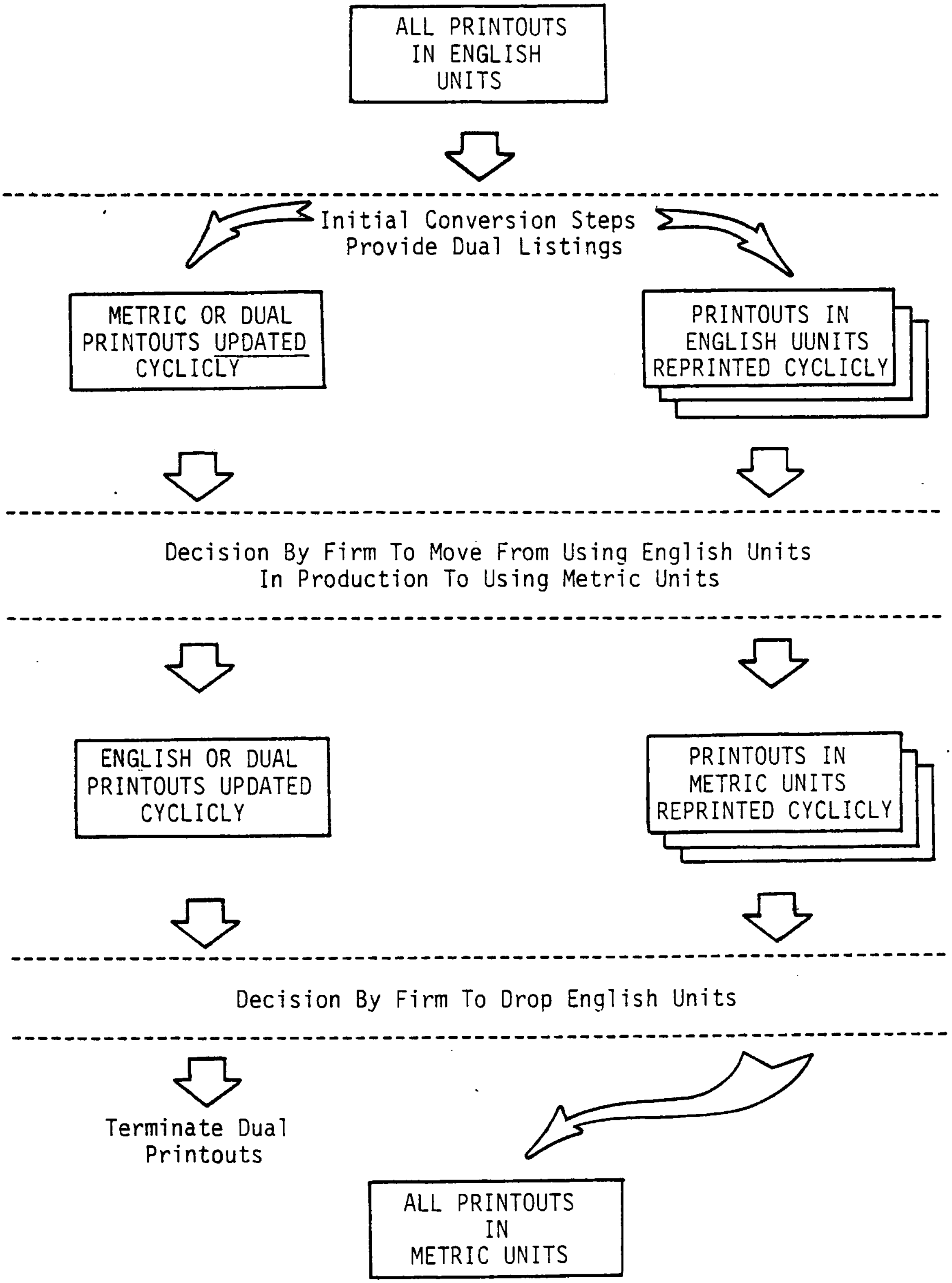

ALL PRINTOUTS IN ENGLISH UNITS
Initial Conversion Steps Provide Dual Listings
METRIC OR DUAL PRINTOUTS UPDATED CYCLICLY
PRINTOUTS IN ENGLISH UUNITS REPRINTED CYCLICLY
Decision By Firm To Move From Using English Units In Production To Using Metric Units
ENGLISH OR DUAL PRINTOUTS UPDATED CYCLICLY
PRINTOUTS IN METRIC UNITS REPRINTED CYCLICLY
Decision By Firm To Drop English Units
Terminate Dual Printouts
ALL PRINTOUTS IN METRIC UNITS

Figure J1

of description are available from the Secondary Description Listing. The part description is the major line item which has customary units, and the conversion of the part description would be required to convert the Item Master. Figure J2 gives an example of a typical Item Master line item with its description. The metric conversion of the part description could be carried on the Secondary Description Listing along with additional metric descriptions and information. When conversion of the Item Master to the metric system is desired, a program can be introduced which will switch the part descriptions with those found in the Secondary Description Listing. The metric description will then be found in the Item Master with the English description found in the Secondary Description Listing.

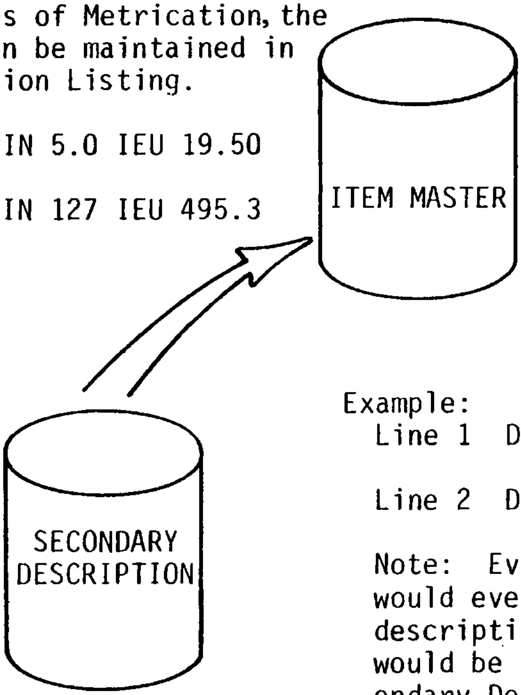
Metrication of the other major listings will be greatly simplified once the Item Master is converted. The part description used in the Item Master is also employed by the other listings and constitutes the major item for conversion in any listing. Therefore, with the conversion of the Item Master, several other listings will also be almost entirely converted. (Figure 3)

The first line of the product description is stored in the Item Master with all supplemental listings in the Secondary Description Listing. During the first stages of Metrication, the metric descriptions can be maintained in the Secondary Description Listing.

Example:

Line 1 DRILL PIPE PIN 5.0 IEU 19.50

Line 2 DRILL PIPE PIN 127 IEU 495.3



During the latter stages of metrication, when the metric description of the item is most important, a program can be substituted into the Item Master and the Secondary Description Listing which will switch the role of the two descriptions.

Example:

Line 1 DRILL PIPE PIN 127 IEU 495.3

Line 2 DRILL PIPE PIN 5.0 IEU 19.50

Note: Even though the Item Master would eventually have only metric descriptions, the English values would be retained on the Secondary Description Listing.

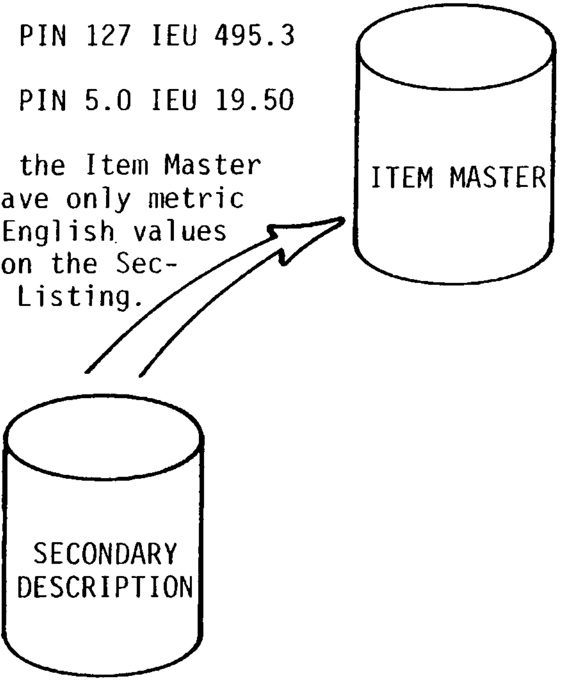


Figure J2

EXAMPLE:

	COMMODITY CLASS	DESCRIPTION
Line 1	050-000-00000000	DRILL PIPE PIN 5.0 IEU 19.50 HISTRENGTH
Line 2		6.370D x 3.50ID NC-50 CONN. STD LENGTH

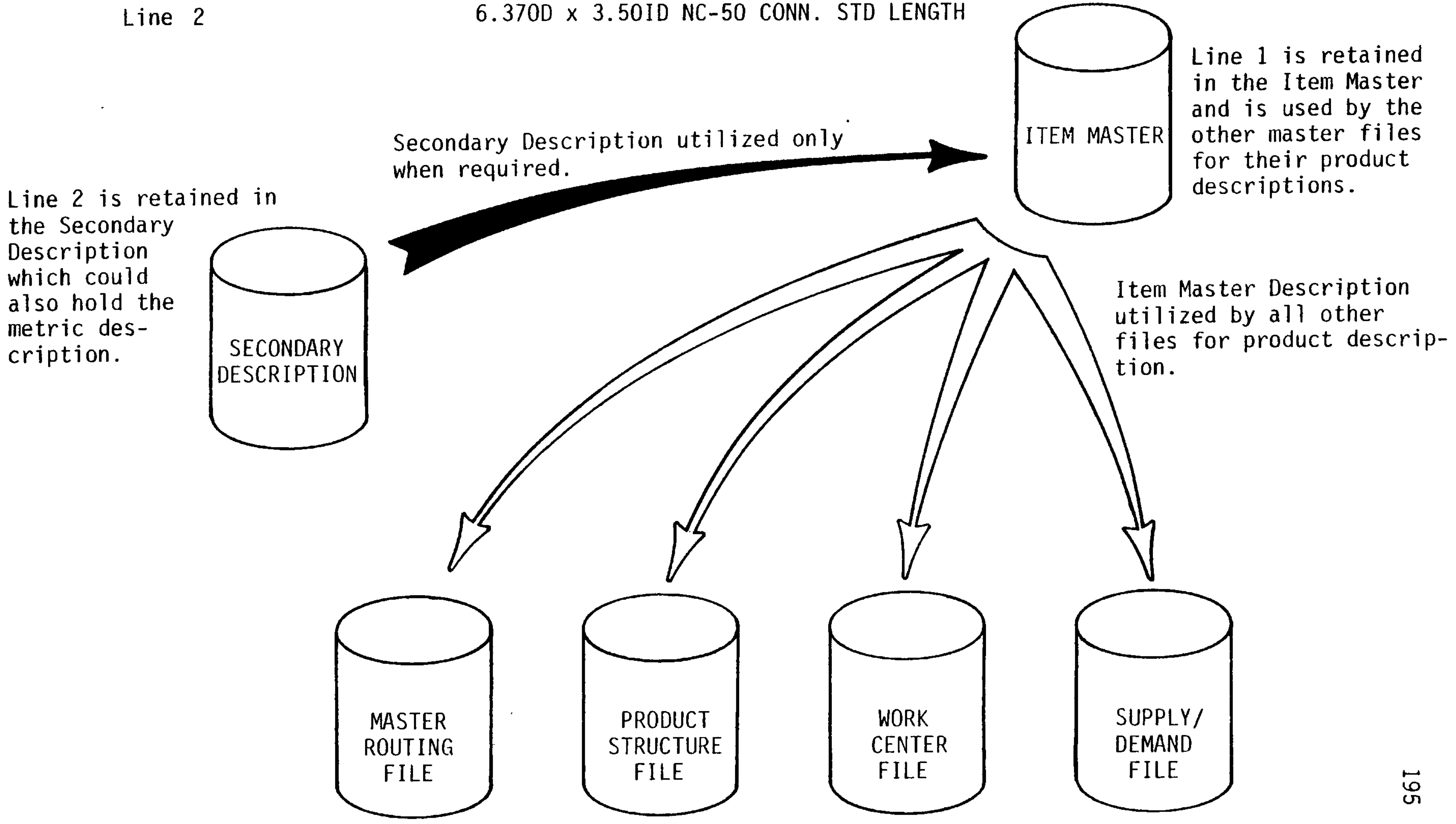


Figure J3

APPENDIX K - DRAWING CONVERSION PRIORITY

One of the most difficult areas to handle in a metric conversion is the assigning of priorities to the metrication of a product line or to a firm's drawings. To assist in establishing a priority for the conversion of Drilco's existing engineering graphics, a previously conducted "A-B-C Analysis" was consulted. This type of analysis originated from the commonly held contention that 80% of a firms profits or total revenues are generated by 20% of its products or services. Products or services were tabulated in the order of their contribution to the total cash flow of the firm; products which made the greatest contributions were singled out in the analysis.

