Chapter 2 of Category I

Being the water-clock of the drummers from which can be told the passage of the solar hours; it is divided into 5 sections

Section 1

Description of its outside appearance and operation

The visible part (*Ṣūra*) is on the outside of an alcove (*Ṣuffa*) or a handsome reception-chamber (*Īwān*) raised about the height of three men above the ground. It is a frieze (*Ifrīz*) like a ledge (*Raff*) projecting from the face of the wall about 4F. in a straight horizontal line. Along its edge there are 12 battlements and at the end of the ledge stands a man (*Shakhṣ*). His right hand is outstretched and his index finger points towards the battlements; when he moves behind the battlements his finger almost touches their points. Above the frieze and parallel to it are twelve glass roundels in a straight line [set] in holes [cut] through to the inside of the house. Below the centre of the frieze is a *miḥrāb* with a falcon in it, as in the first chapter, with a vase in front of it on a projecting bracket, with a cavity [in the wall behind], as [described] previously.

In the floor of the chamber is a platform occupying all the foreground, raised about the height of one man above the ground. On this platform are seven men: on the right two blowing trumpets, on the left two playing cymbals – the rest are drummers. The middle one has two kettle-drums (*Naqqāra*) while the two to his left and right each has a drum slung over his shoulder, its head tilted upwards so that it can be struck by a drumstick (*Ṣawlajān*) held in the right hand. The left hand is lowered on the other side [of the drum]. The one in the middle has a drumstick in each hand with which to strike the kettle-drums.

Now I say that at daybreak the man is at the end of the frieze and moves smoothly until he is behind the first of the twelve battlements, whereupon the falcon leans forward and casts a ball from its beak onto the cymbal in the vase, and the musicians play. This happens every hour as I have described.

It should be understood that the trumpeters, cymbalists and two of the drummers are standing on their feet, not touching each other or supported by anything, while the drummer in the centre is kneeling.

The situation in the night is that all the twelve roundels are [at first] completely lit. Then the edge of the first roundel darkens, [the darkness] increasing until the whole roundel is dark. At that time 11 solar hours of the night remain. The man moves along behind the battlements and is not seen, but every hour the sound of the cymbal is heard, since for this device the operation is the same in the night and in the day, nothing whatsoever being omitted [in the night]. When an hour has passed the musicians (*Nawba*) perform with a clamorous sound which is heard from afar. This is its picture [Fig. 34].

