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02008

ID/WG.259/14

United Nations Industrial Development Organization

Technical Seminar on Contracting Methods and Insurance Schemes for Fertilizer and Chemical Process Industries

Lahore, Pakistan, 25 – 29 November 1977

PERFORMANCE GUARANTEES AND TEST

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SUMMARY

The basic requirements of a good plant are that it comes in to operation on schedule, within the budgeted costs, produces specification product at design capacity, and is reliable over long periods of operation without undue breakdowns and troubles.

In this paper, the authors have discussed various warrantees and guarantees that must be built in the contract between the Engineering Contractor and/or Licensors and the Purchaser in order to ensure that the interests of the Purchaser are safeguarded so that the necessary requirements for a reliable plant are satisfied.

PERFORMANCE GUARANTEES AND TESTS

During the last fifteen years dramatic changes have occurred in the development of new processes for commodity chemicals and products such as synthetic fibres, rubber, plastics, and chemicals fertilizer etc. which are based on cheap gas and petroleum feed stocks. In addition tremendous progress in chemical and mechanical engineering design, and new materials of construction has enabled large scale production of these commodity chemicals at relatively low costs.

In the past emphasis was placed on absolute reliability in operation and on speedy erection of the plant. In the main, the plant sizes were small and individual chemical companies designed and erected their own plants to provide capacity matching a fairly conservative and short term estimate of demand. Plant design, particularly in the case of a new process was generous in providing for operational flexibility and for spare unit equipment. The thinking behind this policy that the plant was unlikely to be rendered obsolete fairly quickly by major technological advances and that it would be economically beneficial to have spare capacity which could be utilized as more and more operating experience was gained.

To-day the attitudes are entirely different. The development of chemical processes and the design and construction of large plants based on new processes are carried out by engineering contracting companies. These companies have accumulated extensive experience in the management of chemical projects. They have developed modern sophisticated techniques such as PERT, critical path analysis, linear programming and computor aided design and construction which has not only helped in cutting down delays in project schedule, but has also exercised control on project costs.

The criteria for good process selection is that the proposed plant is capable of steady, economic, and safe operation and that it comes in-to production on schedule. In order to attract business the engineering contractor has to develop and maintain his reputation and he usually provides guarantees of one form or the other to help convince the operating Company(owners) of his reliability and performance. These guarantees are however, of to great consolation to the purchaser, if a new plant fails to perform. In order to fulfil the guarantees the engineering contractor may be required to replace some part of the plant or modify the system, while the purchaser withhold temporarily a part of the engineering contractor's fee. The Purchaser, on the other hand may suffer a considerable loss in profit due to delays and dislocation in production and they have no hope of receiving any compensation from the contractor.

In a turnkey project specially the engineering contractor's design is liable to be skimpy and tight with the result that the plant may not satisfy the required quality and/or quantity criteria for the product. He may trim the capital costs at the expense of maintenance and services costs. As an example, the adoption of optimistic heat transfer fouling factors will give a plant which will produce the design output during the performance tests when the plant is still clean, but may not perform the required heat transfer duty once the equipment has been in service for sometime. A little extra capital spent to prevent fouling, can soon pay for itself if it results in a plant having to be shutdown less frequently for cleaning. It is not just the cost of cleaning but the production cost while shutting down and re-starting the plant often accompanied by reduction in raw materials and service efficiencies during these periods. As every process operator knows it is worth making considerable efforts to keep a plant on-line continuously for, after a shutdown he can expect a variety of troubles such as leaking joints and leakages in other parts of the plant which may not have been troublesome before the shutdown.

For these reasons, it is necessary that performance guarantees and tests are reasonably well spelled out so that the interests of the purchaser are sufficiently safeguarded by providing incentives and liabilities to the engineering contractor for satisfactory performance during various phases of project development and execution. In addition, it is necessary that the purchaser, specially in the developing countries, has a team of specialists or consultants at their disposal, in order to supervise the work of the engineering contractor and safeguard the interests of their Company.