The A-B-C Analysis which was employed in this study was conducted in June of 1976 as an aid for inventory control. The analysis utilized product part numbers and their percent contribution to the gross contribution of the related commodity class. Because of the structuring of the part numbers and because more than one drawing is required for production of some parts, the analysis could not give a completely accurate indication of the priorities for drawing conversion. However, the analysis did indicate which general areas made the greatest contributions in each commodity class and which general classes of drawings should be converted first.

The analysis showed that 20% of the parts numbers were used in the top 80% of the sales of the firm's product up to June of this year. Assuming uniformity of drawing distribution, the conclusion can be drawn that once 20% of the drawings have been converted (the drawings associated with the top revenue producers), then 80% of Drilco's future orders could be produced using metric values.

The following lists of drawings can be used to establish priorities in a future drawing conversion program. Once these drawings have been converted, the remaining drawings can be redrawn or modified according to a non-priority basis.

COMMODITY CLASS 010

PRODUCT Slick Drill Collars with Features

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
50329	20.57
50268	
50395	
50217	
50134	
50209	54.04
50192	
50482	
50329	
50189	70.39
50246	
50245	
50210	
50389	80.66

COMMODITY CLASS 011

PRODUCT Short Drill Collars

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51698	18.22
51753	
51655	37.96
51661	
51656	48.89
51660	
51662	62.06
51709	
51711	
51652	80.94

COMMODITY CLASS 012

PRODUCT "No-Wall-Stick" Drill Collar with Features

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51112	12.28
51136	
51072	
51058	
51132	45.45
51103	
51678	
51137	65.68
51165	
51142	
51157	
51096	76.83
51116	
51071	81.13

COMMODITY CLASS 031

PRODUCT Hevi-wate Components & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
50634	13.83
06430	
06433	40.56
06977	
06976	
50635	66.29
06432	
17270	
06431	
06977	82.51

COMMODITY CLASS 032

PRODUCT Kellys - Raw Bars & Finished

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51618	8.37
02854	
04154	
50655	30.87
06184	
03476	
50657	53.53
51614	
17150	
03694	
17208	65.52
13492	
02853	
50661	
50667	74.26
50668	
17267	
17208	80.29

COMMODITY CLASS 033

PRODUCT Kelly Shuck Mat'l & Misc. Castings

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51531	3197
06723	5888
51423	8022

COMMODITY CLASS 034

PRODUCT N/R Stab - Components & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
02379	11.25
02487	
02499	
02156	
02379	
02757	37.38
07415	
02377	
02360	54.36
06685	
02765	
02147	
02383	64.82
17147	
03301	
70213	76.97
02150	
02761	
02379	80.77

COMMODITY CLASS 035

PRODUCT Assembly Combo

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51799	100

COMMODITY CLASS 036

PRODUCT RWP Stab. - Comp & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
19625	6.27
17271	
19626	
20813	
15776	24.22
18179	
13812	
18446	
19600	48.5
19914	
19832	
17270	
19626	61.45
15980	
15773	
19637	
19596	
17868	76.37
18176	
19599	
18181	
18179	80.53

COMMODITY CLASS 039

PRODUCT IB Stab. Components & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
17282	13.57
17204	
17226	
17462	40.38
17850	
17401	
17320	
17219	57.15
17460	
17281	
17204	66.57
15440	
15715	74.80
17228	
17456	
15571	80.44

COMMODITY CLASS 041

PRODUCT Ezy-Change Stab. - Comp & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
15033	8.1
17165	
51640	
17173	
14958	
51639	
14956	43.29
14957	
17174	
17482	
51638	
17581	57.37
15027	
14904	
51637	
13289	
17259	75.15
51636	
14952	
15029	
13289	80.37

COMMODITY CLASS 043

PRODUCT W/B Stab - Components & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
08965	13.17
17554	
51693	
06996	49.3
17553	
17557	
17556	64.85
70164	
70222	
17556	80.48

COMMODITY CLASS 045

PRODUCT Reamers & Component Parts

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
02164	4.75
14869	
02259	
13489	21.96
51484	
02087	
02456	
02302	29.93
02703	
02079	
02433	
02479	
02335	39.08
51749	
02334	
02881	
02295	
13490	
02322	46.66
02822	
51487	
02259	
51477	50.32

COMMODITY CLASS 045 (con't)

PRODUCT

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
13489	51.19
02479	
02678	
03148	
02773	
02082	56.58
02823	
51479	
02876	
02381	
02196	
14869	60.2
02459	
02439	
02158	
02163	
02318	63.57
51490	
50982	
02197	
50097	
04406	
02164	68.45

COMMODITY CLASS 045 (con't)

PRODUCT

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
02883	
51015	
02671	
02080	
02676	
02389	73.75
02884	
50104	
06793	
02435	
50107	76.18
02419	
02081	
02259	
02087	78.42
51480	
02703	
02079	80.17

COMMODITY CLASS 047

PRODUCT Rubber Shock Sub Comp & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
03828	6.19
03869	
03867	
03829	
50529	
03870	30.8
50528	
50527	
02579	
02642	
02817	
03868	51.25
02578	
03867	
03826	
03825	
02609	65.74
02576	
02574	
03866	
02817	
02606	
02537	75.05

COMMODITY CLASS 047 (Con't)

PRODUCT

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
03953	
03941	
02547	
02642	80.56

COMMODITY CLASS 049

PRODUCT Hi-Temp Shock Sub.

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
13530	4.05
08277	
18415	
05894	
51017	19.14
05270	
08276	
18424	
09045	
05444	
51605	35.77
07480	
13531	
05881	
09049	
07444	
05878	53.26
09047	
07445	
09050	
05450	
09046	
09048	62.93

COMMODITY CLASS 049 (con'T)

PRODUCT

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
05876	
16396	
08258	
05879	
07480	
50074	
13529	80.43

COMMODITY CLASS 051

PRODUCT Subs

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
03047	5.25
03042	
51348	
03044	
03038	
51386	20.46
51293	
51285	
51242	
51248	
51301	41 10
51341	
51214	
51211	
03041	
51285	
03043	53.25
70007	
51398	
03052	
51200	
51412	
51349	59 15

COMMODITY CLASS______________________________

PRODUCT____________________________________

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51389	
51327	
03036	
51241	
51299	63.95
03037	
51356	
12561	
51341	
03045	
51392	
51300	69.16
70006	
70133	
70021	
70076	
51221	
03059	73.31
51216	
51301	
70111	
03048	
51299	75.1

COMMODITY CLASS 051 (con't)

PRODUCT

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51240	
51398	
51380	
51305	76.05
51596	
51293	
03040	
51397	
51299	80.17

COMMODITY CLASS 053

PRODUCT Rubber Protectors for Kelly Saver Subs

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
50825	53.31
51608	71.83
51607	81.01

COMMODITY CLASS 054

PRODUCT Ezy-Torq Components & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51594	68.35
51595	93.72

COMMODITY CLASS 056

PRODUCT Degasser Components & Assy

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
22122	19.49
17702	
22721	
19690	
20964	46.67
17675	
18489	
18405	
16260	
19590	71.5
20970	
19747	
19628	
19690	
22121	80.09

COMMODITY CLASS 058

PRODUCT Refacing Tools - Raw & Finished

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
02833	4.69
17683	
02864	
17684	
51696	
17649	
17685	
02862	
02829	
17686	34.69
02830	
02863	
02831	
17682	
03136	
17697	
03341	
51697	72.07
17704	
02830	80.37

COMMODITY CLASS 059

PRODUCT Thread Protectors - Raw & Finished

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
17287	7.53
17288	
17273	
17274	
17351	
02049	
17352	
03545	41.89
03546	
02050	
17291	
17292	
17627	
17628	
17294	
17297	61.33
17298	
17293	
30686	
01944	
17290	
17289	
17349	72.68

COMMODITY CLASS 059 (con't)

PRODUCT

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
51624	
50688	
17350	
02057	
50683	
02639	80.05

COMMODITY CLASS 060

PRODUCT Gages - Finished & Raw Mat'l

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
22201	13.22
22200	
22116	
20830	
22132	
22148	57.43
22115	
04266	
02471	
07682	82.1

COMMODITY CLASS 062

PRODUCT Carbide Compacts

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
14921	55.87
02357	76.42
02520	92.86

COMMODITY CLASS 064

PRODUCT Wear Knots

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
17134	59.41
15096	84 14

COMMODITY CLASS 098

PRODUCT Mud Chek

DRAWING NUMBER	% TOTAL CONTRIBUTION TO SALES OF COMMODITY CLASS
17929	55.57
22530	73.85
17747	77.73
17900	81.49

APPENDIX L - COST OF DRAWING CONVERSION

In any metric conversion of a plant/product which has even a moderate degree of complexity, a significant amount of effort will be expended in converting the engineering graphics which employ customary dimensions. In the case of Drilco, depending on the type of conversion which is instituted, the conversion of the engineering drawings and engineering tabulated data will constitute the major conversion cost to the firm. In order to determine the eventual cost to Drilco, several specific pieces of data were needed. These were as follows:

(1) How many active drawings are there in Product, Process, and Plant Engineering?

(2) How complex are these drawings,i.e., how many dimensions will require conversion on each drawing and will each drawing require a complete redraw?

(3) What will be the total cost for converting the existing drawings assuming no present assets are utilized.

To obtain an accurate count of the drawings that would require conversion, a complete inventory was taken of the drawings currently in use by all three departments mentioned above. The totals are given in Figure L1. After each inventory was concluded, a survey was taken to determine how much time would be required to convert those drawings. A sample from each department was extracted and the number of dimensions on each drawing was noted as well as the estimated time required to convert the drawing. This survey indicated that the average number of dimensions on each drawing was between 30 and 35 with the total time required to completely redraw the print set at 2 hours.

However, it was felt that the survey could not adequately reflect the time require for conversion of the drawings due to numerous factors such as emphasis on other drafting projects during the conversion period plus additional equipment costs. Therefore, the estimated time was increased to 3 hours per drawing to compensate for these intangible costs.

DEPARTMENT	NUMBER OF DRAWINGS	
Product Engineering	4354	4400
Process Engineering	1996	2000
Plant Engineering	2373	2400

(Note: Quality Assurance was also inspected, but that departmet had less than 50 active drawings. Therefore, with regard to drawings, it will be disregarded.)

Total Drawings Sampled 259
Total Dimensions on Drawings Sampled 8622
Average Number of Dimensions per Drawing 33.3
Average Standard Deviation for Sample Taken 37.23

Drawings with 30 to 40 dimensions per drawing will take about 3 hours for conversion.

Therefore, total conversion of all drawings will require 26,400 hours.

Assume 7 hours per day for drawing.

Assume 244 days per work year (365 days less 104 days for weekends, 10 days for vacation, and 7 days for holidays)

Therefore, complete conversion of the existing drawings would require about 15.5 man years.

Assume cost to firm for one draftsman for one year to be $12,500. Therefore, total cost for conversion would run $193,750.00 or $.2 million-

APPENDIX M - MACHINE TOOL TASKING

To better establish the conversion requirements of Drilco's heavy manufacturing tools, a survey was conducted to determine the present demands on each piece of equipment. This survey took the form of a personal interview with each machine operator plus interviews with the line leadmen and foreman of the different manufacturing lines. The purpose of the survey was to determine what operations were performed by the different machines, to what extent each of the traversing screws (lead screw, cross-feed screw, and compound-feed screw, etc.) was used, and if there were any special operations or demands which are placed on the tool which might effect its conversion to the metric system.

Each machine operator and other person contacted was first informed of the nature of the survey and exactly what data was to be extracted from the interview. Then, the following questions were asked:

(1) "Exactly what operations are or were performed by this machine, are different operations conducted by different shifts with the machine, and have the tasks assigned this piece of equipment changed over the last 6 months to a year?"

(2) "To what extent are the three main traversing screws utilized in the operations assigned to this machine?"

(3) "When making any precision cuts or during any operation requiring closing monitoring of the point of operation, what dials, gages, etc., which are affixed to the machine are employed in the process?"

(4) "If this machine was converted to the metric system, what components of the tool would require conversion?"

(5) "Are there any other operations not mentioned which would be effected by the metric conversion of this tool?"

With the information obtained in the survey, the extent of conversion was determined, the number of axes which would require conversion was noted, and any special operations were isolated. The results were tabulated and used extensively in determining the costs for conversion.
An extract of the results follows, displaying which machines needed which axes converted.