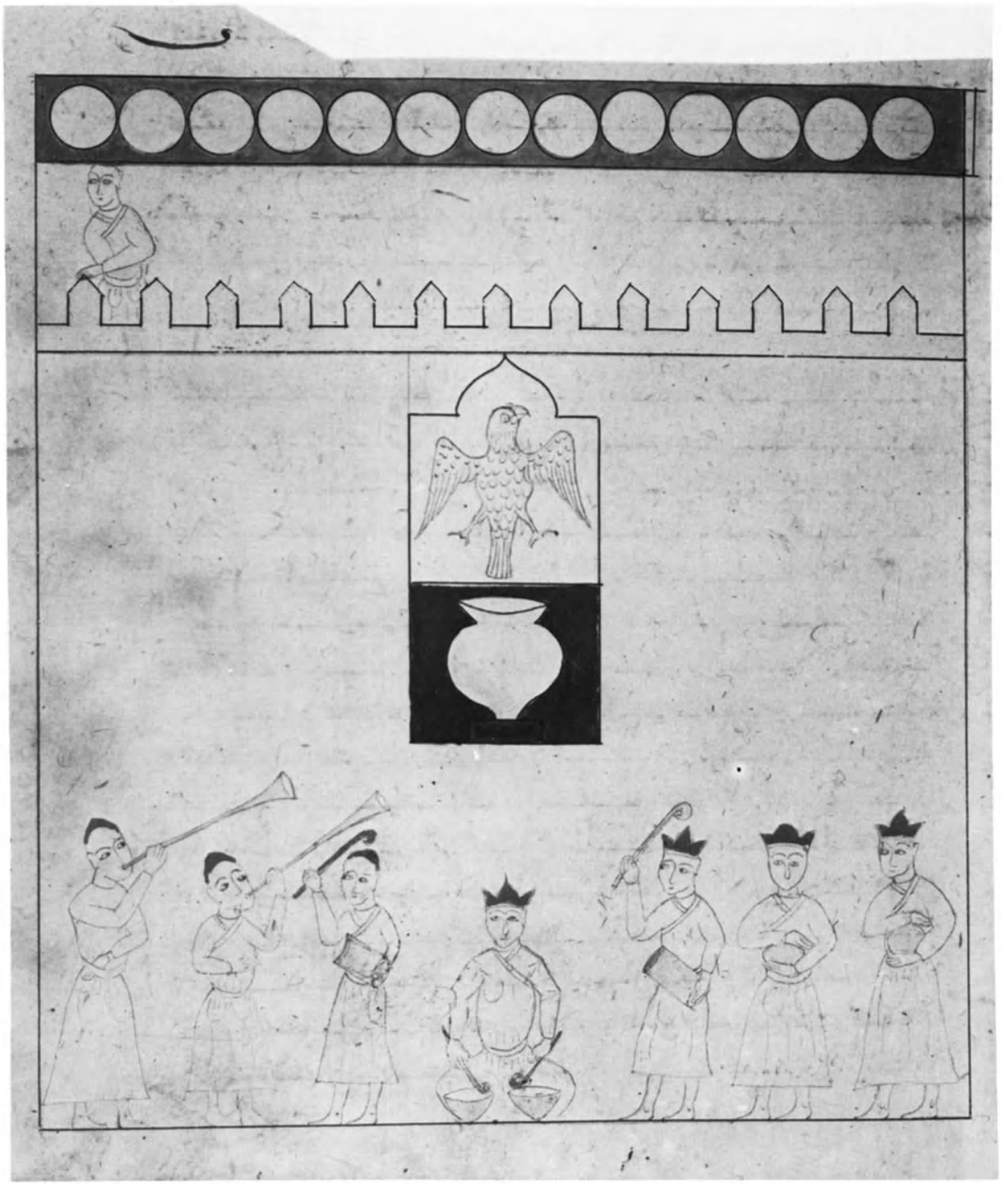


Fig. 34.

Section 2

On the water-instruments, and the functioning of the bucket (Kaffa) which fills and empties every hour.

Know then, that behind this chamber (*Īwān*) is a house which is raised above the chamber and extends beneath the platform. The platform is completely hollow. First I [must] mention that in this chapter there are types of instruments that were described previously in the first chapter. I will not discuss their operation and positioning at length, but will mention them briefly. Among these is a vessel [i.e. the reservoir] made as we described, its height 6 sp. and its width $1\frac{1}{3}$ sp. with a tap at the bottom as before.

Then an oblate float is made from copper, like a hollow turnip which floats on the surface of the water. It has in the centre of one of its faces a staple and a ring, and adjacent to the staple is a hole into which some sand can be poured to weight it. Then the float-chamber (*Rubʿ*) is made, the same shape as the reservoir, its length $1\frac{1}{2}$ sp. and its width 4F, with a float inside it having a plug which closes the bent-over end of the tap in the bottom of the reservoir. [One also makes] the flow regulator (*Dastūr*) for the water outflow as previously, omitting nothing from it. The reservoir is erected as described [before] with the float-chamber directly adjoining it and the flow regulator connected to the float-chamber – the drawing for that [assembly] was shown above.

Now for this device (*Shakl*) one makes a long copper trough about 4 sp. long, its side about 1 sp. high. It is called 'the trough of the bucket' (*Ḥawḍ al-Kaffa*). This trough is placed in front of the flow regulator so that the water which issues from the onyx falls into this trough. Then one takes a piece of copper and hammers it until it assumes the shape of half a hollow weighing-bucket (*Kaffa al-Mīzān*). Then, on the section which is cut away, [i.e. where the central cross-section of the complete weighing-bucket would be] a vertical plate is fitted at the same height as the side of the bucket, which now resembles half a drinking-bowl (*Ṭās*). It is wide at the top, narrowing towards the centre, and is longer than a semi-circle, and [looks] like half a boat. Below the rim of this bucket, near its end, two holes are drilled opposite each other – marked *bb*. An axle is inserted through the two holes, of sufficient length to protrude 1 F from each hole. The bucket should be large enough to contain the quantity of water which issues from the onyx in one hour when it is on the degree of the first point of Cancer, plus a little more. When the ends of the axle of this bucket are placed on two firm supports, and water is poured into it until it is almost full, it will remain stable. If a drop more water is added it will tilt towards its elongated end, and discharge its entire contents. Then it will return to its original position. This is the principle of this bucket. When I made this bucket, even though I did not know that I was the first to make it, I thereby rendered unnecessary many appliances of value in this craft.

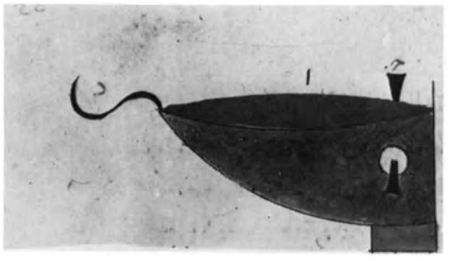


Fig. 35.