In modern large scale energy intensive process technology, the following criteria for effectiveness is used and adequate guarantees must be provided for satisfactory execution of work and to ensure that the project is completed on schedule and that the plant is reliable and easily operatable to yield specified quality and quantity.

a. The Plant must work i.e. it must produce specification product, which should be acceptable internally and internationally, it must produce the desired product at design capacity, it must meet the design yields, and the operation must be free of frequent breakdowns. Of these requirements the ability to produce 'specification' product is the most important. The worst that can happen to a new plant is its inability to produce 'spec' product, because the product will not be saleable. Thus the choice of appropriate and well tried process knowhow and technology in the fundamental requirement of any contract. Developing countries cannot afford to take the risk of experimenting with new technology without previous satisfactory commercial production record of trouble from operation. The licencor or the engineering

contractor must provide absolute guarantee that the plant will produce 'spec' product at design capacity. It is emphasized that this means that the plant must operate continously at an annual designed capacity, and not only for the period of the guarantee test.

b. Cost of Production must be kept low, i.e., the cost of raw materials, utilities, auxiliary chemicals, wastes etc. must be competitive with similar or other process routes for the same product operating in the world. The licensors or engineering contractor must provide adequate guarantees that the overall cost of utilities and raw materials shall be within the design limits specified. Any variations in these limits from design will indicate that the plant is not operating at design yields either due to process deficiencies or equipment inadequacies.

c. Capital Costs must be kept low: Low capital costs involve not only low equipment costs but also minimization of engineering and construction costs. In this connection it must be stressed that underdesign of major equipment, in an attempt to reduce the capital investment, is hard to correct once the plant has been built and modern processes just cannot be run without generous and ample instrumentation. At the same time it is necessary to keep strict cost control during various stages of plant design and construction in order to avoid "overruns" and keep the project costs within the financial resources available. The engineering contractor must provide adequate guarantees that the project will be completed within the budget.

d. Schedule must be met: Meeting schedules will result in low engineering and construction costs, but more important for the Purchaser, is that the end product must be marketed

and supplied to the consumers as planned. In addition if the plant is not completed on schedule, it will affect the financial return. This factor has been amply demonstrated by Holroyd(I) who has calculated DCF for a 1000 ton ammonia plant and has also shown the effect of delay in project completion on the financial return. These figures are recorded in Table-I. (attached). It is evident that all efforts should be made to complete the project on schedule and the engineering contractor must provide adequate guarantees to this effect.

e. Plant Equipment must perform under all Conditions: The reliability of individual items of Plant and equipment can usually be obtained through more stringent specifications in their design and manufacture, or by deliberate overdesign and larger safety margins in performance. Critical items of equipment can be duplicated, a stand-by being immediately brought in to service when the operating equipment fails. It may be possible for one spare item to act as stand-by for several others, for example in the case of pumps, provided proper choice is made in their election. Another approach to improving reliability is by replacing a single piece of equipment by two or more smaller units operating in parallel. In such, a case if one of the units fail, the plant is not shutdown completely, but is able to operate at reduced throughput.

Considerable guidance is needed by the Purchaser in the developing countries in the selection of process equipment, as it occupies the role of less experienced client. Under these conditions, the engineering contractor is exposed to a variety of conflicting constraints. Its commercial interests are best served by supplying a process package

requiring the minimum process modifications. The developing country, on the other hand, is attempting to establish a contract at as favourable a price as possible, and is frequently handicapped by the amount of capital, available. In this bargaining situation economies must be made, and it is in the nature and extent of these economies that the critical effect of process selection and design performance is frequently overlooked.

Nevertheless, the engineering contractor must guarantee that the process equipment will perform without breakdown and that the defective equipment is replaced at their cost.