Machine Type Lathes

Drilco Machine Number	Location	# of Axes Used	Single Point Threading
1094	E-7	2	Yes
1114	F-7	1	No
1182	H-6	1	No
1183	H-7	1	No
1410	E-8	2	Yes
1518	A-2	2	Yes
1586	E-11	2	No
1590	F-7	1	No
1660	B-2	2	No
1662	A-3	2	Yes
1712	D-8	1	No
1722	D-8	1	No
1723	E-8	1	No
1724	F-16	4	No
1869	D-7	2	Yes
2118	F-11	2	No
2126	E-5	1	No
2156	A-3	3	Yes
2169	D-6	0	No
2175	D-7	0	No
2177	D-7	2	Yes
2178	D-8	1	No
2182	E-11	1	No
2183	E-10	1	Yes
3013	D-7	2	No
3014	F-9	2	No
3041	D-9	2	No
3077	E-6	1	No
3112	E-11	1	No
3141	F-7	4	No
3142	F-8	1	No
3143	E-5	1	Yes
3153	A-4	0	No
3180	E-8	2	Yes
3189	E-11	2	No
3202	C-9	1	No
3215	D-6	0	No
3259	A-3	1	Yes
3271	F-7	2	No
3319	D-8	1	No
3328	A-2	2	Yes
3331	A-3	2	Yes
3340	E-10	2	Yes
3346	E-6	2	Yes
3348	E-10	1	No
3396	E-10	2	Yes
3397	E-10	2	Yes

Machine Type Lathes (con't)

Drilco Machine Number	Location	# of Axes Used	Single Point Threading
3401	C-9	1	No
3516	E-8	3	Yes
3517	E-8	3	Yes

Machine Type Mills

Drilco Machine Number	Location	# of Axes Used	Single Point Threading
1189	B-1	3	
1540	C-6	1	
1541	C-5	1	
1542	B-1	3	
1663	B-2	3	
1665	B-2	-0- (Not convertable)	
1856	D-5	0	
1867	B-2	3	
2135	E-8	2	
2179	B-2	3	
2180	C-7	-0-	
3125	C-8	-0-	
3260	B-4	2	
3261	C-8	0	
3311	C-10	1	
3322	C-5	1	
3399	B-3	5	
3400	C-6	3	
3416	C-6	-0-	
3426	C-5	-0-	
3484	B-3	3	
2194	B-2	-0-	
3415	E-10	-0-	

Machine Type Grinders (not used in tool sharpening)

Drilco Machine Number	Location	# of Axes Used	Single Point Threading
1192	Purple	1	
1321	↓	1	
1666	↓	2	
1892	Blue	0	
2109	Purple	1	
2160	↓	1	
2161	↓	1	
2240	↓	0	
3323	↓	1	
3405	↓	0	
3409	↓	0	
3412	↓	0	

Machine Type Grinders (for tool sharpening only)

Drilco Machine Number	Location	# of Axes Used	Single Point Threading
1697	"Tool Grinding Shop"	2	
1962		6	
2134		2	
2245		1	
3069		2	
3127		1	
3185		2	
3414		1	
3421		6	
3422		1	
3425		2	
3508		1	

Machine Type Hobs

Drilco Machine Number	Location	# of Axes Used	Single Point Threading
1519	E-10	N/A	N/A
1750	F-6	↓	↓
1864	F-9		
1941	E-10		
3182	F-9		

APPENDIX N - MACHINE TOOL CONVERSION COSTS

From the Machine Tasking list, the requirements for conversion of each heavy tool at Drilco was determined, establishing the modifications that were required to achieve metric production by the plant's machinery. The cost of metrication of the plant was that examined in light of either two assumptions: (1) no hard metric RSC connections would be developed or ordered within the next 7 to 10 years, or (2) complete metrication of the plant would be required to include RSC connections. The former case had the characteristics that during such a situation either English or metric products could be produced, but that system would have only limited metric capabilities. Notably, this type of conversion would lack the ability to manufacture metric threads. The latter situation had the characteristics that under a complete metrication program, the system could produce metric threads, although it would have very restricted production of English sized parts.

The complete conversion of Drilco production capabilities, from the standpoint of only machine tools, could be accomplished by the total refitting of lathes, mills, and hobs with the necessary metric change gears, lead screws, etc. The conversion cost column labled "complete" represents the cost associated with this type of conversion. However, a "complete" conversion would not include the retention of present day English capabilities. Therefore, it would be difficult to manufacture present day tools without the conversion of their drawings to the metric system. Thus, a complete conversion could only follow the complete conversion of all engineering graphics; it could not preceed the conversion nor could it run concurrently with a graphics conversion. The main advantage to a complete conversion is that metric threads could be easily produced and it would definitely facilitate manufacturing of hard, metric prodcuts.

If there is no apparant need for production of metric threads, a more logical conversion process could be instituted by modifying each machine tool and adding limited dual English/metric capabilities. This could be done through the addition fo dual reading dials on each important axis of each machine. But, if this type conversion was applied, the plant could still have limited metric thread production capabilities; these capabilities would be limited to the NC and CNC machines.

Machine Type Lathes

Drilco Machine Number	Conversion Costs		
	Remarks	Complete	Dual Capabilities
1094	Cuts RSC connections for large-body rmrs	$3450.00	$600.00
1114		1676.00	300.00
1182	Tracer	N/A	300.00
1183	Tracer	N/A	300.00
1410	Tracer	1676.00	600.00
1518	MAA	N/A	600.00
1586		3000.00	600.00
1590		3000.00	300.00
1660	MAA	N/A	600.00
1662	MAA	N/A	600.00
1712		N/A	300.00
1722		N/A	300.00
1723	Tracer	3000.00	300.00
1734		3000.00	1200.00
1869		3000.00	600.00
2118	Turret	1676.00	600.00
2126		1676.00	300.00
2156	MAA	N/A	900.00
2169	Spring mfg	-0-	-0-
2175	Tracer	1389.00	-0-
2177		1676.00	600.00
2178		N/A	300.00
2182		N/A	300.00
2183		N/A	300.00
3013	Turret	1676.00	600.00
3014	Tracer	3000.00	600.00
3041		1389.00	600.00
3077		3000.00	300.00
3112		N/A	300.00
3141		3000.00	1200.00
3142		1676.00	300.00
3143		N/A	300.00
3153	MAA	1389.00	-0-
3180		3000.00	600.00
3189		3000.00	600.00
3202		1202.00	300.00
3215	Spring mfg	-0-	-0-
3259	MAA	3450.00	300.00
3271		1676.00	600.00
3319		N/A	300.00
3328	MAA	N/A	600.00
3331	MAA	N/A	600.00
3340		3000.00	600.00
3346		3000.00	600.00
3348		1676.00	300.00
3396		3000.00	600.00
3397		3000.00	600.00
3401		2382.00	300.00

Machine Type Lathes (cont)

Drilco Machine Number	Remarks	Conversion Costs	
		Complete	Dual Capabilities
3516		< 1676.00	900.00
3517		< 1676.00	900.00

Machine Type Mills

Drilco Machine Number	Conversion Costs Remarks	Complete	Dual Capabilities
1189	DD plus one dial indicator	800.00	630.00
1540	DD plus one dial indicator+1 scale	1500.00	360.00
1541	DD plus two dial indicators	1500.00	360.00
1542	DD plus one dial indicator	800.00	630.00
1663		N/A	900.00
1665	Not convertable	N/A	-0-
1856		N/A	-0-
1867	DD plus one dial indicator	300.00	630.00
2135	needs digital readout	N/A	4400.00
2179	plus anilam conv. plus scale	800.00	260.00
2180	plus anilam conv. plus dial ind.	12,000.00	550.00
3125	plus anilam conv.	N/A	250.00
3260	plus one dial indicator	N/A	630.00
3261	plus one dial indicator	1500.00	30.00
3311	probably does not need conv.	N/A	300.00
3322	plus one dial indicator	1500.00	330.00
3399		3000.00	1500.00
3400		1500.00	900.00
3416	plus one dial indicator	N/A	30.00
3426	CNC - no conversion	N/A	-0-
3484		800.00	600.00
2194	anilams need conversion	12,000.00	750.00
3415	anilams need conversion	12,000.00	1250.00

*Note: DD → Dual Dials

Machine Type Grinders (not used in tool sharpening)

Drilco Machine Number	Remarks	Conversion Costs	
		Complete	Dual Capabilities
1192		1700.00	300.00
1321		1700.00	300.00
1666		1700.00	600.00
1892	- converted engine lathe	-0-	-0-
2109		2000.00	300.00
2160		N/A	300.00
2161		N/A	300.00
2240	plus 2 dial indicators	N/A	60.00
3323		N/A	300.00
3405	plus one dial indicator	Not required	30.00
3409		1700.00	-0-
3412		1700.00	-0-

Machine Type Grinders (Tool Sharpening Dept.)

Drilco Machine Number	Conversion Costs		
	Remarks	Complete	Dual Capabilities
1697	Metric conversion prob-	N/A	600.00
1962	ably not needed for any		1800.00
2134	grinder on this page.		600.00
2245	All of these grinders		300.00
3069	are located in the Tool		600.00
3127	Sharpening Department.		300.00
3185			600.00
3414			300.00
3421			1800.00
3422			300.00
3425			600.00
3508			300.00

Machine Type *Hobs*

Drilco Machine Number	Conversion Costs		
	Remarks	Complete	Dual Capabilities
1519		$1900.00	
1755		1900.00	
1864		1900.00	
1941		1900.00	
2187		1900.00	

APPENDIX O - DUAL DIMENSIONED DIALS

In any metrication program associated with a manufacturing enterprise, conversion of machine tools looms as one of the major costs. If complete replacement of these tools is contemplated, the cost would indeed be astronomical for the average firm. However, modification of existing resources, done properly, offers a much more logical course of action with a greatly reduced price tag. In the case of Drilco, where the predominate machine in the plant is the lathe, machine modification offers considerable savings in capital outlays as well as drastically reduced losses due to machine down time. Because of machine tasking and the presence of NC machines, modification of most or all lathes, mills, and grinders, through the addition of dual reading dials, seems most appropriate.

The dual dial is a comparatively complex dial, having an internal system of gears, such that both inch and metric values can be directly dialed into a machine tool modified with the device. No other modification of the machine tool would be required. The dual dial indicates travel of a tool or platform in either inch or metric units and requires no operator conversion. Most dials are quite simple to install, with down time normally not exceeding 15 to 30 minutes per axis.

Unfortunately, little information is present as to the lifetime of these dials nor of their ability to maintain accuracy. Tests would have to be conducted to establish a more appropriate picture of the devices.

There are relatively few manufacturers of dual dials in the United States, with the major manufacturer being SIPCO Machine Co., of Marion, Massachusetts. SIPCO offers dials specifically designated for several models of grinders, mills, and lathes as well as master dials for adoption to virtually all other machine tools on the American market. Prices range from a low of $170 each to $610 each, with the average price at about $240 to $250 each. The following figures depict several dials in use plus a May, 1976 price listing for several dials.