With the bucket freely balanced as before, the end near the axle, namely the back, is weighted with about 100 *dirhams* of lead, so that it will not tip when filled with water, but will remain in position. Something is [therefore] required to tip it in counteraction to the weight, [namely] a bar of copper on the end opposite the weight, turned upwards to form a bow with a single horn (*Sīya*). This horn is hammered into the shape of a circular plate, convex downwards. When a ball weighing 20 *dirhams* falls into this hollow horn, the bucket tilts and pours out all the water it contains. The ball rolls out of the hollow bow because the concavity is shallow, and the empty bucket returns to its original position. This [Fig. 35] is the drawing of the bucket, its axle, and the bow fitted to it. There are letters on the drawing; on the bucket *a*, on the two holes *bb*, on the ends of the axle *jj*, on the horn of the bow *d*, and on the weight on the fulcrum *e*.

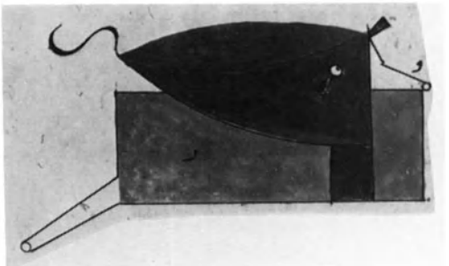


Fig. 36.

The bucket is now placed in the trough in front of the flow regulator, resting horizontally on its fulcrum, the ends of its axle in two holes in the side of the trough. A hole is bored in the bottom of the trough for the insertion of a pipe, which is mentioned below. Then the bucket is filled with water from one hour of the first point of Cancer and a mark is made at the surface of the water, at the top of the vertical side. Above the weight a hole is made in which is fitted a thin horizontal pipe 4 F long, marked *w*. This is the drawing of the trough, marked *z*, with the bucket inside the trough [Fig. 36].

Section 3

At the beginning of this chapter it was mentioned that there is only one *miḥrāb* in the centre, one falcon and one vase on a bracket, the operation of these being the same as in the first chapter, so it is not necessary to go into this at length.

Above the *miḥrāb*, there is a frieze straight across the wall projecting 4 F from the face of the wall; it has an edging strip about 2 F high upon which are battlements, fashioned according to

the choice of the craftsman. Then a slit is cut through the wall at the same level as the surface of the ledge. Inside the wall below the slit a cart track is installed as before, and a copper plate is nailed to the back of the cart which projects through the slit on the frieze almost as far as the edging strip upon which are the battlements. Then the figure of a standing man is made, who has his legs on the plate and his forefinger pointing to the tip of a battlement. Parallel to the frieze, and above it and the figure, are twelve holes in a straight line. In each hole is a glass roundel, the distances between each pair of roundels being equal. In this device the movement of the cart, [is as follows]; to the rear of the cart a string is attached, which passes over a pulley at the end of the track; to the hanging end a lead weight is attached to exert a pull on the cart from behind. A string is tied to the front of the cart which runs along the track, passes over a pulley at the end of the track, then up to the roof of the house and over [another] pulley which is vertically over the centre of the reservoir. Its end is tied to the ring in the float, [the string] having no slack at all. The reservoir is filled with the known quantity of water and when the tap is opened and the float descends the cart moves, and the figure with it. The length of the frieze and the roundels equals the height of the water in the reservoir.

The position with the roundels [is as follows]: at nightfall they are uncovered and the light from the lamp shines through the glass. I will now describe how they are covered so that they darken one after the other.

Near the first roundel a vertical axle is erected, one end of which [the lower] rotates in a bearing[1] set firmly in the end of the wall, and some distance away from it, another bearing is placed over the upper end [of the axle]. Then one takes a roll (*qimāṭ*) of smooth natural hide (*Udm* or *Adam*) wide enough and long enough to cover the roundels, and attaches its end to the vertical axle at the end of the roundels. The axle is rotated and the roll is wrapped round it like a roll of paper (*Darj*). The other end is attached to a rod which is erected in the middle of the top of the cart. It is very clear then that the cart with the rod is on the end of the track opposite the first roundel, and when the cart moves the roll unwinds, covering one roundel after another until all the roundels are covered. This is the drawing [Fig. 37] of the axle marked *y*, the two bearings *mm*, the roll *x* with its end in the rod on the cart *s*. [The roll] is unwound.