Guarantees and their Objectives

In general, the contractor's work has a single objective which is of major financial significance to the purchaser. This is the construction and starting up of a plant within a specified time and allocated financial resources. There are various constraints which may affect the achievement of this objective and the contractor must guarantee that he will fulfil his obligations in accordance with the requirements of his contract with the purchaser. These constraints may be discussed under three headings as follows:

1. **Project Schedule and Cost Control**

   For this purpose the project may be broken down into different phases spaced out in time and the contractor is obliged to guarantee the completion of each phase within the specified time and cost. However, in order to achieve the project schedule and cost, the contractor must be given certain incentives or penalised depending upon his performance. As an example, the program of work and time of completion can be broken down and a time-limit set on various activities as follows:

   a. delivery of time-critical items at the plant-site.
   b. delivery of complete equipment and materials at the plant-site.
   c. construction schedule and mechanical completion of the project.
   d. project cost control.

2. The second area which can affect the achievement of requisite objective is the attainment of specified product quality and design capacity as defined by the purchaser's design criteria. In order to determine whether the plant is capable of meeting this requirement of design capacity and quality, and raw materials and utility requirements, performance tests are carried out for;

a. utilities and offsite plant and equipment;
b. battery limits plants

The contractor/licensor must agree with the purchaser regarding the logistics of these performance tests and also provide absolute guarantees for the quality and production capacity of the plant. The absolute guarantees must be unequivocal and not limited in amount.

3. The third area which can affect the satisfactory commissioning and performance of the plant facilities is the equipment and construction defects which might arise due to design errors, equipment defects, and construction faults. These may be grouped as:

a. defeciencies in process design and detailed engineering
b. defects in equipment design and fabrication
c. construction faults.

It should however, be pointed out that while the contractor has to take action to correct any defects, the cost of making good these defects (including those arising from contractor's mistakes, but not from his negligence or failure to exercise reasonable skill and care) is reimbursable i.e. it has to be paid by the purchaser, who would therefore, make an appropriate provision in his budget. Nevertheless, the contractor has a duty to minimize the possibility of defects. In order to reduce the frequency of errors, the purchaser must define in the contract, his requirements with regard to quality of design, materials, and workmanship. Particular attention should be paid in the specifications to item which may fail during the defects liability period due to normal wear and tear, or due to operation under conditions not in

accordance with the supplier's instructions.

If these conditions are not clearly defined, the purchaser will have the right to invoke the defects liability clause, while the contractor's designers may have intended that the item should be renewed or repaired as part of routine maintenance.

The application of a defects liability period shorter or longer than twelve months may be appropriated for some items under unusual circumstances, and these should be covered by special conditions. It is also suggested that adequate insurance must be taken out by either the purchaser or contractor against design and erection defects and the functions of each should be defined in the contract.

Programme of Work and Time of Completion

A fertiliser plant or a petro-chemical project is based on highly complex, sophisticated technology, and the plant usually consists of several sections or units, some of which are operationally dependent on each other. There is thus a logical sequence in which completion of each unit is required in order to achieve the most satisfactory commissioning of the whole project. As an example, in a fertilizer complex consisting of ammonia and urea units with integrated facilities consisting of steam and power generation, inert gas, plant air, water treatment plant facilities, the utilities and offsites are first commissioned in sequence followed by commissioning of ammonia and urea plants. Thus it is invariable to the advantage of the purchaser to have the project completed to a program. If this is prepared sufficiently early, he will be able to arrange

for the necessary plant operating and maintenance resources to be available at the time of start-up and to coordinate the timing of raw material supplies, utilities and effluent facilities, and marketing activities to coincide with the start-up program.

Liquided Damages for Delay and Bonuses for Early Completion

The word "liquidated" is used to distinguish such payments, the magnitude of which is agreed in advance, from damages assessed later by a court as compensation for the loss suffered by the claimant. Liquidated damages should not, of course, apply to absolute guarantees. The operative dates and the rates of damages should be agreed between the parties at a stage when the contractor can assess his financial risks. As an example, the liquidated damages for failure to complete the project according to the schedule should be properly defined at the proposal stage, and the contractor's potential liability should be made clear at that time.

It is also worth considering the payment of a bonus by the purchaser as a reward for early completion. The spirit of such a arrangement is in contrast to the liquidated damages clause. It is for the purchaser to set the target date and the rate of bonus at a level which will be profitable to him in the long run. He is encouraging the contractor to come forward with proposals, and to take actions to progress at the maximum achievable rate. If completion of construction can be achieved ahead of schedule, it will be beneficial for the contractor as well as the purchaser.