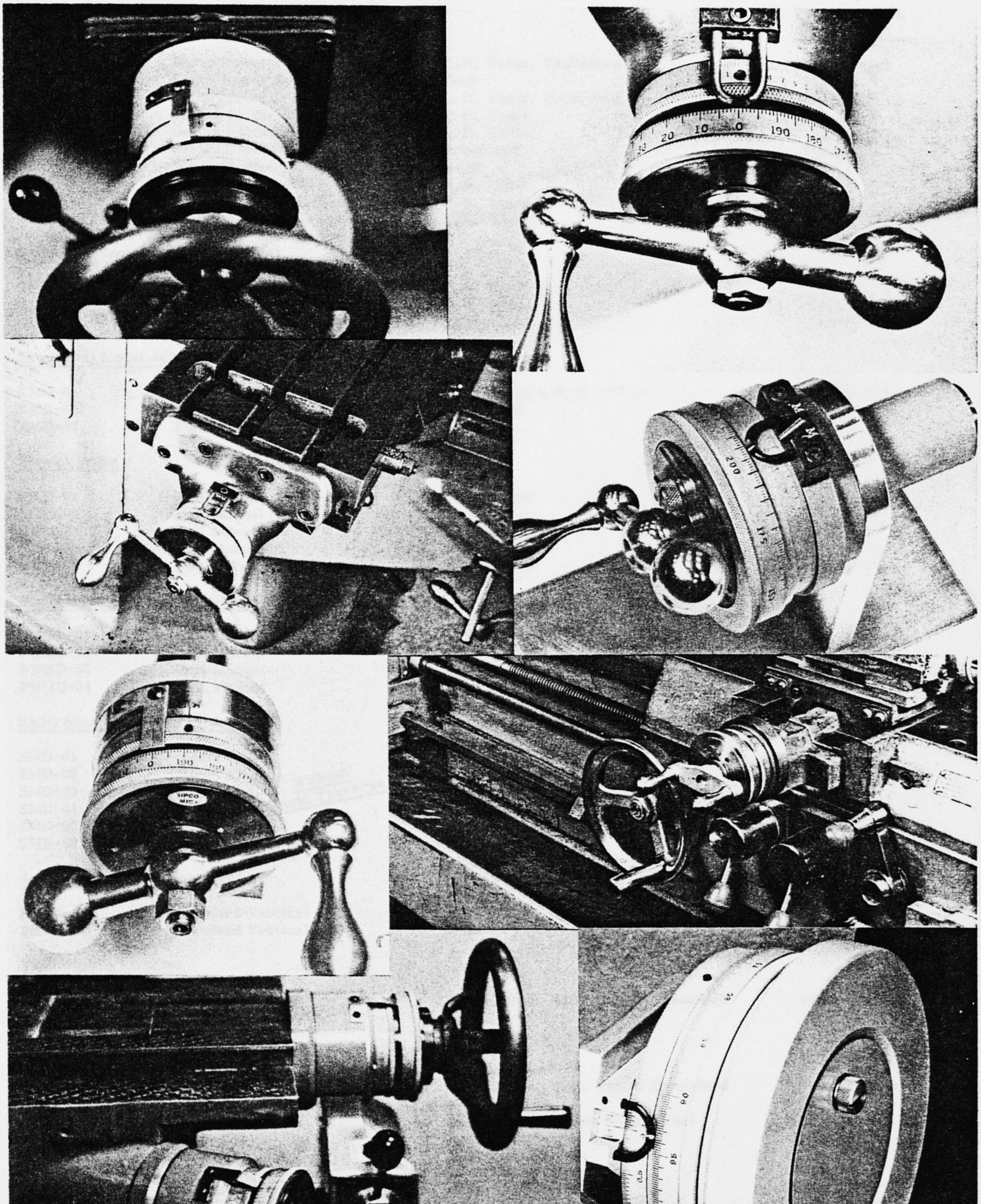


FIGURE 01

When Ordering, Please Give
Make, Model, Serial #, & Axis

SIPCO - MIC
INCH/METRE CONVERSION DEVICES

May 20, 1976

MILLING MACHINES

Prices F.O.B.
Marion, MA

Bridgeport Machines

BMD-06	Servo Power Feed	R.H. Table, Crossfeed	$235.00 each
BMD-07	Servo Power Feed	Knee	235.00 "
BMD-08	True Trace	L.H. Table, Crossfeed	310.00 "
BMD-09	Series I Mills Manual	R.H. Table	190.00 "
BMD-10	Series I Mills Manual	L.H. Table	190.00 "
BMD-11	Series I Mills Manual	Crossfeed	190.00 "
BMD-12	All Bridgeport Models	Knee	190.00 "
BMD-13	G.S. Power Feed	R.H. Table	190.00 "
BMD-14	OEM Inf. Variable Feed	R.H. Table	190.00 "
BMD-15	OEM Inf. Variable Feed	L.H. Table	190.00 "

Cincinnati Toolmaster (American)

CMD-01	Full Manual	L.H. Table & Crossfeed	$300.00 each
CMD-02	Full Manual	R.H. Table	300.00 "
CMD-03	Full Manual	Knee	300.00 "

Ex-Cell-O Model 602

XMD-01	Full Manual	L.H. Table & R.H. Table	$190.00 each
XMD-02	Full Manual	Crossfeed	190.00 "
XMD-03	Full Manual	Knee	190.00 "

Helmut Holke

HMD-01	Full Manual	L.H. Table	$190.00 each
HMD-02	Full Manual	Elevating	190.00 "
HMD-03	Full Manual	Crossfeed	190.00 "
HMD-04	Full Manual	R.H. Table	190.00 "
HMD-05	Power Feed	R.H. Table	190.00 "

Powermatic-Burke -- Millrite

PBMD-01	Full Manual	L.H. Table	$190.00 each
PBMD-02	Full Manual	R.H. Table	190.00 "
PBMD-03	Full Manual	Crossfeed	190.00 "
PBMD-04	Full Manual	Knee	190.00 "

SAJO Model Numbers 52 & 54

SMD-01	Model 52	R.H. Table & Crossfeed	$220.00 each
SMD-02	Model 52	L.H. Table	220.00 "
SMD-03	Model 52	Knee	230.00 "
SMD-01	Model 54	L.H. Table & Crossfeed	220.00 "
SMD-03	Model 54	Knee	230.00 "
SMD-04	Model 54	R.H. Table	220.00 "

Without
Rapid Traverse

South Bend Milling Machine

SBMD-01	Standard Vertical	L.H. Table, R.H. Table, Crossfeed	$210.00 each
SBMD-02	Standard Vertical	Knee	210.00 "

Tree Milling Machine

TMD-01	Full Manual	L.H. Table, R.H. Table, Crossfeed	$234.00 each
TMD-02	Full Manual	Knee	234.00 "

Wells Index Mill Models 747, 847, 860, 887

IMD-01	Manual	L.H. Table, R.H. Table, Crossfeed	$225.00 each
IMD-02	Manual	Knee	225.00 "
IMD-03	Power	Saddle, R.H. Table (with Servo)	235.00 "
IMD-04	Power	Knee (with Servo)	235.00 "
	Model 645		
IMD-05	Manual	L.H. Table, Crossfeed	225.00 "
IMD-06	Manual	R.H. Table	225.00 "
IMD-07	Manual	Elevating	225.00 "

Prices subject to change without notice.

When Ordering, Please Give
Make, Model, Serial #, & Axis

SIPCO - MIC
INCH/METRE CONVERSION DEVICES

May 20, 1976

TURNING MACHINES

			Prices F.O.B. Marion, MA
American Tool Lathes			
ALS-01	14" thru 20"	Compound (250)	$250.00 each
ALD-02	14" thru 20"	Cross Slide (400)	350.00 "
ALS-03	14" thru 20"	Tailstock (200)	260.00 "
Barer-Meuser			
BMLS-01	KMI - 16"	Cross Slide (250)	$258.00 each
BMLS-02	KMI - 16"	Compound (250)	258.00 "
Clausing Lathes			
CLS-01	Model 1300	Cross Slide (200)	$181.00 each
CLS-02	Model 1300	Compound (100)	185.00 "
CLS-04	Model 1500	Cross Slide (200)	181.00 "
CLS-05	Model 1500	Compound (100)	185.00 "
CLS-07	Model 5900	Cross Slide (200)	181.00 "
CLS-08	Model 5900	Compound (200)	170.00 "
CMT - Lansing "T" Lathes			
FTD-01	16", 18" & 20"	Cross Slide (400)	$375.00 each
FTD-02	16", 18" & 20"	Compound (200)	300.00 "
Dean, Smith & Grace Lathes			
DSLD-01	Model 1342	Cross Slide (400)	$282.00 each
DSLS-02	Model 1342	Compound (250)	198.00 "
Elliott Machine - Invicta Lathe			
ELD-01	17" & 20"	Cross Slide (400)	$350.00 each
Graziano Lathe			
GLD-01	SAG 14"	Cross Slide (400)	$390.00 each
GLS-02	SAG 14"	Compound (100)	210.00 "
Hardinge Brothers Lathes			
HLS-01	Model HLV-H	Cross Slide (200)	$170.00 each
HLS-02	Model HLV-H	Compound (100)	170.00 "
HLS-03	Model HLV-H	Tailstock (100)	180.00 "
HLS-04	Model HLV-H	Carriage (120)	180.00 "
Harrison Lathe -- 15"			
HALS-01	15" Lathe	Cross Slide (200)	$185.00 each
HALS-02	15" Lathe	Compound (100)	181.00 "
Houdaille-Powermatic Logan Lathes			
PLLS-01	10" & 11"	Cross Slide (100)	$185.00 each
PLLS-02	10" & 11"	Compound (100)	185.00 "
PLLS-03	12"	Cross Slide (100)	207.00 "
PLLS-04	12"	Compound (100)	180.00 "
PLLS-05	14"	Cross Slide (100)	207.00 "
PLLS-06	14"	Compound (100)	180.00 "
Le Blond Lathes			
LLS-02	13", 15" & 16" Regal, 14" T&D	Cross Slide (250)	$185.00 each
LLS-03	13", 15" & 16" Regal, 14" T&D	Compound (100)	181.00 "
LLS-04	17" & 19" Regal	Cross Slide (400)	215.00 "
LLS-05	17" & 19" Regal	Compound (200)	185.00 "
LLS-06	21" & 24" Regal	Cross Slide (400)	230.00 "
LLS-07	21" & 24" Regal	Compound (250)	185.00 "
LLS-08	14" T&D	Tailstock (192)	185.00 "
LLS-09	Special 15" C Regal	Compound (100)	185.00 "

Prices subject to change without notice.

When Ordering, Please Give
Make, Model, Serial #, & Axis

SIPCO - MIC
INCH/METRE CONVERSION DEVICES

May 20, 1976

TURNING MACHINES (cont'd . . .)

Prices F.O.B.
Marion, MA

Lodge & Shipley Lathes

LLD-01	AVS 2013, 2013-17, 2XB13, 2XC16, 2XC20	Cross Slide (400)	$375.00 each
LLD-02	AVS 2013, 2013-17, 2SB13, 2XC16, 2XC20	Compound (200)	275.00 "
LSLD-03	AVS-1408	Cross Slide (400)	400.00 "
LSLS-04	AVS-1408	Compound (200)	275.00 "
LLD-05	GA 14 x 10	Cross Slide (200)	336.00 "
LLD-06	GA 14 x 10	Compound (200)	331.00 "

Kerry Lathes

KLS-01	Model 1140	Cross Slide (100)	$205.00 each

Monarch Lathes

MLS-04	10" EE	Cross Slide (250)	$285.00 each
MLS-02	10" EE	Compound (200)	173.00 "

Rockwell Delta Lathes

RDLS-01	25-100 Series 11"	Cross Slide (200)	$207.00 each
RDLS-02	25-100 Series 11"	Compound (200)	185.00 "
RDLS-03	25-200 Series 14"	Cross Slide (200)	207.00 "
RDLS-04	25-200 Series 14"	Compound	185.00 "
RDLS-05	25-700 Series 10"	Cross Slide (200)	185.00 "
RDLS-06	25-700 Series 10"	Compound (200)	185.00 "

Sheldon Machine Lathes

SHLS-01	R Series 10" - 17"	Cross Slide (250)	$233.00 each
SHLS-02	R Series 10" - 17"	Compound (125)	198.00 "
SHLS-03	M & S Series	Cross Slide (250)	233.00 "
SHLS-04	M & S Series	Compound (125)	198.00 "

South Bend Lathes

SLS-01	13", 14" & 16"	Compound (200)	$185.00 each
SLS-02	13", 14" & 16"	Cross Slide (250)	198.00 "
SLS-03	10" & 12"	Cross Slide (200)	185.00 "
SLS-04	10K, 10" & 12"	Compound (200)	185.00 "
SLS-04	10K	Cross Slide (200)	185.00 "
SLS-05	17" & 20", Turn-nado	Cross Slide (250)	221.00 "
SLS-06	17" & 20", Turn-nado	Compound (200)	185.00 "
SLD-08	Nordic 15"	Cross Slide (400)	332.00 "
SLS-09	Nordic 15"	Compound (200)	185.00 "

Standard Modern Lathes

SMLS-01	D1-4	Cross Slide (200)	$185.00 each
SMLS-02	D1-4	Compound (200)	185.00 "
SMLS-03	D1-6	Cross Slide (400)	238.00 "
SMLS-04	D1-6	Compound (200)	185.00 "
SMLS-05	D1-8	Cross Slide (400)	238.00 "
SMLS-04	D1-8	Compound (200)	185.00 "

Prices subject to change without notice.