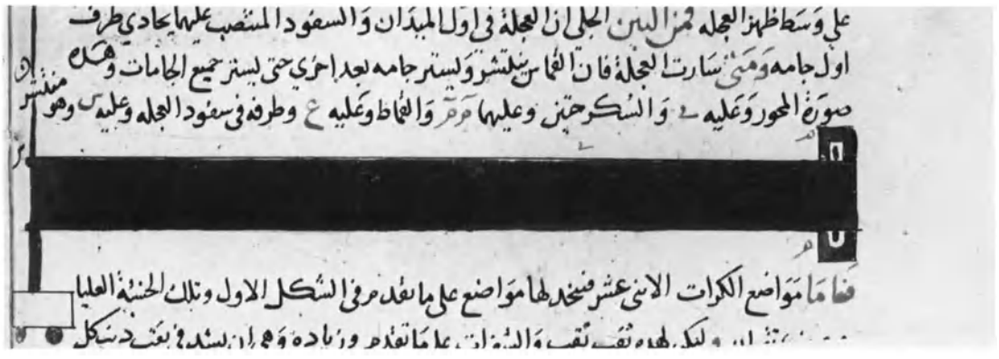


Fig. 37.

The 12 balls have places made for them like those in the first chapter except that in the upper piece of wood there is only one hole whereas in the other there were two. The blades are like they were previously. For the rest, one attaches a string 1 sp. long to the hole in the tail of each blade, and a lead weight, heavier than the blade, is tied to the other end. Running below the tails of the blades is a piece of timber with 12 hooks as was described in Chapter 1, with weights hanging from them. At the bottom[2] of each weight is a fine, smooth, long ring. This is the drawing [Fig. 38] of one ring in a weight on the end of one hook. The weight is marked *s*, the ring *ṣ* and the hook *x*. Then an iron rod with a smooth end is fitted to the top of the cart, and its end is bent over so that it passes below the hooks and above the weights which are suspended by the rings to the hooks. The bent-over end of the rod pushes one ring after another, and the weight falls, lifting the blade. The ball rolls down the groove, into the [wooden] channel, comes out of the centre of the wooden channel into the copper channel, then into the top of the *miḥrāb* and falls into the falcon's head.

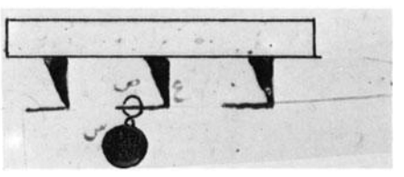


Fig. 38.

[1] *Sukurruja* = bowl or plate. Here evidently a bearing.
[2] Should read 'top', as shown in Fig. 38.

Section 4

On the construction of the men

Seven men are made from jointed wood; I shall describe the construction of one of five [percussion players] and one of two [trumpeters]. For the one of five one takes dry knot-free wood which is pieced together into the shape of the torso (*baṭn*) of a man, the back being hollow. The left thigh, lower leg and foot are joined to this, – they are not hollow. The right thigh, lower leg and foot are hollow, with a straight hole inside extending from the bottom of the foot through to the torso. For the right hand[3] a shoulder and [upper arm] up to the point of the elbow are made and fixed in position. From the point of the elbow a slit is made through to the hollow part of the torso – this is for the forearm. Then one makes a forearm, palm and fingers, which are clasped around a drumstick. A [piece] about 1 sp. [long] is separated from this forearm [i.e. there is a continuation piece] beyond the point of the elbow and a hole is pierced laterally at the end of the separation [i.e. where it joins the forearm]. In it an axle is inserted the ends of which rest in the slit made at the elbow, and the hand is mounted on this [axle] – when it moves it moves up and down. In the end of the extension inside the body there is a hole with an iron ring in it, to which [is attached] the end of a copper wire – the other end comes out of the hollow foot. When the man stands on his feet and the end of the copper wire is pulled down the arm moves upwards, and when the end of the wire is released the hand moves downwards by natural disposition. Now the other hand is made. With the drummers the face of the drum is held from underneath, and with the cymbalists, the edge of the cymbal is held in the usual place. A head is now made, adorned by the craftsman to the best of his ability, and painted in the colour of human skin. He is clothed in fine garments, which conceal the mechanism for the hand, with a headcovering such as musicians wear when on duty. Four men are made on this pattern – two trumpeters and two cymbalists. As for the drummer who leads them all, who is kneeling, his body is hollow, and his thighs also, the holes extending to the knees; the action of the hands is as described above, and each carries a drumstick. Then two trumpeters are made [standing] close together, in the hand of each of them a trumpet of the usual design, with the end in his mouth in the normal way. The trumpeters are placed on the right of the platform and a drummer with a drum is near them; next to him is the leader, kneeling with two large kettle-drums made of copper in front of him. Next to him comes a drummer with a drum and two cymbalists [all] in a line. The feet of each man are fixed securely – it is easy to do that. Beneath each foot in which there is the end of a wire, a slit is cut leading to the hollow interior of the platform, and beneath the knees of the leader there are two slits. The ends of the copper wires hang down inside the platform. Slung over the shoulders of the drummers are wooden drums, like the well-known drums.