I. a) Bonus/Penalty Formula for the Delivery Schedule of Time-critical Equipment

An example of the application of bonus/penalty clause for the delivery of time critical equipment is given in Appendix I. It is considered that it would be in interest of the purchaser to give sufficient incentives to the contractor to complete the delivery of critical items of equipment before schedule, because it will ultimately determine whether the project can be mechanically completed on time. However, as outlined in this example, the penalty for delay can be made to increase without any time limit, while the bonus can be made to apply for a limited period because the delivery of these items too early in the construction stage may not be helpful beyond a certain maximum limit.

b) The same criteria can be used for the delivery schedule of complete plant equipment and bulk materials.

c) Construction Schedule and Mechanical Completion of the Project

Mechanical Completion

Towards the end of construction, mechanical commissioning of equipment is undertaken under the direction of the construction organisation although the purchaser's operating personnel also help in inspecting, checking, and commissioning the equipment. These operations include alignment of pumps and drivers; inspection of rotary equipment such as compressors, turbines, pumps, turbo-generators, etc; circulation of lube oil, and seal oil through bearings, gear boxes; checking of motor rotation; testing and installation of relief valves, safety valves; hot checking of turbines;

blowing and flushing of process lines; and drying of refractories. When all the equipment has been inspected and checked, the plant is handed over to the operating personnel and the project is considered mechanically completed.

A time limit is set in the contract for the completion of the project which for a fertilizer complex in a developing country may very between 28 to 36 months. If the project is not completed within the specified schedule, the contractor is liable to a penalty clause. On the other hand, the contractor may complete the job before schedule by allocating additional construction resources, and it is in the interest of the purchaser to provide this incentive in the contract by the addition of a bonus clause.

The usual pattern in international contracts is to allow a grace period of say ± 15 days on the actual completion target date, and if the project is completed early or beyond this grace period, the contractor is either penalized or rewarded for his performance. In addition a maximum limit of say 90 day or a sum of say $ 450,000 is set as the maximum penalty/bonus clause.

d) Project Cost Control

a. Lump-Sum Contracts

Project cost control for lumpsum contracts is the responsibility of the contractor, because such contracts are negotiated on competition tendering. They are agreed upon following the evaluation of several offers all made on substantially the same basis. However, before

entering into Lump-sum contracts, the purchaser must clearly define the scope of the work in the form of Design criteria, both in its technical content and commercial/contractual basis of the project. The exact battery limits of the supply, and contractors obligation to supply within these battery limits equipment (except that specifically to be supplied by the Purchaser) should be detailed in the Contract.

Once a contract is finalised, the contractor exercises control on the project costs, because it is in his own interest that these do not over-run the budgeted costs. However, it would be in the interest of the Purchaser to see that there are no deviations in design, and the contractor does not under-design the equipment, and introduces economies at the construction stage at the cost of the purchaser. The main feature of this type of contract is that the purchaser does not carry the risk of cost overruns, but does not benefit from any savings.

b. <u>Re.imburseable contracts</u>

There are many variations of the re-imburseable contracts. These may include:

i. Cost plus a percentage fee
ii. Cost plus a fixed fee i.e. Lumpsum Fixed Price.
iii. Target (Shared over-run)
iv. Guaranteed maximum selling price

In most of these variations, the contractor is re-imbursed all the costs he actually incurs.

The essence of the re-imbursable contract is that the contractor supplies such goods and/or services as the purchaser requires and, provided he exercises his normal professional skills, the contractor is re-imbursed for all the costs he incurs including corrective costs arising from design and construction errors. The purchaser gains the benefits of any engineering, material, or construction cost savings but, does of course, bear the risk of any over-expenditure. In view of the possibility of over-runs or under-runs, it would be necessary that suitable penalty/bonuses are introduced in the contract in order to protect the interests of the purchaser.