When Ordering, Please Give
Make, Model, Serial #, & Axis

SIPCO - MIC
INCH/METRE CONVERSION DEVICES

May 20, 1976

GRINDING MACHINES

Prices F.O.B.
Marion, MA

Boyar-Schultz Surface Grinders

BSGS-01	Model 612 & 618	Elevating (.050)	$550.00 each
BSGS-02	Model 612 & 618	Crossfeed (.100)	550.00 "

Brown & Sharpe Surface Grinders

Sipco Model #	B & S Model #	Style	Feed	Axis	
BGS-01	510, 612	Old	.0002	Elevating (.050)	$550.00 each
BGS-10	510, 612	Old	.0001	Elevating (.050)	610.00 "
BGS-05	510, 612	New	.0002	Elevating (.050)	550.00 "
BGS-12	510, 612	New	.0001	Elevating (.050)	610.00 "
BGS-03	510, 612	Old	.0002	Crossfeed (.100)	550.00 "
BGS-09	510, 612	Old	.0001	Crossfeed (.100)	610.00 "
BGS-04	510, 612	New	.0002	Crossfeed (.100)	550.00 "
BGS-11	510, 612	New	.0001	Crossfeed (.100)	610.00 "
BGS-02	618	Old	.0001	* Elevating (.050)	610.00 "
BGS-15	618	Old	.0001	** Elevating (.050)	610.00 "
BGS-13	618	Old	.0002	Crossfeed (.100)	550.00 "
BGS-14	618	Old	.0001	Crossfeed (.100)	610.00 "
BGS-07	618, 818	New	.0001	Elevating (.050)	610.00 "
BGS-06	618, 818	New	.0002	Crossfeed (.100)	550.00 "
BGS-08	618, 818	New	.0001	Crossfeed (.100)	610.00 "
BGS-17	824	Old/New	.0001	Elevating (.050)	610.00 "
BGS-16	824	Old/New	.0001/.0002	Crossfeed (.100)	610.00 "

Note: "New Style" Machines can be identified by the 4" Blue Disc on the handwheels.
*: Bed Mounted Handwheel
**: Column Mounted Handwheel

Clausing Surface Grinders

CGS-01	Model 4020	Crossfeed	$575.00 each
CGS-02	Model 4020	Elevating	575.00 "
CGS-03	Model 4002	Crossfeed	575.00 "
CGS-04	Model 4002	Elevating	575.00 "

Gardner Grinders

GGS-01	Model 618	Crossfeed	$595.00 each
GGS-02	Model 618	Elevating	575.00 "

Harig Surface Grinders

HGS-01	F-612 & F-618	Elevating (.050)	$550.00 each
HGS-02	F-612 & F-618	Crossfeed (.100)	550.00 "
HGS-03	F-612 & F-618	Crossfeed (.050)	550.00 "

Hybco Surface Grinders

HYGS-01	Model 1900	Elevating (.100)	$550.00 each
HYGS-02	Model 1900	Crossfeed (.100)	550.00 "
HYGS-03	Model 1900	Table (.100)	550.00 "

Parker-Majestic Surface Grinders

PGS-01	Model 2Z	Elevating (.01)	$550.00 each
PGS-02	Model 2Z & Model 2	Crossfeed (.125)	575.00 "
PGS-03	Model 2	Elevating (.050)	575.00 "

Pratt & Whitney Tool & Radius Grinders

PWGS-01	R-6 & R-9	Cutter Swivel Top Slide (.100)	$220.00 each
PWGS-02	R-6 & R-9	Wheel Spindle Col. Base Slide (.100)	220.00 "
PWGS-03	R-6 & R-9	Work Spindle Col. Vertical Slide (.100)	220.00 "
PWGS-04	R-6 & R-9	Cutter Swivel Cross Slide (.100)	220.00 "

Taft-Peirce Surface Grinders

TGS-01	Model #1	Elevating (.050)	$550.00 each
TGS-02	Model #1	Crossfeed (.100)	550.00 "

K.O. Lee Surface/Tool & Cutter Grinders

KLGS-01	Elevating (.050)	$550.00 each
KLGS-02	Crossfeed (.100)	550.00 "

Prices subject to change without notice.

APPENDIX P - EDUCATIONAL REQUIREMENTS

One of the most misunderstood segments of a metric conversion is the education and retraining aspect of employee indoctrination. The generally held belief is that an extensive metric education will be required by all segments of the firm to assure the success of any conversion program. This training would be required by all employees, including non-technical personnel, and that the training would require several class hours.

However, retraining and education should be one of the minor areas of an extensive conversion program; but, it will be the first step needed before any metrication activity can be started. Before commencing with such training, two factors should be considered:

(1) the training should cover only those areas of metrication that directly impact the job of an individual and familiarity with that aspect of the metric system would be needed for adequate completion of the particular job, and

(2) the training would be required just prior to implementation of a conversion program for the particular job.

Failure to adhere to these two points will result in either over training, under training, or inadequate training. The education would be wasted. It is important that the classes should cover only a minimum amount of material but enough to assure competancy for the level of work to be done by the student. And, the classes should be given just prior to the particular metric activity, assuring that the training will be fresh in the minds of the students.

The following lists, by general job description, are suggested for establishment of the specialized classes. Several blocks are quite similar and could be easily standardized for application to groups.

JOB DESCRIPTION

General (simplified) - training for individual not exposed to or working with metrics.

COURSE DESCRIPTION

1. General definition of metric units and prefixes.
2. General definition of derived metric units.
3. Exercises using metric and derived units.

ALLOCATED TIME

Minimum: ½ hour
Maximum: 1 hour

MATERIAL

Simplified metric text

NOTE - Classes at this level would not required for any metrication program, could be purely voluntary, and could be non-mandetroy.

JOB DESCRIPTION

General (non-specific) - training for top and middle managers, non-technical personnel handling product descriptions, salesmen, and department heads.

COURSE DESCRIPTION

1. History and structure of the metric system.
2. History and definition of prefixes and suffixes for the metric system.
3. Definition of supplemental and derived units.
4. Exercises covering general metric topics, including use of prefixes and suffixes.
5. Exercises covering general everyday use of metrics at Drilco.

ALLOCATED TIME

Minimum: 1 hour
Maximum: 2 hours

MATERIAL

Simplified metric text.

JOB DESCRIPTION

Technical - for technicians, shop personnel, machinists, inspectors, and draftsmen.

COURSE DESCRIPTION

1. Definition and history of metric units.
2. Definition and history of metric prefixes.
3. Definition and history of derived and supplemental units.
4. Exercises using metric units.
5. Exercises using metric prefixes.
6. Exercises using derived and supplemental units.
7. Dual measuring systems.
8. ISO gaging systems and modified OMFS gaging systems

ALLOCATED TIME

Minimum: 1½ hours
Maximum: 2 hours

MATERIAL

Simplfied metric text with suppliments on dual measuring systems (extract from ANSI Drafting Standards) and on the modified OMFS.

JOB DESCRIPTION

Engineers - for engineers, scientists, and associated individuals

COURSE DESCRIPTION

1. Definition and history of metric units.
2. Definition and history of metric prefixes.
3. Definition and history of derived and supplemental units.
4. Exercises using metric units.
5. Exercises using metric prefixes.
6. Exercises using derived and supplemental units.
7. Dual measuring systems.
8. ISO gaging systems and modified OMFS gaging systems.
9. Simplification of accepted mathematical formulas using metrics.
10. Round off errors and their consequences.
11. Appropriate metric reference texts and accepted metric standards.

ALLOCATED TIME

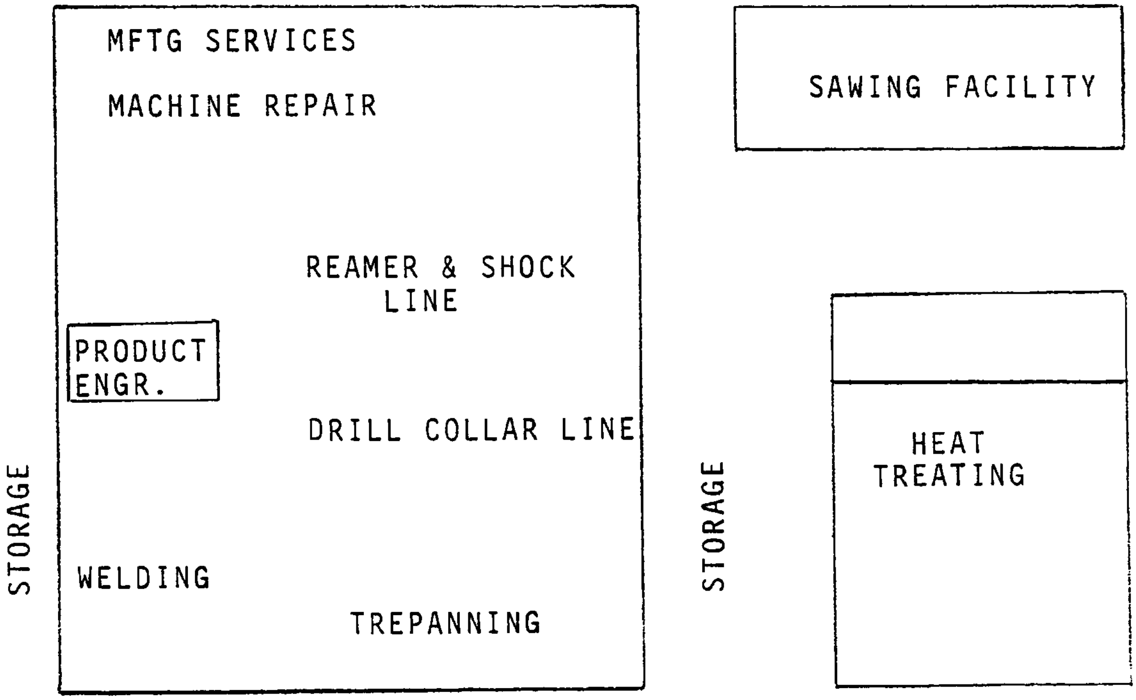
Minimum: 2 hours
Maximum: 3 hours

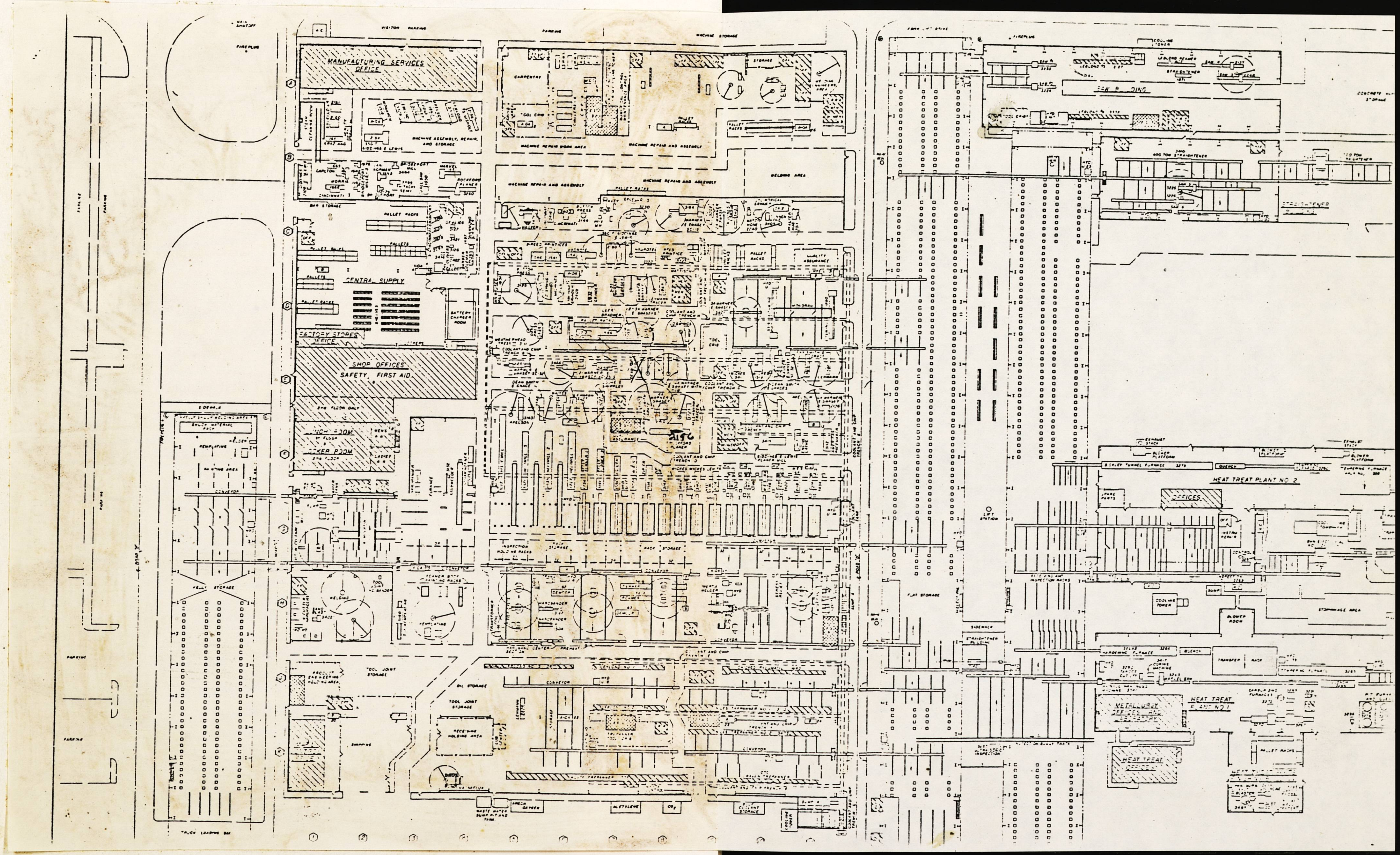
MATERIAL

Advanced metric text
API Pub. 2563
API Pub. 2564

APPENDIX C

The figure below depicts the basic plant layout of the Drilco, Houston, manufacturing facilities. A more detailed plot plan, on the succeeding page, was used to identify and analyze the use of machinery in the manufacturing process.