Section 5

On the means for imparting motion to the hands of the drummers and cymbalists, and the instrument from which the sound of the trumpeters issues

A hollow axle is made of beaten copper as long as the chamber (*Īwān*) is wide, or somewhat shorter than that. Its ends are light. The axle is located in the hollow of the platform, vertically beneath the men's feet. On the end [of the axle] below the foot of the second trumpeter, a copper scoop-wheel of 2 sp. diameter is erected, strongly made with large hollow scoops [able] to withstand the weight of water which falls on them, as described below. A trough is installed beneath this wheel to catch the water falling from the scoops, and a hole is cut in this trough near the [first] trumpeter. Then a vessel (*qidr*) is made from copper, which has the capacity for the amount of water which fills the [tipping] bucket set in front of the flow regulator. A siphon is fitted to it like the one described in the first chapter for the flute. A hole is made in its cover, and between this hole and the hole in the bottom of the wheel's trough a pipe is fitted which is narrower than the pipe which discharges into the scoops of the wheel – which is mentioned below. Then another hole is made in the cover, narrower than the pipe which discharges into the vessel, into which a fine pipe is fitted which rises to the level of the platform and passes through the wall of the chamber to a small aperture (*Kūwa*) to the right of the first trumpeter. To the end of this pipe is fitted a jar (*ḥuqq*) for a flute, as described in the first chapter.

[3] *Yad*. Here as elsewhere the translation may be 'hand' or 'arm'.

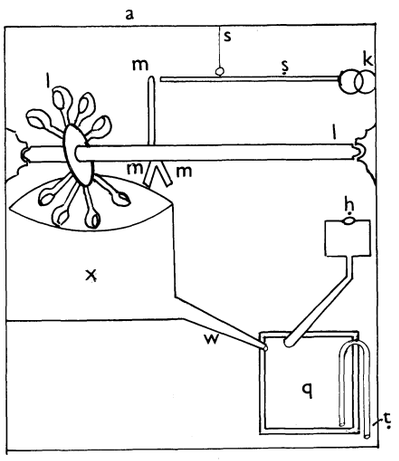
Then a pipe is fitted to the hole in the bottom of the [tipping]-bucket's trough, which extends to and discharges over the scoops of the wheel. When the [tipping]-bucket fills with the [quantity of] water which issues from the onyx in one hour of the longest day, this is the least [quantity] of water of all the hours [in the year]. At this juncture the ball falls into the head of the falcon, thence onto the bracket[4] whence it rolls inside the house. A channel is provided for the ball leading from the bracket to the horn of the bow on the end of the [tipping]-bucket. So when the ball falls onto the horn the bucket tilts and empties all its contents into the trough underneath it, and the ball falls from the horn to the ground. The water flows from the bucket's trough through the pipe in its base onto the scoops of the wheel, turning the wheel. The water falls from the scoops into the trough, and flows through the pipe connecting the trough and the [air]-vessel, expelling the air in the vessel through the jar of the flute. The flute plays with a sound which is heard from afar. As the vessel fills the water rises to [the bend of] the siphon, and discharges through it into a cistern by the side of the vessel.