Guaranteed Maximum Selling Price (GMSP)

In this form of contract, the contractor submits an Estimated Maximum Selling Price (EMSP) for the complete project including his fees (Lumpsum Fixed Price) at the time of tendering its Technical Proposal. According to the terms of the contract, the Engineering Contractor agrees to furnish GMSP required by the "Request for Proposal" within a specified period of time after the initiation of the project. In the event the GMSP exceeds the EMSP which the contractor submitted in its Technical Proposal, the contractor is obliged to pay penalties which may be 2 to 5% of the difference between the GMSP and EMSP. On the other hand, if the contractor is able to reduce the GMSP below EMSP, he may be given a bonus as a incentive to reduce the overall cost of the project.

2. Absolute Guarantees for Product Quality and Quantity

In order to demonstrate that the battery limits plant can produce the specified product at design capacity, within

contractor's guarantees regarding raw materials and utility requirements, and that the battery limits plant is capable of producing the required amount of the end-product, the contractor must give absolute guarantees that the battery limits plant shall be capable of performing as set forth in the Design Criteria.

Performance tests for offsites must also be performed in accordance with the set procedures in order to ensure that each unit is capable of producing the specified utilities and that these conform to the Design Criteria for quality and capacity. Offsites usually include:

a. Raw material supply and treatment
b. Water supply and treatment
c. Steam generation and supply
d. Power generation and supply
e. Product handling and shipping
f. Cooling water systems
g. Plant and instrument air
h. Effluent disposal

Performance Tests

Performance tests are performed by the Purchaser under the direction of the contractor/process licensor's personnel, the start-up personnel, and any other personnel deemed necessary by the contractor and approved by the purchaser. The contractor prepares and proposes the details of the procedure and arrangements to be followed during the tests, including performance tests for the offsites not less than six months prior to the anticipated dates of such tests, and supplies the operating and maintenance manuals not later than six months before such tests.

The performance tests for the battery limits plants is specified to last seven days in order to establish the guaranteed quantity, quality of the end-product and raw materials and utility consumption and is conducted under safe operating conditions. It is suggested that the 7-day test should only be run after the plant has been continiously working for 21 to 30 days.

During the performance tests, the consumption of raw materials, and utilities are measured and firmly established per metric ton of the end product produced. The methods of measuring raw materials and utilities are also established by the contractor and the purchaser as set forth in the Design Criteria.

Liquidated Damages

In the event that the contractor fails to meet the guarantees, he is obliged to promptly make such changes, additions, alternations, adjustments, repairs, replacements as may be required in order to achieve the necessary product quality.

In addition if the production capacity of the plant is not met after the conclusion of the performance test, the contractor is obliged to make remedies as follows:

1. If the production is less than 95% or 98% or more of the guarenteed quantity, the contractor has the option to pay liquidated damages in lieu of making repairs or carry out its obligations to repair and modify the plant in order to achieve the desired capacity. The liquidated damages must be negotiated between the contractor and the purchaser.

2. If the production is less than 95% or 98%(depending upon the type of Plant) the contractor shall have an absolute obligation to carry out the modifications/repairs until the specified production capacity is achieved.

Raw Materials and Utility Costs

If the guaranteed consumption of the raw materials and utilities is not met, the contractor is also obligated.

1. To pay liquidated damages if the utilities/raw material consumption is less than 10% above the specified design limits.

2. If the consumption of raw materials or utilities exceeds 10% above the design limit, the contractor is obligated to make necessary repairs/modification to the plant in order to achieve the desired consumption rates.

In addition the contractor must provide absolute guarantees for product quality and quantity for the rest, the extent of the maximum liability is considered to be about 10 to 15 percent of the Lump Sum Fixed Price (Contractor's Fees).

3. Design Errors, Equipment Inadequacies and Construction Faults

When the plant equipment are subjected to design temperatures and pressures for the first time, there are bound to be failures. Pump seals will surely cause problems, so will the instruments, compressors, turbines, and other rotary equipment. Despite Vender tests and rigorous inspection procedures, inferior workmanship is an ever present problem and many failures occur due to defective shop fabrication as well as field constructed equipment. Most of these problems have been ascribed to frequent changes in design and prices rivalry. Because inspection costs money, it is most likely to be done perfunctorily or just ignored altogether at a time of intense competition.