PLOT PLAN OF THE DRILCO
MANUFACTURING FACILITY

APPENDIX D

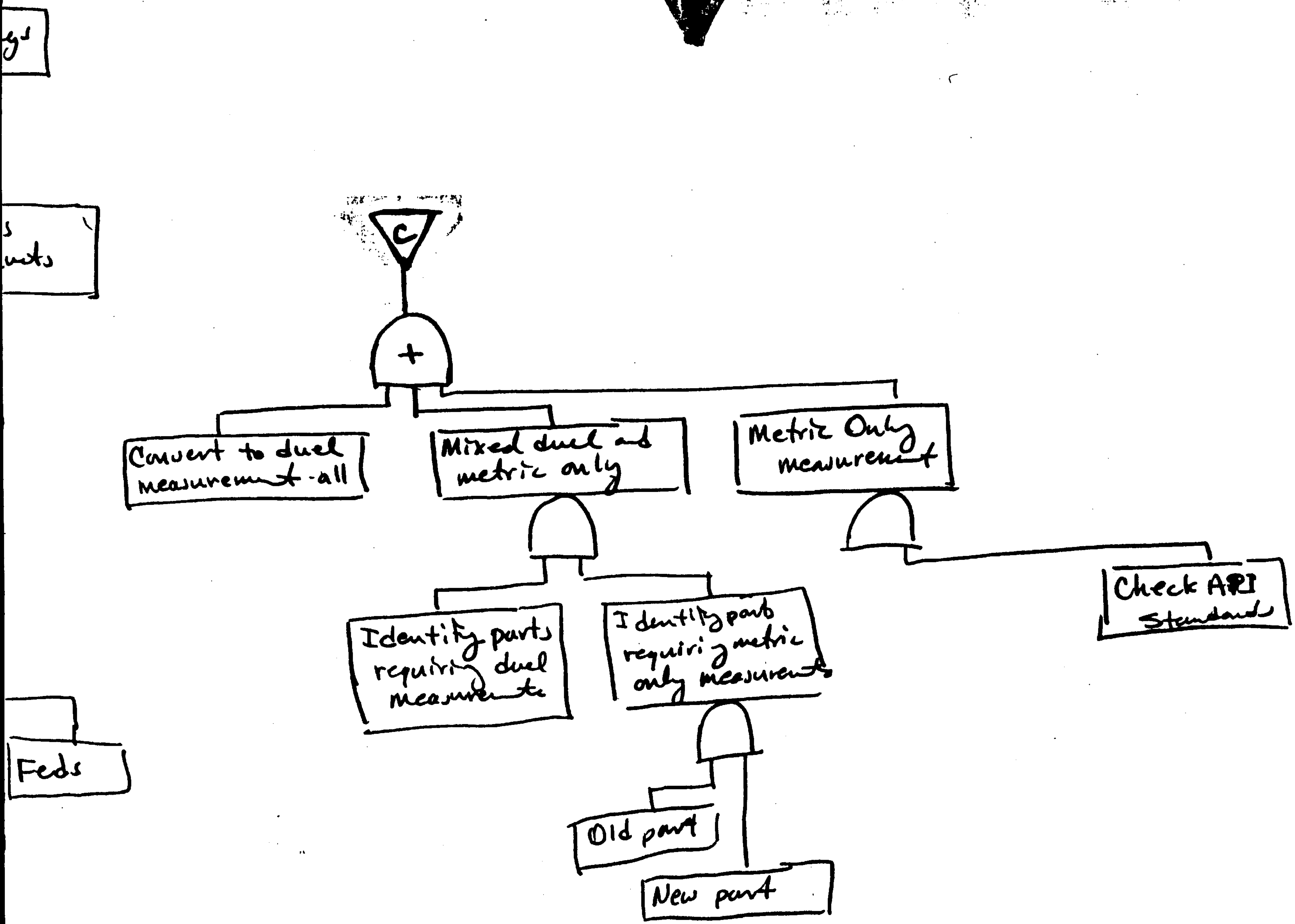
The following diagram was extracted from an extensive network analysis of the Drilco Manufacturing Plant. The complete network covered an area 8'x5', and detailed the anticipated methods for conversion of the plant.

This particular branch deals with the conversion of plant machinery to one of three choices: convert all machines so that they have complete dual measuring and readout capabilities, convert some tools to the metric system and leave others as they are, or convert all machines to the metric system.

If the machines had dual measuring capabilities, they could be utilized in the manufacturing of either English or metric drilling tools. Futher consideration of that portion of the branch was not necessary.

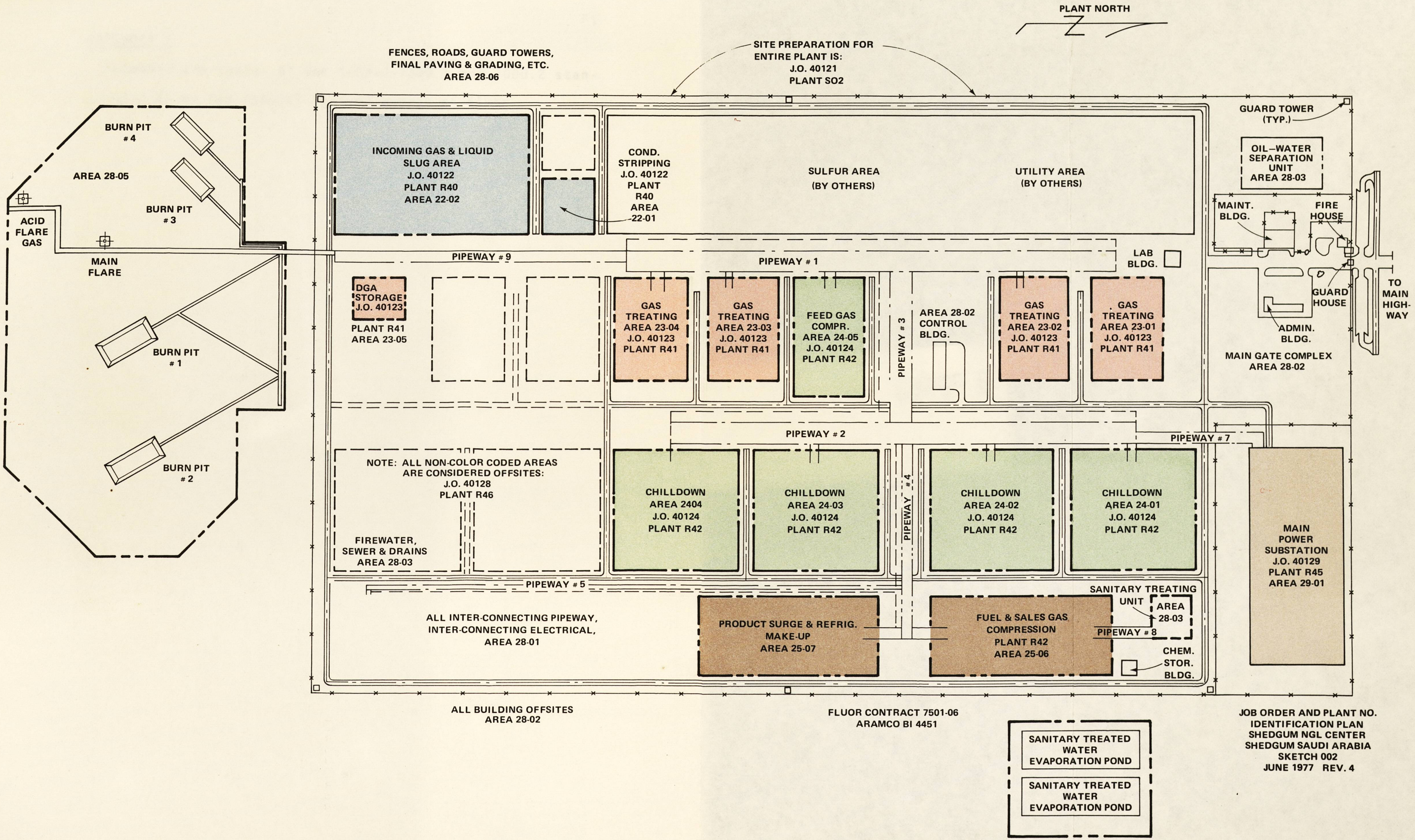
If some machines were converted and other were not, problems would arise which would require the shifting of unfinished parts during manufacture. Therefore, this situation dictated that the branch be continued to consider the impact of such a conversion technique on the flow of material through manufacturing.

Finally, if all machines were converted to the metric system only and all drawings were in metric, the major impact would fall on the adherence to API standards.


gs
s
nts
C
+
Convert to duel measurement-all
Mixed duel and metric only
Metric Only measurement
Identify parts requiring duel measurements
Identify parts requiring metric only measurements
Check API Standards
Old part
New part
Feds

APPENDIX E

The following is the plot plan for the Shedgum NGL Center.



JOB ORDER AND PLANT NO.
IDENTIFICATION PLAN
SHEDGUM NGL CENTER
SHEDGUM SAUDI ARABIA
SKETCH 002
JUNE 1977 REV. 4

[redacted]

SECTION 9 - CONTROL VALVES

1.0 Control Valves

1.1 Bypass valves. The bypass valve shall have a capacity which is equal to or slightly greater than the capacity (CV) of the control valve and it shall be a globe or throttling ball type according to the type of control valve. Control valves shall be supplied with a handwheel where a bypass valve is not required.

CV VALVES FOR BYPASS VALVES

	GLOBE TYPE	BALL TYPE
1"	12	------
1½"	28	------
2"	48	------
3"	110	------
4"	195	500
6"	450	1,000
8"	750	1,650
10"	1160	2,600
12"	1620	3,600
16"	2560	6,000
24"	----	13,500

1.2 The standard sizes, connections and minimum ratings of control valves shall be:

1.2.1 Control valves for all process services 1" through 16" shall be flanged service ANSI 300 lbs. RF minimum.

1.2.2 24" flanged V-Ball flanged service ANSI 150 lbs. RF. minimum, can be considered.

1.2.3 For butterfly valves - heavy pattern Fishtail disc (or equal) 12" , 16", 20", 24", 30", and 36" for mounting between ANSI 150 (Min.) lbs. RF flanges.

NOTE - 1 Use of Highball valves 600 lbs. and up should be avoided Use , , or trunnion type control valves.

NOTE - 2 ball control valves have approximately 3% leakage.

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ENGR.

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J.O.				

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SECTION 9 - CONTROL VALVES - (Continued)

1.3 Types of valves to be used.

1.3.1 Cage trim type globe valves shall be used up to 8" in body size. Larger valves may be used if required by process conditions.

1.3.2 Throttling type ball valves shall be used in sizes from 4" and up, except where noise level is excessive.

1.4 When tight shutoff is required, except for temperature over 450°F, soft seated valves shall be specified. These are to be used for water drainoff and knockout drums, not for gas supply isolation.

1.5 The noise generated by a valve and its associated diffuser or silencer on gas or steam service shall be calculated and shall not be greater than 90 dBa at 3 ft, except for recycle valves and other valves which are normally closed for which the noise limit shall be 95 dBa.

1.6 Low noise trim valves, low dB plates, diffusers and silencers shall be used as necessary. Special attention should be given to possible plugging with low noise trim valves: (, , , and shall be considered).

1.7 Where noise calculation is greater than 90 dBa use 7° taper reducers and schedule 40 pipe or heavier, downstream. With ball valves and butterfly valves, use schedule 40 or heavier both upstream and downstream. For 85 to 90 dB use 12° taper reducers. Below 85 dB use standard reducers.

1.8 In those applications where the use of low noise valves and increased line schedule still do not provide a low enough noise level, use of heavy duty rock wood and lead sheeting downstream and upstream of the valve will be required.

1.9 When cavitation is likely to occur precautions must be taken to minimize cavitation damage. Calculations shall be done according to AES-J-23. Anti-cavitation trim shall be used where necessary. When appreciable cavitation may be expected a noise calculation shall be done. (Control Valves should be considered for high differential pressure liquid application.)

1.10 Capacities, noise calculations, etc., may be shown on a second specification sheet for all control valves, if enough space is not available on the first sheet.