Now I will describe the means for imparting motion to the hands of the drummers, and I will do this for the movement of one hand [only]. Vertically beneath each hanging wire a mark is made. By one of these marks a straight, copper strip, beaten into the shape of a ruler (*miṣṭara*), is positioned. It is about $1\frac{1}{2}$ sp. long. One end is bent round to form a ring, which is attached to a staple fixed to something solid at the same level as the axle of the wheel. Then a hole is made in the ruler, a certain distance from the other end, and this hole and the end of the copper wire directly above it are connected by an iron ring. The ruler is thus raised to the level of the axle of the wheel, and is horizontal. The hand of the figure is heavier than the copper wire and the ruler which it supports. If the end of the ruler is forced downwards by something, the hand of the man moves upwards, and when the ruler is released from the thing which pushed it the end of the ruler will lift to its [original] position and the hand of the man will descend. Now, opposite the end of the ruler in a straight line from the axle of the wheel, a peg is fixed in the axle, its end as firmly fixed as the [end of] the ruler. It is of sufficient length for its other end to reach to the end of the ruler. When the axle turns the end of the peg presses on the end of the ruler which goes down with it for about 1 sp. and then comes away from it. Then one makes for this ruler, in addition to this peg, two other pegs whose ends are fixed to the axle on the opposite side to the first, and are opposite the end of this ruler. [i.e. they are in the same vertical plane as the first peg.] Since two of the three ends of the pegs are close together, the fall of the drumsticks on the drum is varied – [first] two raps then one rap – and likewise with the cymbal. In this manner the hands of the drummers and cymbalists are operated. [The positioning of] the pegs should be varied as much as possible. In this instruction it should be understood that the drum is tilted, so the axle for the hand of the drummer must also be tilted. The rise and fall of the hand of the drummer is not in a straight line from foot to head, but slanted from right to left. This is the drawing [Fig. 39] of one drummer standing on the platform marked *a*, the drawing of the axle, with the wheel on it, both marked *l*, and three pegs on the opposite side of the axle, marked *m*. The wheel's trough is marked *x*, the pipe connecting it to the flute's vessel is *w*, the flute's vessel is *q*, and on the end of the siphon leading from it is *ṭ*. There is a *j* on the jar of the flute, on the wire hanging from the drummers hand is *s* and on its end connected to the end of the ruler is *ṣ*. On the other end of the ruler, in a firm ring in a firm support, is *k*.

It is very clear that: the reservoir, marked *a* [Fig. 40] is filled with water at the beginning of the day, the water outlet is on the first point of Cancer on the flow regulator, marked *b*, and the water discharges from the onyx into the [tipping]-bucket in the trough, marked *y* and *j* respectively. The balls *d* are in the grooves in the wood restrained by the blades *sh* and the weights are on the hooks *e*.

The man is on the reverse of the drawing at the end of the frieze, moving smoothly, since he is attached to the cart, until, when one hour of the day has passed, his finger is near the tip of the first battlement. I mentioned previously that the glass roundels are screened by a roll of leather, which should be coloured *baqqam*[5] – red, so that [by day] they appear red, to match their darkness in the night. The roundels are marked *d* and the roll *z*. When a roundel is completely red, the rod pushes a weight, a blade lifts from a ball, which falls from the falcon's beak onto the cymbal, and the sound is heard. It rolls through the channel *ṭ*, falls onto the horn of the bow *s*, fixed to the end of the [tipping]-bucket *y*. The bucket is filled with water. If the hours have lengthened after some days then some of the water which falls into the bucket flows out of the pipe in the top, marked *j*, which is outside the trough of the bucket, and runs over the ground into the cistern. When the ball falls onto the horn of the bow, the bucket tips and discharges all

[4] Under the vase.