Holroyd, in his analysis of plant start-up problems has reported that 61% of the start-up problems are caused by equipment deficiencies, 10% due to design inadequacies, 16% due to construction shortcomings, and 13% by operating errors. Although such problems may vary somewhat, they usually occur and pinpoint equipment failures or construction faults as the source of major troubles which most frequently delay plant start-ups. These problems are not insoluble although they would result in loss of production.

However the contractor must guarantee workmanship of all materials, equipment, supplies, and the offsites and battery limits plants constructed by him. In addition the contractor must guarantee that he agrees to remedy by repairs or replacements any plant or equipment promptly upon receipt of written notice from the purchaser despatched within 10 days after discovery and recognition provided these faults/errors are reported within 12 months warranty period after the final acceptance of the battery limits plant. The contractor, however, is not responsible for undertaking any remedial action necessitated by normal wear and tear, corrosion or erosion, improper maintenance and operation, etc.

The contractor shall provide 18-months warranties after start-up either himself or through his vendors/sub-contractors for defects as to material, workmanship, and mechanical design and performance of equipment and machinery, supplied by sub-contractors and vendors.

The contractor's obligations for breach of warranties are limited:

1. To the repairs and modifications to be carried out under his supervision subject to the limitations that he will be liable for paying the cost of correction in excess of a minimum negotiated value which varies with the size and nature of the contract.

2. There will be an upper limit for the cost of correction to be borne by the contractor. This limit is usually set by the size of the contract and may vary between 2 to 3% of the Lump Sum Fixed Price (LSMP or Contractor's Fees).

Performance Bonds

As a safeguard for the various performance guarantees, the contractor is required to furnish a performance bond or Bank Guarantee in the amount of the equivalent of five percent(5%) of the Estimated Maximum Selling Price (EMSP) of the project. This performance Bond is realised by the purchaser after all the guarantees in connection with the project are fulfilled.

TABLE - I

DFC RETURN FOR 1000 ST/DAY AMMONIA PLANT USING VARIOUS PLANT OUTPUT LEVELS AND CONSTRUCTION PERIODS

	Annual Output		D.C.F. RETURN		
			No. Delay 2 years construction period	6 months Delay	12 Months Delay
Case I	Year 1 onwards	100%	26%	23%	21%
Case II	Year 1	60%	16%	14%	13%
	Year 2	80%			
	Year 3 onwards	100%			
CaseIII	Year 1	30%	12%	10%	9%
	Year 2	80%			
	Year 3	90%			
	Year 4 onwards	100%			
Case IV	Year 1	30%	7%	6%	5%
	Year 2	70%			
	Year 3 Onwards	90%			

APPENDIX I

Bonus/Penalty Formula for the Delivery Schedule of Critical Items of Equipment

Assume total value of critical equipment — $ 10 m.

Also each equipment cost is a multiple of — $ 100,000

Total No. of points to be awarded to all items of equipment — $\frac{10 \times 10^6}{10 \times 10^4} = 100$

If the seven critical items for a particular unit are,

$$X_1 \ldots\ldots\ldots\ldots\ldots\ldots X_7$$

and the value of each item is

$$Y_1 \ldots\ldots\ldots\ldots\ldots\ldots Y_7$$

No. of points allocated to each equipment are: $X_1 = \frac{Y_1}{10^4}$

$X_2 = \frac{Y_2}{10^4}$ .....

And the bonus money for each item would be

$$B_1 = \frac{Y_1}{10^4} \times \frac{270,000}{100}$$

Example

The cost of a chemical reactor is $ 2 m.