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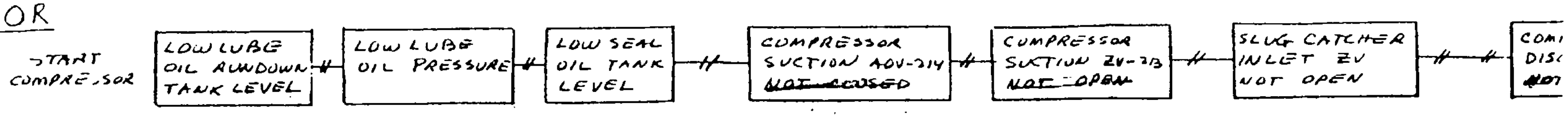
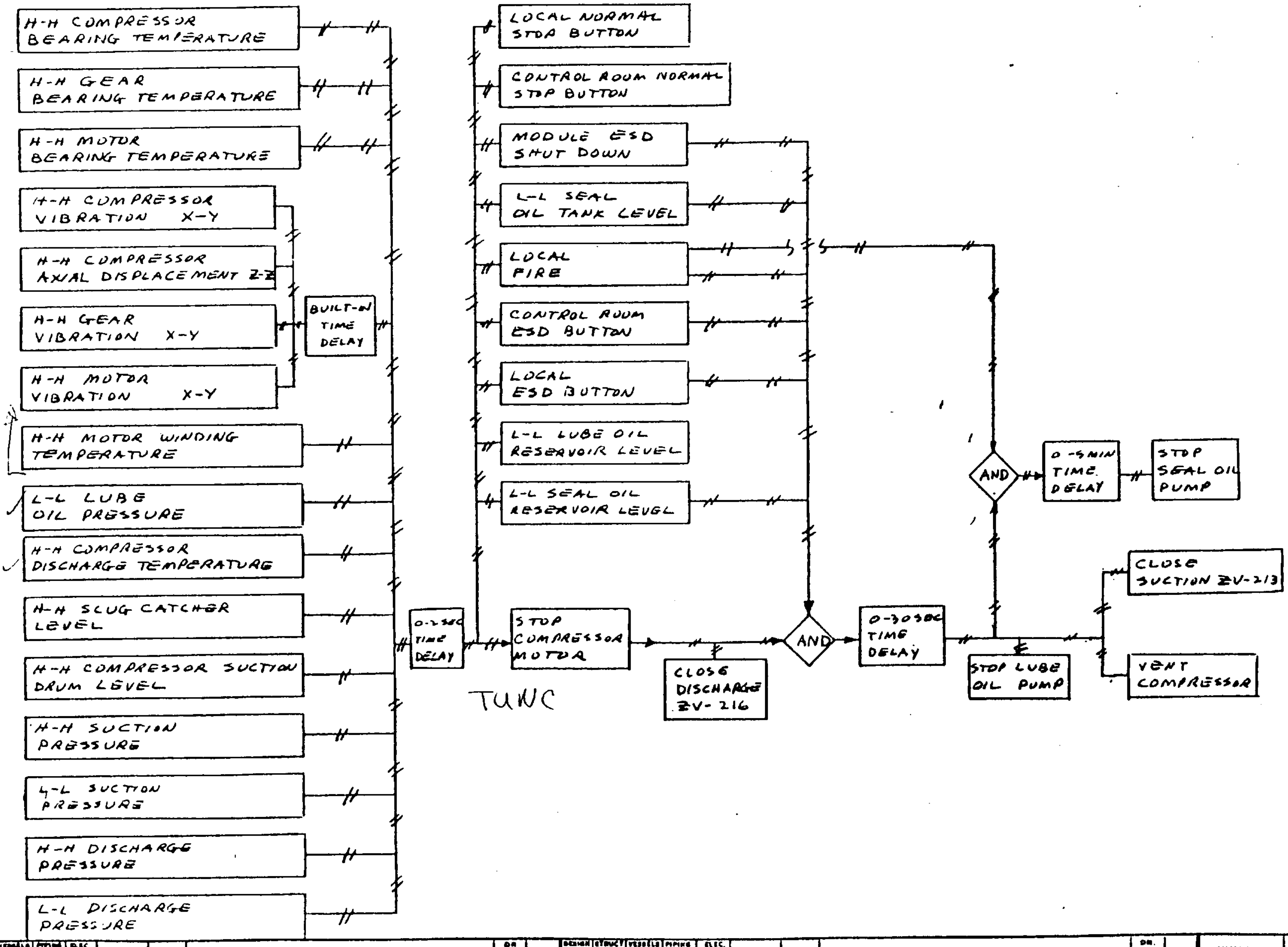
APPENDIX G

Many of the requirements and specifications for the LPPT compressor's ESD logic diagrams were derived from a process flow chart (first attachment). These were converted into a logic design which could be used for the construction of the ESD logic cards.

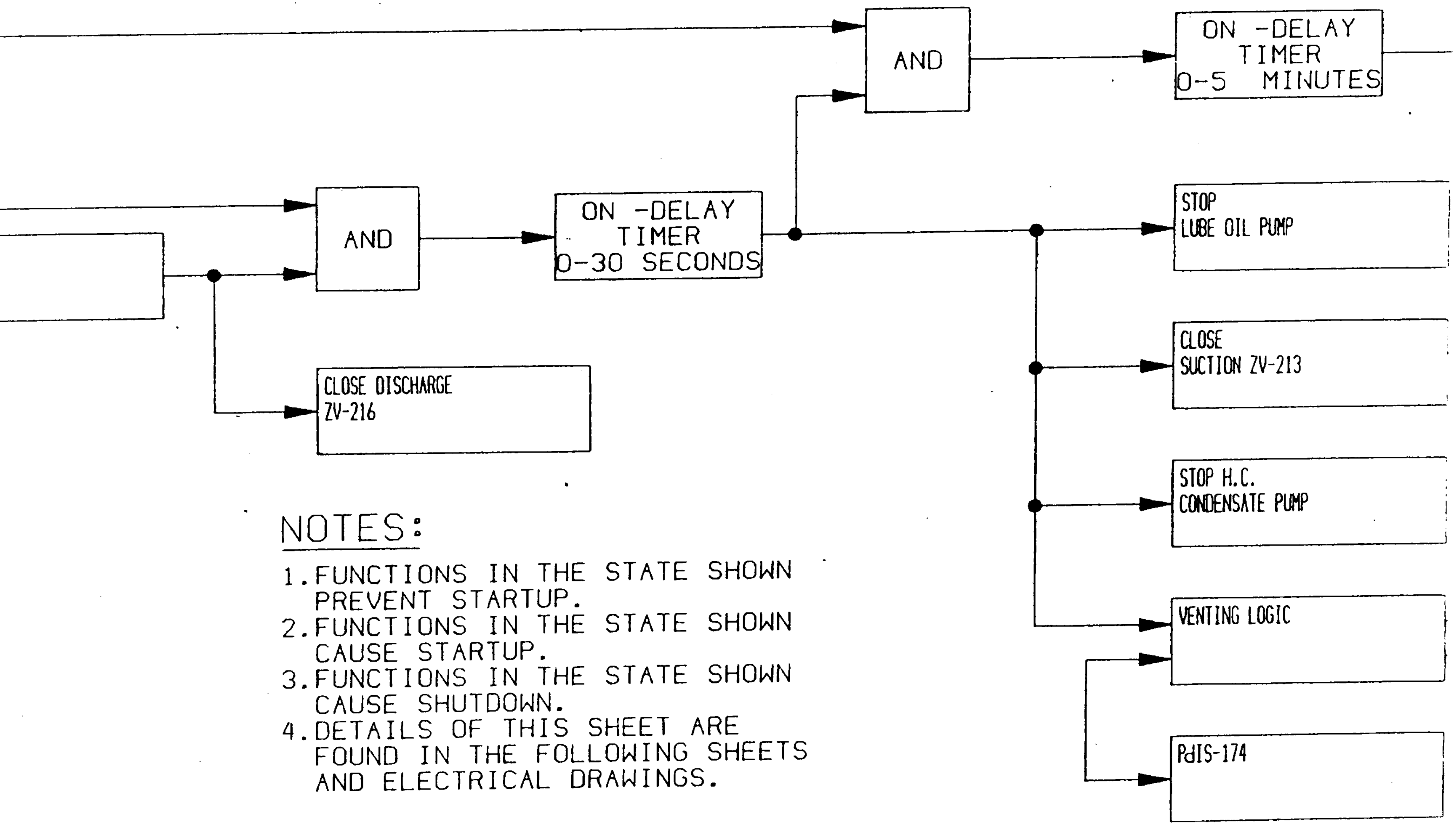
START COMPRESSOR



SHUTDOWN COMPRESSOR



DESIGN	STRUCT	VESSELS	PIPING	ELEC.	MK	DATE	REVISIONS	DR. CH.	APP.	DESIGN	STRUCT	VESSELS	PIPING	ELEC.	MK	DATE	REVISIONS	DR. CH.	APP.	NUMBER	REF



NOTES:

1. FUNCTIONS IN THE STATE SHOWN PREVENT STARTUP.
2. FUNCTIONS IN THE STATE SHOWN CAUSE STARTUP.
3. FUNCTIONS IN THE STATE SHOWN CAUSE SHUTDOWN.
4. DETAILS OF THIS SHEET ARE FOUND IN THE FOLLOWING SHEETS AND ELECTRICAL DRAWINGS.

APPENDIX H

Attached are copies of the data sheets for the individual loads assigned to the UPS and a summary sheet showing how the loads were distributed.

DATA SHEET

FOR

UPS INDIVIDUAL BRANCH CIRCUIT LOAD

1. Load description: SHUTDOWN SOLENOID RELAY
Qty/Module = 20 ; # Modules = 1
TOTAL = 20

2. Emergized Load

2.1 Nominal VA & Power Factor VA 3 PF ___

2.2 Maximum VA & Power Factor VA 4 PF ≈.35

3. Transient Characteristics

3.1 Inrush VA & Power Factor Negligible VA ___ PF ___

3.2 Load energy feed back to UPS VA 0 for 0 Seconds

3.3 Non-linear load to UPS Yes ___ No ✓

4. Load Duty Cycle Continuous ✓ Momentary ___

5. Load Location

5.1 Cable length to UPS — Feet

5.2 Plant area or substation (see attachment) # CONTROL ROOM RACK

5.3 Assigned to or part of Equip. # Equip. # ___

5.4 Load effects process train(s) None ___ #1 X #2 ___ #3 ___ #4 ___

6. UPS Suppling Load (see attached Equipment List) Equip. # ___

Your Name ___ Extension ___ Room ___

Your Comments:

RETURN TO:
KEN ALLEN T2-788E
For questions call X-3315

PLANT	INDEX	DRAWING NUMBER	SH. NO.	REV.
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J.O.				

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INSTRUMENT POWER SUPPLY DESCRIPTION	# MAIN	# AUX	NOMINAL LOAD VA	MAXIMUM LOAD VA	INRUSH AMPERES	UPS LOAD (TOTAL NOMINAL LOAD/TOTAL MAX LOAD)			
						R46-P-132X-1	R46-P-132X-2	R46-P-132X-3	R46-P-132X-4
ANALOG EQUIPMENT	2	0		850	15	0/0	/	/850	/850
ANALOG EQUIPMENT - BACKUP	0	1	70	850	15	70/850	/	0/0	0/0
RIGHT ANNUNCIATOR STATION	1	0	508	750	16	0/0	/	508/750	0/0
LEFT ANNUNCIATOR STATION	1	0	90	750	16	0/0	/	0/0	90/750
ANNUNCIATOR STATION BACKUP	0	1	60	750	16	60/750	/	0/0	0/0
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
STATUS LIGHTS	40	-		5.88	-	/	/	212/212	24/24
POWELL C-2 SYSTEM	0	-		12.0	.3	/	/	0/0	0/0
ZV - AOV RELAYS	6	-		4.0	-	/	/	24/24	0/0
INTERPOSING RELAYS	0	-		4.0	-	/	/	/	/
MOV - AOV - ZV STATUS LIGHTS	12	-		5.88	-	/	/	18/36	18/36
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
SHUTDOWN RELAYS	21	-		4.0		/	/	40/40	44/44
H_2S AREA CONTROLLERS	0	-				/	/	/	/
						/	/	/	/
Dual Coil Solenoid	6			50	1.125	/	/	300/300	/
						/	/	/	/
						/	/	/	/
						/	/	/	/
						130/1600		1102/2212	176/1704

PANEL NO. R42-61 XCR991 LOCATION Fuel & Sales Gas AREA 25-06

APPENDIX I

To monitor the status of P.O.s, a tracking log was maintained (an example page is attached). Jobsite Need Dates on the log were derived from the Commodity Procurement Schedule, similar to the Jobsite Need Date Schedule which was just resently created.