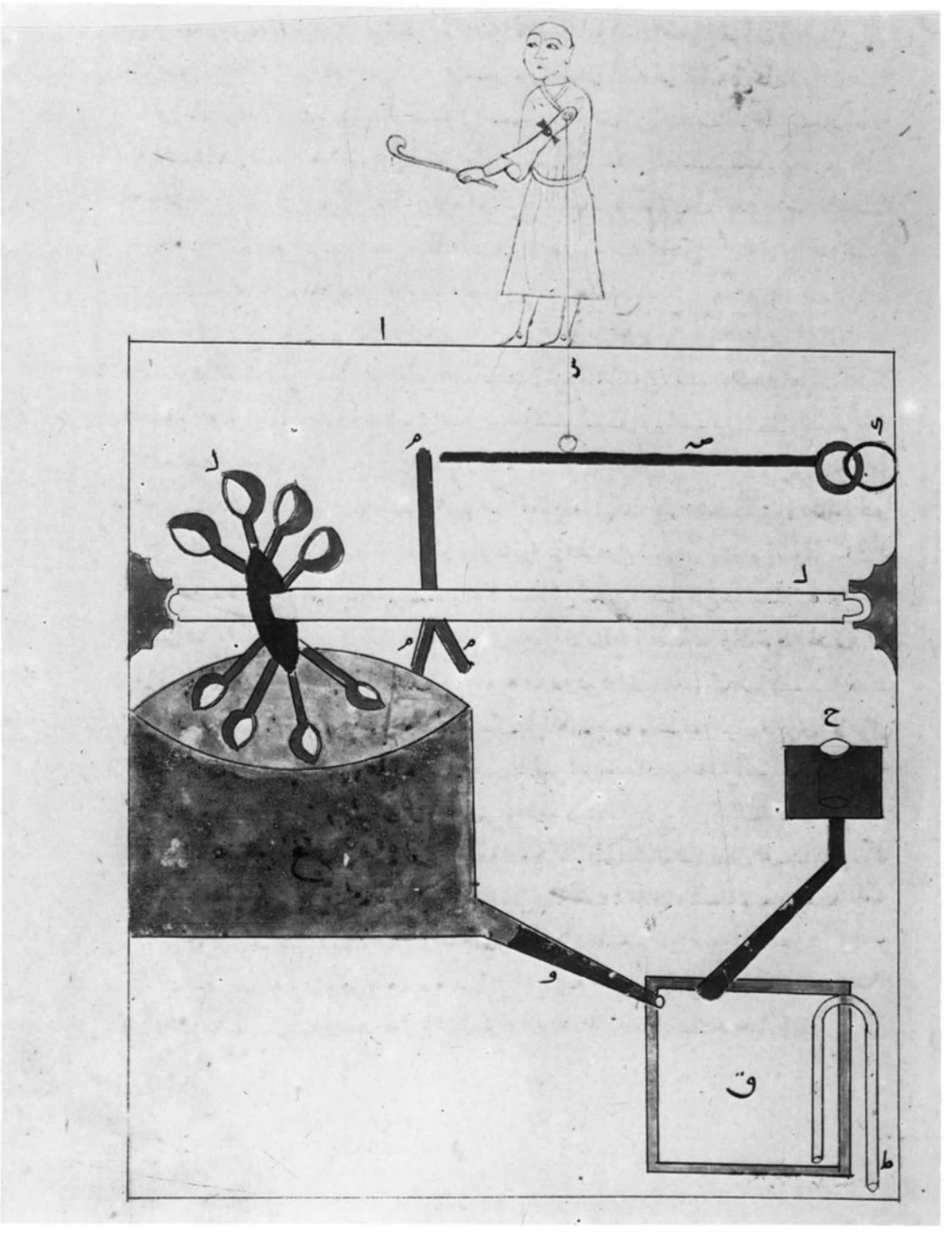


Fig. 39.

the water it contains into its trough. The water flows into the pipe *k* connected to the trough and into the scoops of the wheel *l* [Fig. 39]. The wheel turns with its axle, and the three pegs fitted to it, marked *m*, push the end of the ruler *ṣ*, moving the hand of the drummer up and down. The water collects in the wheel's trough *x* and flows through the pipe joining it to the flute's vessel *q*. The air in it [the vessel] is driven out through the pipe into the flute's jar *j*, which blows, and the blowing is thought to come from the trumpeters. There is no need to demonstrate the movements of the remainder of the hands of the trumpeters and cymbalists. Their description and mechanisms are similar to what was said above for a single hand – [namely] the axle, pegs, rulers and the wires hanging down from the extensions of the arms.

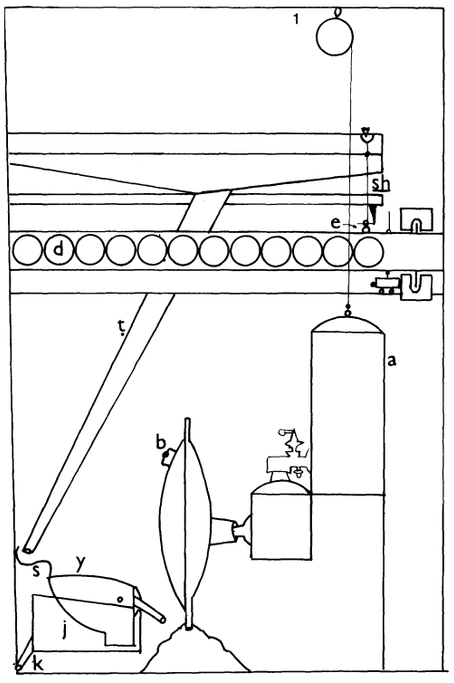
The members of the band perform as long as the water falls on the scoops of the wheel. Then their movements and the sound of the trumpets cease until water discharges from the [tipping]-bucket [again] when another hour has passed. So it continues until twelve hours have passed to sunset. The servant then pours the water back into the reservoir, moves the man to the side of the frieze, replaces the balls in the grooves, and the weights on the hooks, winds the roll and the axle, and turns the division marker [i.e. on the flow regulator] to the first point of Capricorn. He lights the lamp, whereupon the roundels are filled with light – whenever a roundel has darkened [completely] an hour of the night has passed. Then the falcon drops a ball, the musicians perform, and so on until twelve hours have passed.