No. of points allocated to it are: $= \frac{2 \times 10^6}{10 \times 10^4} = 20$

And the max. bonus money for this item would be

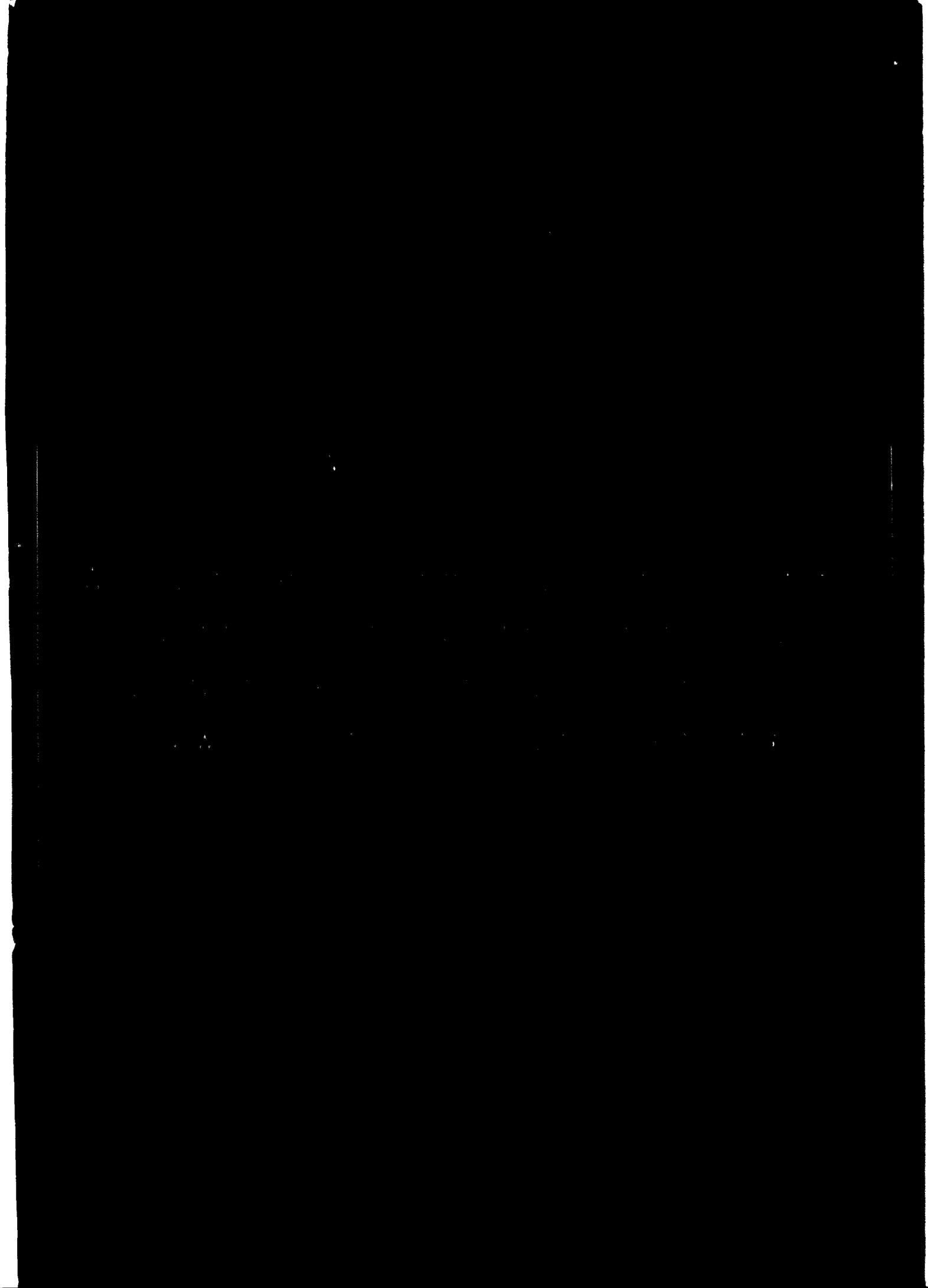
$$270,000 \times \frac{20}{100} = \$\ 54000$$

Penalty/Bonus over 90 days = $ 54000

Bonus/day $ 54000/90

= $ 600

With the proviso that penalty will go on increasing of the delay in delivery extends beyond 90 days at the same rate; but the bonus will be limited to $ 54000 even if the delivery is before 90 days period.