DATE 5/20/77

PAGE ___ of ___

BY OMK

PLANT Shedgum

PO # F6-RXX-04-0007 & 0107

BALL VALVES

MANUFACTURER	REQUISITION #	INSTR.	AREA	DATE PO LET	PROJECTED FAB TIME (MONTHS)	VENDOR SHIPPING DATE	EXPECTED JOBSITE DELIVERY DATE	REQUIRED JOBSITE DELIVERY DATE	DAYS BEHIND SCHEDULE	
[redacted] √	R40-04-0007		22-01,02	2/7/77		12/1/77	3/1/78	3/1/78	0	
√	R41-04-0007		23-04	1/4/77		12/1/77	3/1/78	3/1/78	0	
	↓		23-03	↓		↓	↓	9/1/78	0	
	↓		23-02	↓		↓	↓	11/1/78	0	
	↓		23-01	↓				1/1/79	0	
√	R42-04-0007		24-04	1/20/77		11/1/77 1/1/78	2/1/78 4/1/78	12/1/77	60 120	7 5
	↓		24-03	↓		↓		10/1/78	0	
	↓		24-02	↓		↓	↓	12/1/78	0	
	↓		24-01	↓		↓	↓	2/1/79	0	
√	R42-04-0107		25-07	1/20/77		12/1/77	3/1/78	12/1/77	90	18
	↓		25-06	↓		↓	↓	5/1/78	0	
√	R46-04-0007		28-01,05	1/3/77		9/1/77	12/1/77	7/1/78	0	
√	R42-04-0007		24-05			7/1/77	12/1/77	1/1/78	0	

LEGEND

△ JOBSITE NEED DATE

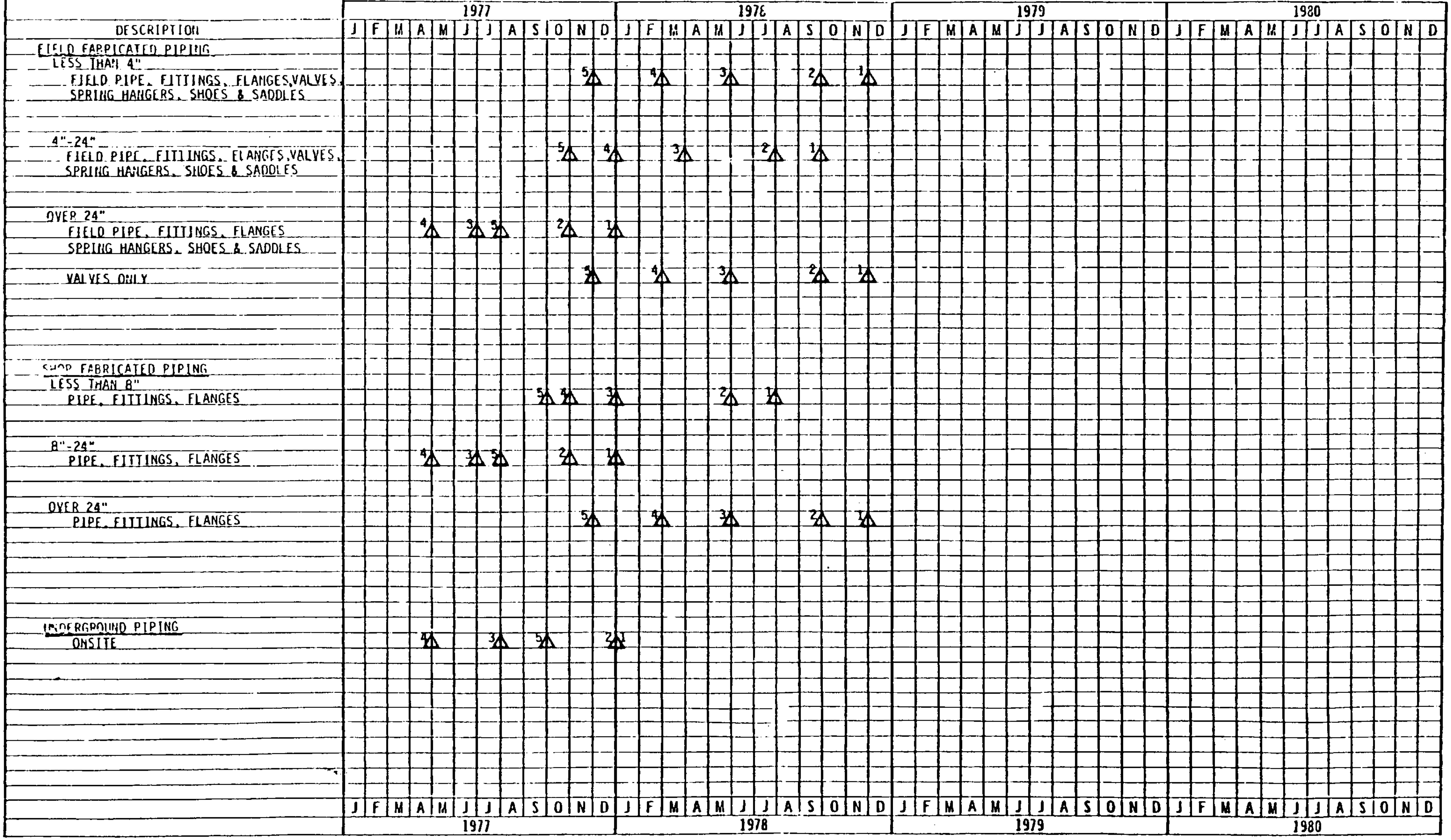
AREA 23

[redacted]

JOBSITE NEED DATE SCHEDULE

PIPING

[redacted]



APPENDIX J

Attached are copies of two I.A.M. bills distributed at the Drilco gates. Also, the reply circulated at the plant by management is included. The union was quite active for short periods of time, but only really attempted unionization of the plant after the author had left. The union succeeded in calling an election, but the attempt failed.

WHO RUNS THE UNION?

...YOU DO!

In The AFL-CIO, You and Your Fellow Employes Run the Union

YOU *elect your own local union officers.*

YOU *run your own local union affairs.*

YOU *elect your own negotiating committee.*

YOU *make the decisions on your own union contract.*

YOU *choose your own shop stewards.*

YOU *decide important policies and actions of your own union by majority vote.*

YOU *elect your international union officers.*

YOU *elect your own delegates to the international union conventions.*

YOU *—the membership—are the final voice of authority and decision in your* AFL-CIO *Union.*

YOU *are the Union's real 'boss.'*

YOU ARE THE UNION

CONGRATULATIONS:

DRILCO IS IN THE PROCESS OF HANDING OUT THE YELLOW EVALUATION SLIPS!

VERY FEW OF YOU RECEIVE A RAISE...MOST OF YOU RECEIVED ONLY A NAME CHANGE IN JOB CLASSIFICATIONS; WITH NO WAY TO REACH TOP PAY IN YOUR PARTICULAR CLASSIFICATION.

THIS RE-EVALUATION AND CLASSIFICATION CHANGE LOOKS GOOD ON PAPER BUT TRY TO TAKE THE SLIP YOU RECEIVE AND SPEND IT IN THE STORE.

WITH A UNION CONTRACT YOU KNOW FOR SURE WHERE YOU STAND; AND HAVE A VEHICLE TO

ATTENTION DRILCO EMPLOYEES:

THE INTERNATIONAL ASSOCIATION OF MACHINIST AND AEROSPACE WORKERS, AFL-CIO, WILL CONDUCT OPEN COMMITTEE MEETINGS ON JANUARY 4, 5, AND 6, 1977 AT THE GREENSPOINT INN, ROOM #103, LOCATED ON INTERSTATE #45.

THE MEETING HOURS WILL BE AS FOLLOWS:

TUESDAY, JANUARY 4th.	...	12:00 NOON	TO	12:00 MIDNIGHT
WEDNESDAY, JANUARY 5th.	...	7:00 AM	TO	12:00 MIDNIGHT
THURSDAY, January 6th.	...	7:00 AM	TO	12:00 MIDNIGHT

GET THE STRAIGHT FACTS ON WHAT THE MACHINIST UNION ORGANIZING PROGRAM IS ALL ABOUT AND HOW IT CAN BENEFIT YOU.

YOU ARE WELCOME TO COME BY ANYTIME DURING THESE HOURS AND JOIN WITH YOUR CO-WORKERS IN ESTABLISHING A UNION AT DRILCO THAT WILL REPRESENT ALL THE PEOPLE.

IF YOU HAVE NOT HAD THE OPPORTUNITY TO FILL OUT AN AUTHORIZATION CARD, COME BY, ASK QUESTIONS AND IF YOU ARE SATISFIED WITH THE ANSWERS...SIGN-UP.

CONGRATULATIONS ON YOUR RECENT PROPOSED INCREASE IN BENEFITS AND PAY. HAVE YOU GOT IT YET? WILL YOU GET IT? IF SO, WILL YOU GET TO KEEP IT? DOESN'T IT SEEM STRANGE THAT ALL OF A SUDDEN THE COMPANY SEEMS TO HAVE YOUR BEST INTEREST AT HEART?

DON'T BE MISLEAD OR FOOLED BY COMPANY PROPAGANDA. ANYTHING THEY PROMISE OR GIVE NOW CAN JUST AS EASILY BE TAKEN AWAY LATER, UNLESS YOU HAVE A SIGNED UNION CONTRACT.

THE RECENT MAJOR REDUCTION IN YOUR BONUS AT CHRISTMAS TIME SHOULD BE A REMINDER TO ALL OF YOU, WHAT THE COMPANY IS CAPABLE OF DOING.

KEEP UP THE GOOD WORK AND LETS ALL WORK TOGETHER AS A TEAM TO BRING YOUR ORGANIZING CAMPAIGN TO A SUCCESSFUL CONCLUSION. ONLY THEN, CAN YOU BE ASSURED OF A STRONG VOICE, THAT WILL BE HEARD, FOR THE BENEFIT OF YOURSELF AND YOUR FAMILY IN THE FUTURE.

INTERNATIONAL ASSOCIATION OF MACHINIST AND AEROSPACE WORKERS, AFL-CIO

DRILCO

January 10, 1977

Dear Drilco Employee:

As you are probably aware by now, the International Association of Machinists (I.A.M.) is interested in you. They have handed out literature and planned meetings, and have promised the "straight facts" of the benefit they offer you.

What obligation do they have to give "straight facts?" The answer, of course, is none. To get the "facts straight" the Union can promise and promise, but they offer you nothing; they can only negotiate on your behalf.

Let's analyze the green "fact sheet" the Union handed out at the gate last Tuesday.

Statement #1 - You are welcome to come to a meeting.

Fact - I am sure this is a fact. Drilco is now a large enough Company, and offers enough potential dues paying members to the I.A.M. that they welcome the opportunity to benefit you. In 1969, when the UMWA was attempting to organize Drilco employees, the I.A.M. asked to have their name added to the election ballot. Drilco was a very small Company then, and the I.A.M. spent no time welcoming you to anything then.

Statement #2 - Doesn't it seem strange that all of a sudden the Company seems to have your best interest at heart?

Fact - Drilco always has its employees best interest at heart. The fact that Drilco was planning benefits and a cost of living increase has been common knowledge for several months. Doesn't it seem strange that the Union wants to give you the impression "they got you something."

Statement #3 - Anything Drilco promises, they can take away.

Fact - This is a true statement. This has been a true statement ever since you were employed by Drilco, but what has Drilco ever given that was later taken away? Drilco's past record speaks for itself.

Statement #4 - Reduction in your bonus should be a reminder of what the Company is capable of doing.

Fact - Your 1976 bonus was smaller than 1975, but your 1976 bonus was larger than your bonus has been for 8 of the last 10 years.

... Continued

Your Profit Sharing Plan is regulated by state laws, the United States Department of Labor and the Internal Revenue Service. The amount of money available to the Profit Sharing participants is 15% of Drilco's pre-taxed profits. To manipulate the bonus to make it larger or smaller, (as the I.A.M. would have you believe) could only result by Drilco's misstating its profits. Such an act would not be tolerated by the Securities Exchange Commission and could prevent Smith International, Inc. stock from being listed on the New York Stock Exchange.

The I.A.M. wants you to believe that the Christmas bonus would have been different if a Union were representing Drilco employees. This is wishful thinking, unrealistic and an insult to you.

Statement #5 - Come by and sign an authorization card.

Fact - Read the card carefully and you will notice the card neither offers nor promises anything. They are asking you to bind yourself in writing, but what do you get in return? Before signing a card ask them to give you in writing what they can guarantee in exchange for the dues you may be required to pay. Ask them for a copy of their constitution because that is what you are binding yourself to.

The law allows the Union to pass out handbills, conduct meetings in motels, contact you at home, etc, etc, etc. So, you probably will be exposed to more "facts" in the future. Keep a tally of the "straight facts" the Union gives you. You determine what is propaganda.

Jimmy R Gray

Jimmy R. Gray
Vice President of Personnel