The remarks [which follow] concern the reservoir, not the float-chamber and the flow regulator, for I say that the reservoir of this device is small and that a larger one is needed [only] when the quantity [of water] discharging into the bucket is increased, and the bucket is enlarged, so that the period during which the musicians play is lengthened.

This is what I set out to describe clearly. This [Fig. 40] is the drawing of that has been described, from inside the house.

Now I will describe a water-clock which I made for showing the constant hours. I have witnessed [the correctness] of its basic principle. It is the *Ṭarjahār*, of which there are various types.

[5] *baqqam* is sappan wood, originally from India and E. Africa. A red dye is obtained from it.



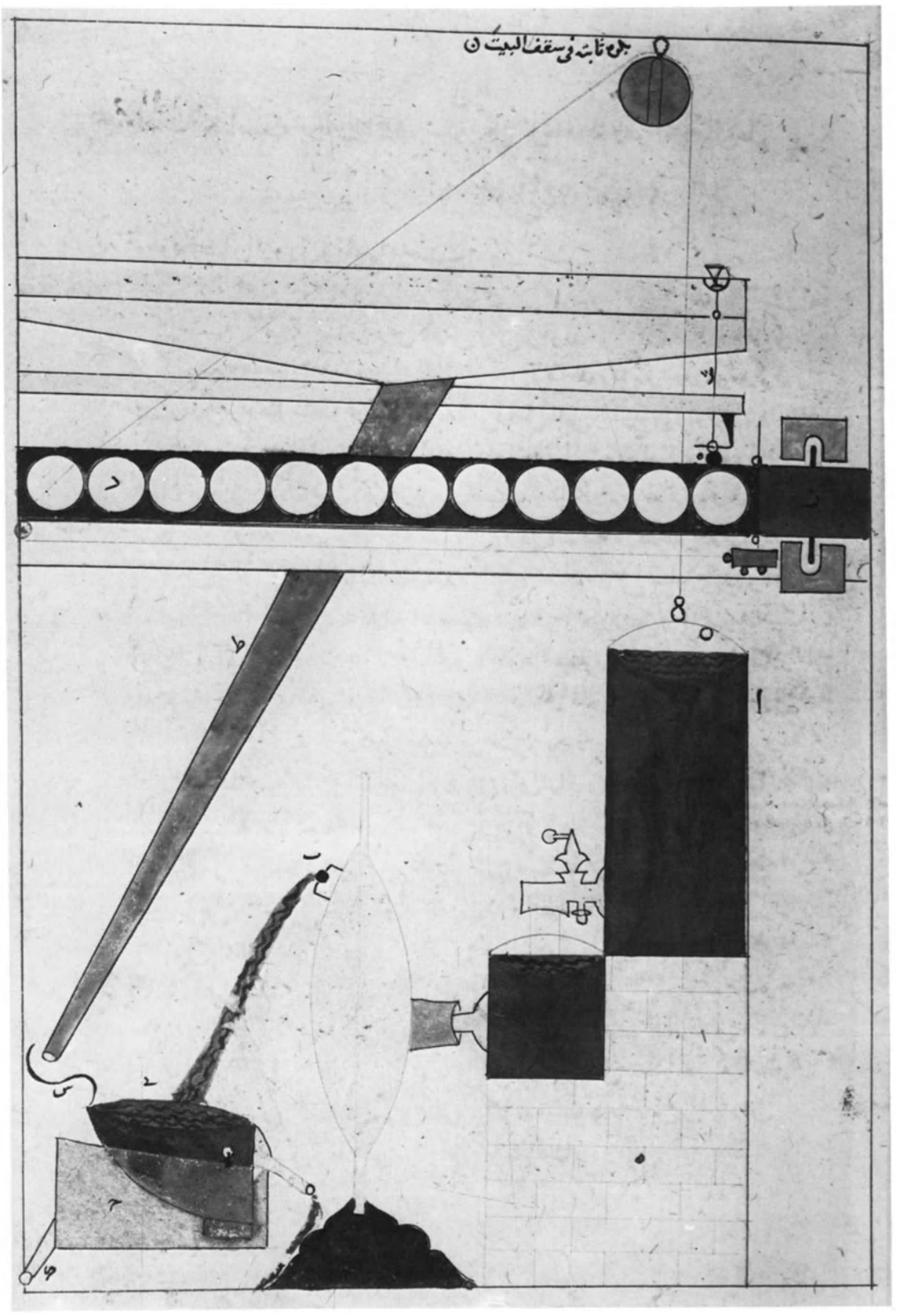


Fig. 40. Caption, at 1 on line drawing, reads: 'Pulley fixed to the roof of the house'.