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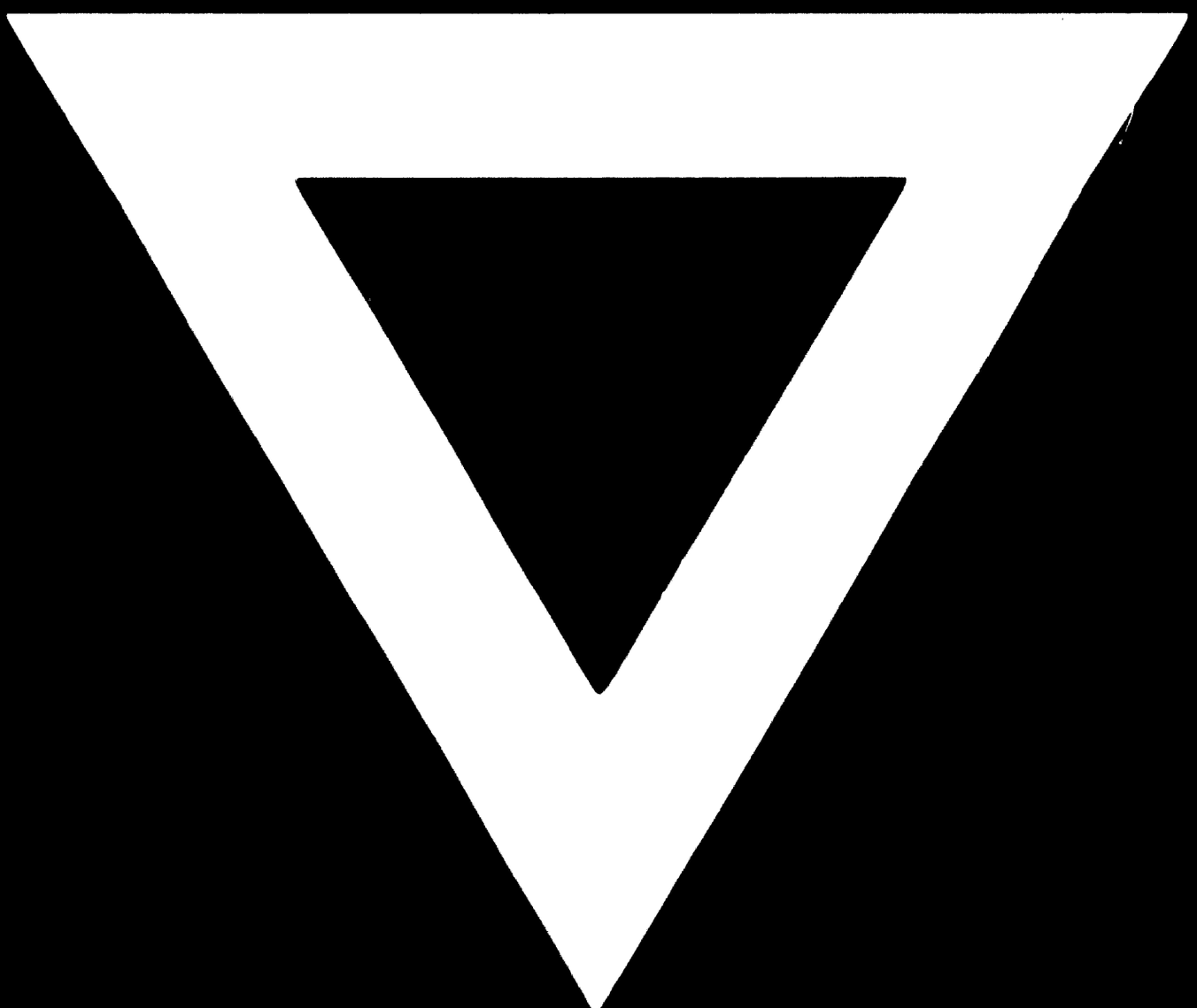

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